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Bachelor Thesis

IMPACTS OF SONG BUNG 4 HYDROPOWER PROJECT TO BIODIVERSITY AND HYDROLOGY OF VU GIA – THU BON BASIN IN QUANG NAM PROVINCE, VIETNAM

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I. INTRODUCTION

Vietnam was ranked by the World Conservation Monitoring Center in 1992 to be within the 16 most biological diverse countries in the world. Being located in a tropical monsoon climate region with high temperature and rainfall together with complicated and diverse topographies and expanding in a considerable latitudinal range might explain the richness of biodiversity of the country. The diversity can be shown from the fact that original forest types in Vietnam comprise of evergreen broad-leaved forests, semi-deciduous forests in low and medium mountain, limestone rocky mountain forests, and mixed evergreen coniferous forests on high mountain (Clark [1] recited from Biodiversity Action Plan for Vietnam 1995). In the country report to the Biodiversity Convention Secretariat in 2008 [2], it was reported that terrestrial ecosystems in Vietnam host 310 in 4,000 total of the world's mammals species and approximate 13,800/220,000 of the world's floral species.

Vietnam is also home of riverine and aquatic families in a variety of ecosystems. Its wetland ecosystems are composed of notably mangrove forests, Melaleuca forest, estuarine wetland, riverine wetlands. The abundant resources in marine and coastal water are important sources of protein for Vietnam and also the principal source of income of nearly 20 million people living near coastal areas of Vietnam [3].

However, the trend of biodiversity in Vietnam, sadly, is the decrease in quantity and degradation in quality, both with unprecedented rate, due to many causes. For example, mangrove forests shrank from 255,000 in 1990 to only 131,520 in 2012 and half of the mangrove forest area is "planted" with very low diversity of species [3, p. 19]. Stakeholder consultations in a research of Critical Ecosystem Partnership Fund in 2011-2012 identified and ranked the most urgent threats to biodiversity of Vietnam, they are: (1) Illegal wildlife hunting and trade; (2) Habitat loss, degradation and fragmentation; (3) Climate change; (4) Logging; (5) Unsustainable exploitation of non-timber forest products (NTFP) [4, p. 131].

The exploitation of natural resources is of highly important for the growth of economy Vietnam and livelihood for its people, while nearly 20% of Vietnam's GDP in 2012 was generated from agriculture, forestry and fisheries sectors. Although being counted for not significant share of GDP, nearly half of the labor force in the whole Vietnam worked in these sectors in 2011 [5].

Moreover, the economic growth and population growth has put high pressure on the environment. With GDP rate of 6.68% in 2015 compared to 2014 [6], the infrastructure, therefore, are also needed to be developed to meet the current and future demand. In 2011, about 12,157.08 ha of forest land was converted to infrastructure development ([3, p. 24] cited from *Statistics on forest change over year by FPD, 2013*). The construction of dams, reservoirs, roads, houses and other infrastructure have not only caused natural habitat loss but also fragmentation of ecosystems, consequently affect the survival of wildlife population. The Vietnam Red List 2007 recognized 882 species of threaten status, increasing 161 species compared to the period 1992-1996. Also 10 species increased in the level of threaten from being classified as "Endangered - EN" to "Extinction in the wild - EW" [3, p. 20].

The infrastructure development largely involves energy sector. It was stated in Vietnam's Master Plan VII that electricity production and imports is set to be of 194 billion kWh in 2015 and about 695 billion kWh by 2030 to meet domestic electricity demand. This requires to increase installed capacity of 104,300 MW more within 15 years. Transmission lines also need to be upgraded and expanded. The plan also set one specific objective to ensure the access of almost all rural households to electricity by 2020.

As part of plan to increase electricity production, Vietnam in recent years have witnessed mushrooming of hydropower dams of every size. In report No.06/BC-UBND dated on 10 January 2014 of Quang Nam People's Committee (PPC) on governmental management of land, environment, water and meteorology-hydrology towards hydropower projects in Quang Nam province, 42 projects projects with total capacity of 1583.36 MW were approved (10 projects of cascade system with total capacity 1147 MW and 32 other projects of small and medium size) to be operated or planned on Vu Gia - Thu Bon basin.

II. RESEARCH QUESTIONS AND GOALS

Subject of research of this thesis is Song Bung 4 (SB4) hydropower dam on Bung river ("song" means "river" in Vietnamese) of Vu Gia – Thu Bon Basin. The project resides in Ta Poo and Zuoih Communes of Nam Giang district, Quang Nam province, Vietnam with capacity of 156MW.

Purposes of this bachelor thesis are to look for evidences for impacts of Song Bung 4 to biodiversity and hydrology in Vu Gia - Thu Bon rivers basin and criticize on mitigation practices. Scope of research in this report is reduced from full environmental impacts assessment (EIA) to only two aspects of an EIA work: Biodiversity and hydrology. Of biodiversity, ecosystem is the level that is more concerned in the research. The research questions to be sought for answers are:

1) What are the impacts of the project to biodiversity and hydrology?

2) How have environmental mitigation or compensation methods been implemented?

3) What and how can these environmental management practice be added or improved?

To answer these questions, main objectives to be achieved are set as follows:

<u>In literature part:</u>

- Search for all possible impacts by hydropower to biodiversity, from world experience/records and Strategic Environmental Assessment report of the projects in the Vu Gia – Thu Bon Basin.
- Get an overview of the project and the surrounding nature.

<u>In practical work:</u>

- Identify biodiversity impacts that are shown in technical papers of the project, are considered by local stakeholders as well as are by personal observation.
- Critically assess/evaluate on the mitigation practice.

This thesis is expected to identify impacts of hydropower to the highly biological diversity in this specific region. Also, it presents evaluation and suggestions on mitigation programs done by project owners and project management unit.

III. APPROACH AND MATERIALS

A. Information Gathering Approach

First, impacts of HPPs together with their mitigation practice that are recorded in history through different types of literature are reviewed and made generalization. Next, specific impacts of SB4 is picked from technical documents of the projects, mainly its EIA report, Environmental Management Plan (EMP) and monitoring reports. Besides, interviewing is chosen to gain deeper qualitative insights from some stakeholders. In addition, visiting was done for personal observation and picture reporting. Finally, findings from the above sources are combined and analyzed.

B. Analyzing Approach

Criticisms are to be made based on comparing literature reviewing results and results of findings on SB4.

C. Main Materials

For the literature review part, the main sources of information are from two reports: (1) *Biodiversity Impacts of Large Dams* by Don McAllister John Craig; Nick Davidson; Dianne Murray and Mary Seddon On behalf of IUCN – The World Conservation Union; (2) *SEA of the hydropower plan in the Vu Gia-Thu Bon River Basin* by ICEM in 2008.

For the practical part aiming at answering thesis questions that are specific for Song Bung 4, the following documents/occasions are the main sources for writing:

- **Song Bung 4's EIA Report**: Was prepared by Sweco (an engineering consultancy company headquartered in Stockholm) for Asian Development Bank (ADB) in 2007.
- **Song Bung 4's Environmental Management Plan**: Was approved and updated to the Loan Agreement No. 2429 – VIE signed 06 October 2008 between the Government and ADB and acts as requirements for mitigation measures for environmental impacts during monitoring process.
- **Song Bung 4's Monitoring Reports**: Numerical data of analysis on monitoring parameters as well as update on findings and compliance rate of EMP are reported

up to the date of conducting monitoring. Up to November 2014, 17 environmental monitoring visits were done and reports are made accessible on ABD official website. In addition, one final report for construction phase and various annual and semi-annual reports are also made available.

- **Interviews:** Two interviews were made. The first one was with Ms. Cam Tu, an Environmental staff of Song Bung 4 Project Management Unit and was done through phone on 05 April 2016. The second one was with Mr. Phong, a staff of Song Thanh Natural Reserve on 06 April 2016 in the office of the Reserve.
- **Sites Visiting:** A visit to Song Thanh Natural Reserve's office as well as dam site and power house of Song Bung 4 was made on 06 April 2016. Address of STNR office is at Pa Ting hamlet, Ta Bhing commune, Nam Giang district, Quang Nam province, Vietnam. As I was unable to get permit to go inside to the dam site and power house due to security reason, the made visit was around the reservoir, outside the dam site and outside the power house. All these sites are easily accessed by large roads.
- **Additional Study Visits**: Three visits to three hydropower plants in construction phase: Nam Nghe (Hum Bua commune, Muong Te district, Lai Chau province), Nam Pay (Mun Chung commune, Tuan Giao district, Dien Bien province) and So Vin (To Mua commune, Moc Chau district, Son La province) was made on 15, 16 and 17 March 2016, respectively. The purpose of these visits was to have the first experience about how a hydropower project was designed and constructed and recognize some impacts during the construction phase.

IV. THEORETICAL BACKGROUND

A. Some of Previous Researches in Vu Gia – Thu Bon Basin

In 2008, ICEM published a report on Strategic Environment Assessment (SEA) for hydropower projects in the same basin. This is a pilot SEA in Vietnam with the aim to demonstrate the use of SEA in identifying cumulative benefits and risks of hydropower for better integrity of watershed management. The method used for this SEA is trend analysis as the main analytical tool with issues identified at 3 scenarios: Current situation, future trend without the hydropower plan and future trend with the hydropower plan. Risks were identified through connecting recorded risks with natural and operational conditions of the basin. Mitigation measures were also proposed for each concern. Many of the risks and associated mitigation from this SEA paper are used in this thesis report in later sub-chapter *Impacts from Hydropower Development and Mitigation*.

A new method for sustainable management of water quality that was introduced to Vietnam recently is the From Ridge to to Reef being conducted by [7] and the Vu Gia - Thu Bon basin was chosen to illustrate the Ridge and the coastal area of Da Nang - Quang Nam as the Reef in this approach. The approach is combined of watershed area management and coastal area management, which is new to the current traditional method of Vietnam which is management separately by group of users and purpose. This old method of management leads to contradiction and unfair division of water use and cumulative effects downstream.

B. Definition of Biodiversity and Three Levels of Biodiversity

Biodiversity or biological diversity is defined in the Conventional on Biological Diversity [8] as the variability among living organisms from all sources including, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part, on three levels: genetic diversity, species diversity and ecological diversity. According to Biodiversity Law 2009 of Vietnam, biodiversity is defined as the abundance of genetic resources, species and ecosystems in the nature.

Genetic diversity is the variety in genes among individuals at different levels including population, species, community and biome. These variety is the raw material for evolution

and adaptation as some individuals with the genes that adapts with the change in environmental will survive better. [9].

Species diversity is influenced by the number of species and the evenness in the number of individuals among species within an ecological community [10]. Most of studies are focused on species level as it is the easiest to work on: The species can be identified by human eyes while on the field [9].

Ecosystem is defined as a functional unit in which all individuals interacts with each other and their surrounding environment and vice verse [8].

Biodiversity of a target area a can be also considered at the three above biodiversity levels as well as ecological functions that this biodiversity brings about [11, p. 1].

C. Major Components, Glossaries and Power Output of Hydropower System

1) *Reservoir*: Reservoir act as a water storage and ultimately, it increases water depth, decreases hydraulic gradient, create head and also help regulation of water discharge in multi-purpose dams (for instance for irrigation, draught control...). Reservoir can be built across the river/stream by constructing a dam to store the water flowing into it naturally or be built in a dry valley to which the natural water flow is diverted [12].
    - Fuel supply level: The vertical elevation in meters or feet of reservoir water surface level.

2) *Dams*: Often are made mainly from concrete and/or masonry. A dam also can have a spillway structure for flood discharge. There are many types of dams that can be classified based on functions or structure/design. Based on design, some types of dam are: Gravity, arch, buttress.
    - Gravity dam: A massif-sized dam made of concrete or stone masonry. Being fabricated of these materials, the massif weight of the dam holds the dam to the ground and resist the horizontal push of water against it.
    - Arch dam: A dam with convexity toward the upstream river. This design transfers water pressure to river flanks. [13]

3) *Water diversion/ Intake*: This act as a gate to a water conveyance structure (pipeline or penstock) which is typically the highest point (head) of the hydropower system. In small hydropower, dam is often built to divert water while in most large hydropower system the dam itself embeds intake gates. The intake is located deep enough in the water pool to create air-free water input to lessen turbine damage. Depending on design, the dam can have another gate acting as a screen for trash filtering and is structured to have "quite-water place" where dirt and other sediment can sink [14] or the intake itself is designed to have this function. See *Figure* 1: Sediment gate (left) and intake (right) from Nam Pay project (visit 16.3.2016 to Dien Bien province, Viet Nam).

Figure 1: Sediment gate (left) and intake (right) from Nam Pay project

- Tower intake structure: Another common intake structure. The tower is made of reinforced concrete and houses a trash rack and gate/valve for water flow controlling. [15]

4) *Pipeline/ Penstock*: Pipeline is nearly horizontal tunnel in diversion setup hydropower system, built to convey water to the site of powerhouse site which is located further downstream of the dam, before surge tank. Penstock is a steeply

sloping closed channel conveying water after the surge tank. In non-diversion development with storage/reservoir, penstock is built next to dam structure. Penstock is closed to create head pressure increasing with its vertical elevation drop to rotate turbine.

5) *Surge Tank/Tower*: An excavated open chamber connected between the pipeline and penstock. Main functions of surge tank/tower are to reduce damage on penstock caused by rapid change of pressure during the water load fluctuations and supply water to turbines at start-ups. [16]
6) *Power House*: A building that houses turbine(s), generator(s) and control system.
7) *Tailrace*: The channel that carries water away after the turbine.
8) *Power Output*: Generated electric power output of a HPP is calculated through the general equation:

$$P = 9.81 * H * Q * \eta$$

in which: P is the power output (kW)

H is net (effective) head of water (m)

Q is water flow through turbine (Discharge) (m^3/s)

η is turbine/generator efficiency

Head: The difference in elevation expressed in meters or feet of reservoir water level and the tailrace stream water level.

D. Classification of Hydropower Plants

Since ancient time, engineering used water power has been carried out to achieve different purpose: Construction of canals for irrigation, building of dams to store fresh water, diverting of water to community reservoirs, waterwheels for fulfilling labor-intensive tasks such as grinning grain, water-lifting for irrigation... These uses of water power still can be seen until today, often in agriculture areas.

Hydropower plants are very diverse and there is no concrete defined classification rules. Figure 2 shows some basic classifications of HPP.

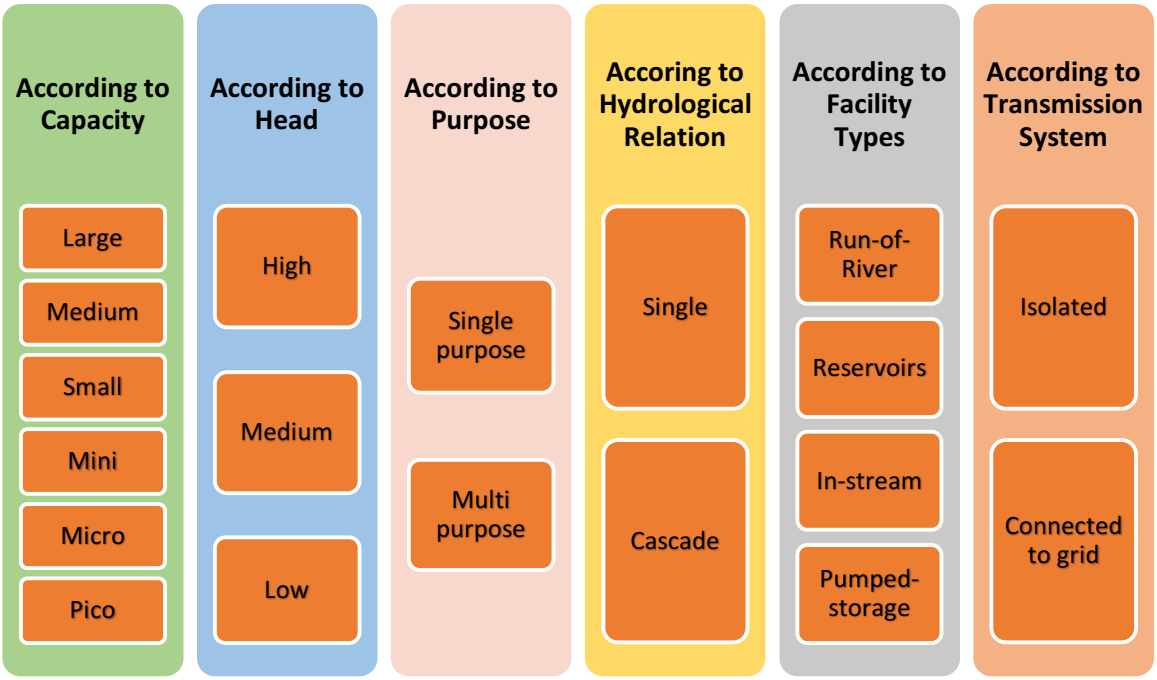


Figure 2: Classification of Hydropower Plants (Rewrote from source [17])

- **Multi-Purpose HPP:** In addition to main purpose of an HPP which is generating electricity, it also can be developed and used in conjunction with flood control, irrigation, and municipal water and industrial water supply.
- **Cascade HPP:** Two or more HPPs are constructed in different levels so that the discharge flow of the upper HPP is the intake flow of the downstream one.
- **Run-of-River (Without storage) Facility:** Natural water flow and gravity are used to run the turbine.
- **Reservoirs (Impoundment) Facility:** Dam is built across the river and water level is monitored within the reservoir. Water released from the reservoir are passed through intake and pipeline and/or penstock to generate electricity. The facility can have diversion and non-diversion development.
    - **Diversion-storage hydropower plant:** Dam is built to create a reservoir where water is diverted from the natural flow to turbines through intake gates to a long horizontal headrace tunnel then a surge tank and penstock (Figure 3: Diversion- storage HPP).
- **Pumped-storage HPP:** Often have 2 reservoirs to operate: One is at high elevation and the other is lower. The lower reservoir is fed by a lake or a river or a stream, sometimes by pumping water from the ocean. At low demand, water is pumped up to the higher reservoir utilizing cheap off-peak to store

water that can be released to generate power at peak hours for higher price. This type of plant typically needs high-capacity pump-turbines.

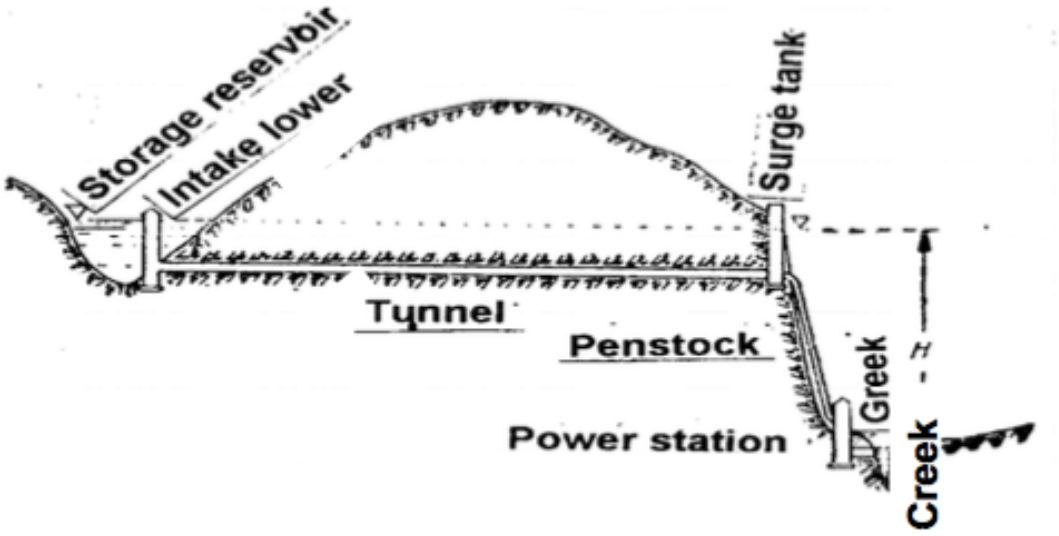


Figure 3: Diversion- storage HPP

E. Impacts from Hydropower Development and Mitigations

Impacts to ecosystem can be classified at three levels of impacts [18, p. 74]: First-order impacts including physical, chemical, geomorphological consequences; Second-order impacts involving alternations in primary biological productivity of ecosystems involving plants and habitats; Third-order impacts are those caused to fauna by the first-order or second-order impacts. This can be seen as cascade effects of physical blocks or chemical inhibitions leading to disruption in biology.

Impacts to hydrology, water quality and sediments can be seen as first-order impacts which directly or indirectly affect terrestrial and aquatic life and ecosystems.

1) *Hydrology and Water Quality*

Irregular Floods: Sudden floods might occur due to technical failure or operator induced for testing. In addition, floods can be repeated or magnified when the reservoirs of the same river or basin are opened in series or at the same time.

Mitigation: Ensure adequate competence of trained design and construction teams; There is coordination between operation unit of reservoirs; Proper beforehand notification for downstream citizens when spillages or flood discharges happen.

Prolonged drought duration and estuaries and induced salinity intrusion: In Vu Gia – Thu Bon Basin, light rain might be present after dry season and the runoff from these may also be captured in the reservoir. The HPPs' reservoir filling period and this reduced flow period in the years might occur at the same time. This causes a drought period longer than natural cycle in not only downstream but more profound at downstream plains.

Induced effects: Prolonged drought can cause salinity intrusion in estuaries when there is not enough flow coming out from the stream so sea water comes in to agriculture fields and fresh water weirs. [19]

Mitigation: Combine electricity generation with water supply (dual purpose) [19]. Construction of a salinity intrusion prevention dam as has been done in Vinh Dien River (Dien Ban town of Quang Nam) [20].

Floods Control: Modest storage reservoirs would not improve much the flooding situation in large main season floods but they can possibly reduce small floods. Larger reservoirs can store more flood water and release later gradually. The flood control in reservoir leads to reduced flow in flood season and higher flow in dry season.

Irregular Flow: With HPPs that operate in a peaking manner, the flow rate and water level of the river stream are increased or diminished suddenly.

Induced effects: Erosion at downstream riverbank is induced. Also people and animals might not have enough time to displace. [21]

Mitigation: Gradual increase/decrease by steps is done at each start and stop. [21]

Decreased Water Tables: Due to monitored flow, water tables lateral to the river might be decreased.

Induced Effects: Recharge of water aquifers, springs, artesian flows and cave streams might be reduced.

Nutrients: Nutrients is decreased in upper stream due to that migratory salmons that go upstream for spawning and their dead bodies contribute to nutrients formation. Also as vegetation growth is limited along the reservoir bank, insects, leaves and twigs are also less likely to fall to the streams. [11, p. 17]

During some first years after inundation, nutrients as Phosphorus, Nitrogen from agricultural fertilizers and organic matters of inundated terrestrial catchment are decomposed then settled out in reservoirs which leads to eutrophication in reservoir, increased nutrients transport to downstream and low oxygen content.

2) *Sediment*

Sediment transport: There will be significant decrease in sand and silt-sized materials transport downstream due to being trap behind reservoirs. For instance, A Vuong reservoir (another HPP near SB4) was estimated that 90-97% of total sediment is trapped by sedimentation in reservoir. [19]

Induced effects: River bank and downstream erosion are likely to happen by the effect of hourly water surface fluctuations and sand-free and silt-free. In long-run, the offshore delta front might possibly retreat due to reduced incoming silt materials.

Mitigation: Include a sediment flushing system to the dam design and operate it in a scheduled and environmental-friendly manner.

Water loss due to evaporation: Happens in reservoir built upstream of catchment [22].

Land slide: (From the additional study visit to Nam Nghe Hydropower (15.3.2016, Hum Bua commune, Nam Nhun district, Lai Chau province, Vietnam), see Figure 4: Exploded rock slides to river): Caused by exploding land during construction which cause blocking river in dry season and high solid matters transportation in flood season.

Mitigation: Transport excavated land to disposal sites.

Figure 4: Exploded rock slides to river

3) *Terrestrial Biodiversity*

Forest Destruction: The first and direct impact of hydropower dams is destruction of riverbank forests during construction of and later inundation of reservoir.

Compensation: An alternative to mitigation approach is Environmental offset which has compensation approach in which replanting is required. India is an example of country that has this legal requirement. [18, p. 75]

Direct Loss of Species: It is commonly that some animals are drowned during reservoir filling. Destruction and inundation of forest at reservoirs also displaces animals to neighborhood area.

Habitat Fragmentation: Reservoir, access roads can block the migration or food-finding routes of animals. It also reduces the productivity and functioning of terrain forests or wetland. Habitat fragmentation reduces the size of living area of fauna and floral population and the gene exchange, resulting in decreasing population of the species and possibly eventually extinction.

Salinity intrusion: Reduces the yields of rice and other crops which do not tolerate high salinity water and eventually leaving the land unproductive. [18]

Mitigation: Construction of a salinity intrusion prevention dam as has been done in Vinh Dien River (Dien Ban town of Quang Nam) [20]; Release water from dam to push away salinity.

Downstream Affected Riparian Forests: Flow regimes of spatial and temporal patterns affect how population of riparian forest species community are distributed and organized. Also riparian habitat downstream might be lost due to For example, some species depend on flooding flow regime for seed regeneration

4) *Aquatic, Riparian Biodiversity and Fisheries*

Increased Area and Yield for Fisheries: Reservoirs in the few first years after impoundment due to trapped nutrients make aquaculture yield increase.

Reduced Nutrients Transport Offshore: The coral reefs which are already damaged by nutrients and sediments runoff might get advantageous with reduced coming nutrients. [23]

Barrier to migration: Vietnam has many migratory species. Many species undertake migration across spatial and temporal scales, which is crucial for successful reproduction, grow and survival. These affects severely on fish requires long distance between sea and upstream or specific distance between reservoirs. In addition, there might be not enough water flow when they are in migration period. More reservoirs also mean less space for spawning areas.

- Of family Anguillidae which are among catadromous eels, adults are killed by the turbines while migrating downstream. [11, p. 20]

*Mitigation***:** Fish ladder technologies are done in some projects worldwide however, are proved ineffective from world-wide experience; Establishment of intact river corridors on selected branches of the basin (See Figure 5: Proposed Intact River corridor in Vu Gia – Thu Bon Basin [18]). The method is to ensure at least one continuous and protected waterway from the headwater to ocean. [19]

- **Habitat Fragmentation**: Fragmentation causes restocking of some species of a tributary stream blocked from the population in another nearby river or the main stream, which leads to local extinction [19, p. 135]. Genetic exchanged is also reduced when the stream is blocked [11, p. 18].
- The decrease of migratory fishes (25-73% migratory fishes are carnivorous) would expand the population of some fishes including invertebrate species and other aquatic species that are preys of migratory fishes. This would result in the ecosystem that support smaller species and less number of species. [24, p. 55]
- Freshwater mussels that attach to migratory fishes are also reduced in population and distribution [24, p. 52]. Low Dissolved Oxygen (DO) content due to eutrophication eliminates mussels. [11, p. 19]

Drawdown of the river flow during the filling period can delay the start of the flood season which is a clue for migration of migratory organisms and for other behaviors of fishes and other aquatic species. The delay cause the migration or reproduction come later, when the habitat conditions might be not optimal. [24, p. 54]

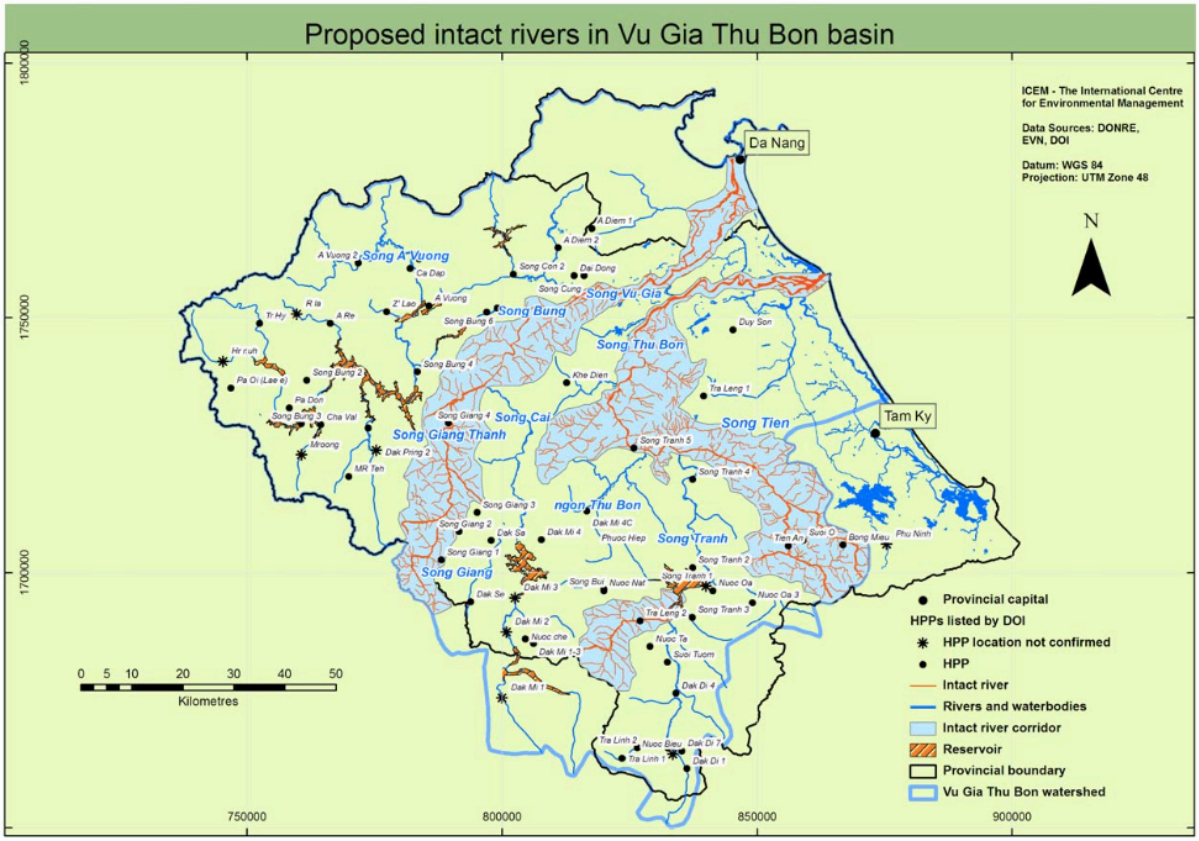


Figure 5: Proposed Intact River corridor in Vu Gia – Thu Bon Basin [18]

Habitat Loss and Change:

- Nutrients for growth and reproduction are disrupted. The flow also impacts the prey/predator dynamics, which can feed-back to the community structure.
- Sediment and fine detritus are food of very small organisms in the river. In aquatic food web, these very small organisms are preys of small organisms which are again preys of large organisms and so on. The sediment reduction, thus, cause the degradation of all aquatic species.
- Induced impact: The location of Estuary Turbidity Maximum (ETM) zone where large concentration of small juvenile and larva fish are present is affected. Together with the flow, the turbidity, sedimentation, erosion and re-suspension of sediment directly affect biodiversity and productivity. The increase in salinity intrusion also shifts the estuaries to more marine faunas.
- Some species that are dependent on lotic habitat (running water) will decline and go to extinction when the river becomes lentic habitats (still water). [11, p. 22]

Abiotic Change: Water in the reservoir is heated up during the summer and the discharge is normally from the epilimnion under the upper layer, thus the flow to the river below is cooler and less oxygen than normal in summer and warmer in winter. This physical change can effect the biota in pretty far downstream. [11, p. 25]

Mercury: Mercury can present in the sedimentation soil in the organic harmless form. However, under the activity of bacteria in the reservoir in low oxygen condition, mercury is transformed to methyl mercury that passes up the food chain (bioaccumulation). [11, p. 23]

Inland Deltas: The loss of sediment and silt and fresh water withdraw results in severe retreat and/or dry-up of inland deltas where are spawning, feeding and overwintering grounds for fishes. [11, p. 25] [11, p. 26]

Loss of Nursery: Some young fishes are born when floods come, bringing them to vegetated shaded riverine to hide and also foods and proper conditions such as temperature for growth. [25]

5) *Indirect Impacts*

Increased Pressure on Biodiversity: Workers at certain peak period come in large amount. Restaurants, camps are certainly erected to support them.

Introduction of Exotic Species: Alien species can invade the river in some cases, especially in inter-basin hydropower case.

V. VISITING SITE: SONG BUNG 4 AND VU GIA – THU BON BASIN

A. Song Bung 4 Project Descriptions

Song Bung 4 is built on Bung river and within the Vu Gia - Thu Bon hydropower cascade. The project is located in Nam Giang district of Quang Nam province. Song Bung 4 dam sites on the boundary of Zuoih and Ta BHing commune (currently called Ta Poo commune) and the reservoir inundates part of these two commune. Water from the reservoir is diverted to a underground channel of length 3.2km and penstock to a power station located about 5km downstream of the dam (See Figure 6: Dam and power house sites on Satelite map).

Song Bung 4 is the first power project financed by multilateral institutions: Asian Development Bank (ADB) for Electricity of Vietnam (EVN) is the main financer loaning 196 million USD, Vietnam Electricity and Vietnam Development Bank. This is also the first public loans that ADB gives to a hydropower project in Vietnam. EVN is the project owner. The EIA report done by SWECO was prepared for ADB's consideration of financing the project. According to Following ADB environmental classification criteria, the project was classified of category A (projects with potential for significant adverse environmental impacts and an environmental impact assessment (EIA) is required to address significant impacts [26]).

The main civil work components of Song Bung 4 project are dam, spillway, diversion intake, intake gate, headrace tunnel, surge tank, powerhouse and tailrace canal, 220kV distribution station and connection to the power system, site office, access roads to resettlement sites and to the national traffic routes. In addition to the main works, the project also has auxiliary works to serve the construction such as waste disposal sites, steel processing shop, rock exploitation areas, work camps. [27]

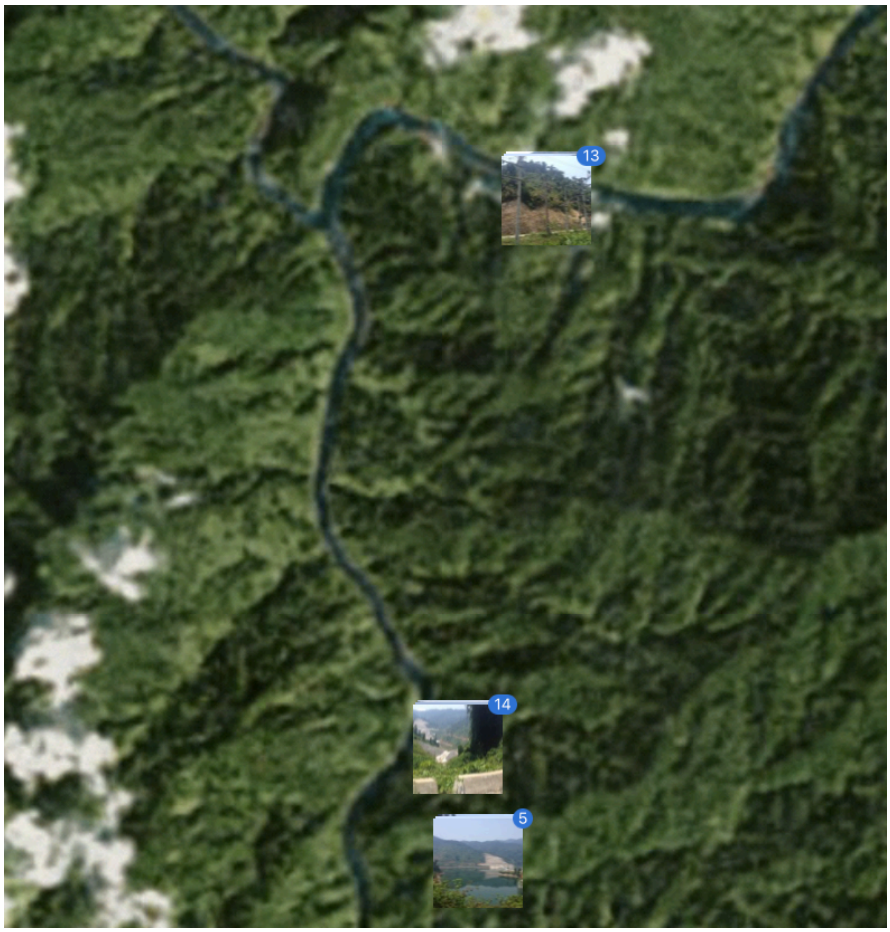


Figure 6: Dam and power house sites on Satelite map

The elevation difference between the reservoir and the power station is about 125m at FSL.

Operation of Song Bung 4: Filling period of the reservoir mainly falls in wet season, from the end of August to end of December. It was designed to achieve Full Supply Level (FSL= 222.5m) at the end of filling period and be drawn down to Minimum Operating Level (MOL=195m) for electricity generation in August. The reservoir has area of nearly 16km^2 storing 493m^3 of water at FSL while at MOL it covers 7.8km^2 and contains 173m^3. Song Bung 4 operates in daily peaking mode: The plant will operate during day time, typically from 6am to 10pm and stop at night although it might operate only in the day hours in dry season. [21]

Box 1: Song Bung 4 Project - Main Figures [27]

Reservoir:

- Full supply level: 222.5m
- Death operating level: 205m
- Gross storage: 510.8 million m^3
- Active storage: 233.99 million m^3
- Reservoir area at FSL: 15.56km^2

Dam:

- Type: Gravity Roller Compacted Concrete
- Maximum height: 114m
- Dam crest: 229m

Head:

- Maximum head: 121.3m
- Minimum head: 101.6m
- Medium head: 112.73m

Spillway:

- Gates: 5 radial gates, 6 gaps, size 12m*12m/gap

Concrete-lined Headrace tunnel:

- Length: 3.2km
- Inside diameter: 7.2m

Maximum flow through the plant: 166m^3/s

Intake gate: Tower type, threshold elevation: 186m

Surge tank: Reinforced concrete well-type, diameter 16m

Penstock: Underground, total length = 270m, diameter = 5.2m

Turbine: 2 vertical Francis turbines

Generator: 2 generators, vertical three-phase, f = 50hz, capacity 78MW

Energy Parameters:

- Installed capacity: 156MW
- Mean annual energy: 586.25 million kWh

Key progress milestones:

- Construction commencement: 3/9/2010;
- River backfilling: 16/1/2012;
- Storing water in the reservoir: 1/8/2014;
- Operation of the Electricity Generation Unit No. 1: 9/2014;
- Operation of the Electricity Generation Unit No. 2: 10/2014;
- Construction completion: Quarter 1/2015.

Figure 7: Reservoir in upper stream before dam and Figure 8: Dam and intake tower epics the scenes taken at site during the visit.

Figure 7: Reservoir in upper stream before dam

Figure 8: Dam and intake tower

B. Baseline Conditions

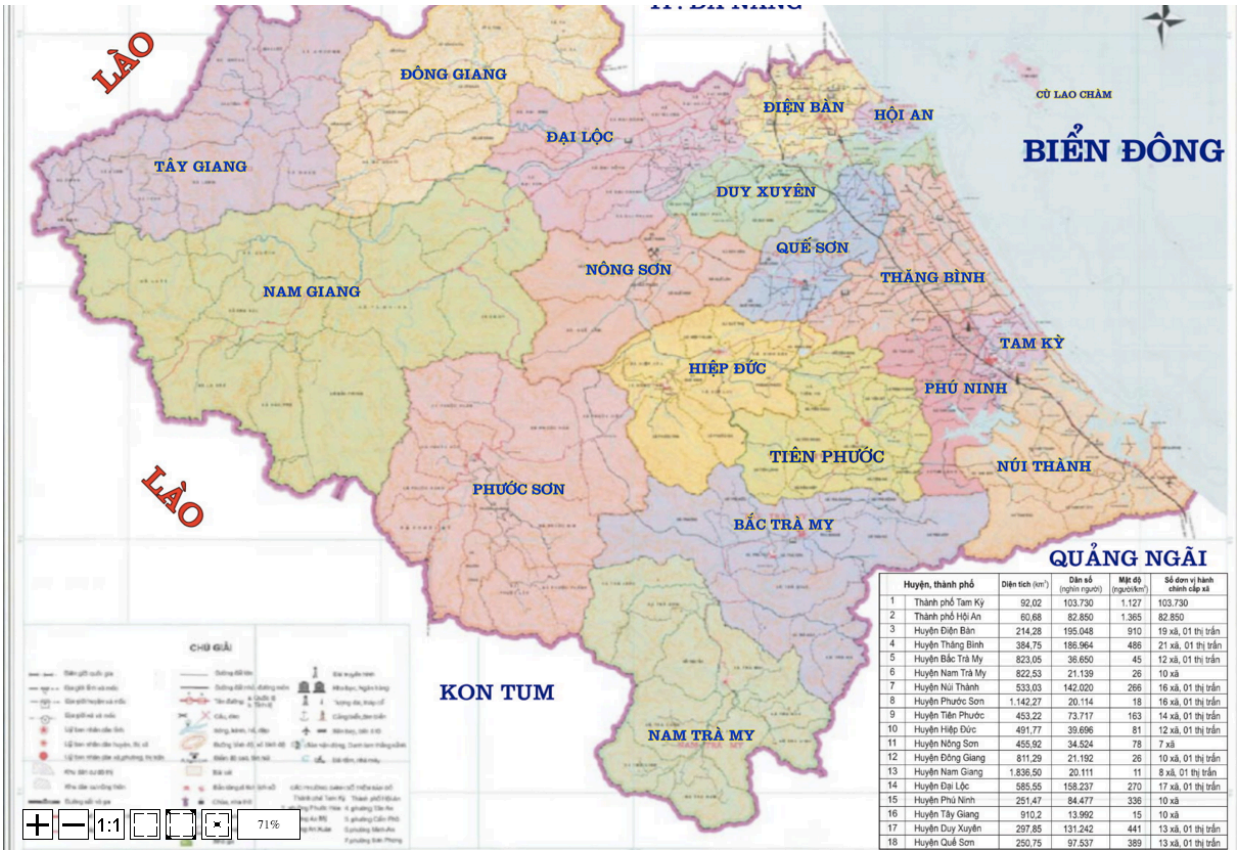
1) *Quang Nam*

Song Bung 4 is within the cascade hydropower projects on Vu Gia - Thu Bon River basin whose catchment is on Quang Nam province. Quang Nam is a central coastal province of Vietnam. To the north of Quang Nam is Da Nang city, to the south are Kon Tum and Quang Ngai province. It is bordered with Laos PDR to the West and has East sea (South China sea) to the East. The province has 2 cities, 1 town and 15 districts as listed in

Table 1: Quang Nam's Administrative Areas. Also see Figure 9: Quang Nam Administrative Map.

Table 1: Quang Nam's Administrative Areas

Town	Dien Ban
City	Hoi An, Tam Ki
Mountainous districts (9 districts)	Tay Giang, Dong Giang, Nam Giang, Bac Tra My, Nam Tra My, Tien Phuoc, Hiep Duc, Nong Son and Phuoc Son
Plain districts (6 districts)	Dai Loc, Duy Xuyen, Thang Binh, Que Son, Phu Ninh and Nui Thanh



	Huyện, thành phố	Diện tích (km²)	Dân số (nghìn người)	Mật độ (người/km²)	Số đơn vị hành chính cấp xã
1	Thành phố Tam Kỳ	92,02	103.730	1.127	103.730
2	Thành phố Hội An	60,68	82.850	1.365	82.850
3	Huyện Điện Bàn	214,28	195.048	910	19 xã, 01 thị trấn
4	Huyện Thăng Bình	384,75	186.964	486	21 xã, 01 thị trấn
5	Huyện Bắc Trà My	823,05	36.650	45	12 xã, 01 thị trấn
6	Huyện Nam Trà My	822,53	21.139	26	10 xã
7	Huyện Núi Thành	533,03	142.020	266	16 xã, 01 thị trấn
8	Huyện Phước Sơn	1.142,27	20.114	18	16 xã, 01 thị trấn
9	Huyện Tiên Phước	453,22	73.717	163	14 xã, 01 thị trấn
10	Huyện Hiệp Đức	491,77	39.696	81	12 xã, 01 thị trấn
11	Huyện Nông Sơn	455,92	34.524	78	7 xã
12	Huyện Đông Giang	811,29	21.192	26	10 xã, 01 thị trấn
13	Huyện Nam Giang	1.836,50	20.111	11	8 xã, 01 thị trấn
14	Huyện Đại Lộc	585,55	158.237	270	17 xã, 01 thị trấn
15	Huyện Phú Ninh	251,47	84.477	336	10 xã
16	Huyện Tây Giang	910,2	13.992	15	10 xã
17	Huyện Duy Xuyên	297,85	131.242	441	13 xã, 01 thị trấn
18	Huyện Quế Sơn	250,75	97.537	389	13 xã, 01 thị trấn

Figure 9: Quang Nam Administrative Map

The land part of Quang Nam covers an area of 10.406 km^2. Quang Nam has population of 1.435.629 till the end of 2012 [28].

2) *Topography:*

Vu Gia – Thu Bon Basin Topography

Originating from the eastern side of Truong Son mountain range, two rivers Vu Gia and Thu Bon forms the Vu Gia - Thu Bon watershed which cover totally a catchment area of 10 350 km^2 [7] [19, p. 17], accounted for 86% of the area of Quang Nam province (See Figure 10: River basins in Quang Nam).

There are many tributaries to Vu Gia River, the largest namely: Dak Mi (Cai River), Bung, A Vuong, Con rivers. The Vu Gia River meet the sea in Da Nang. Its course length is 204 km.

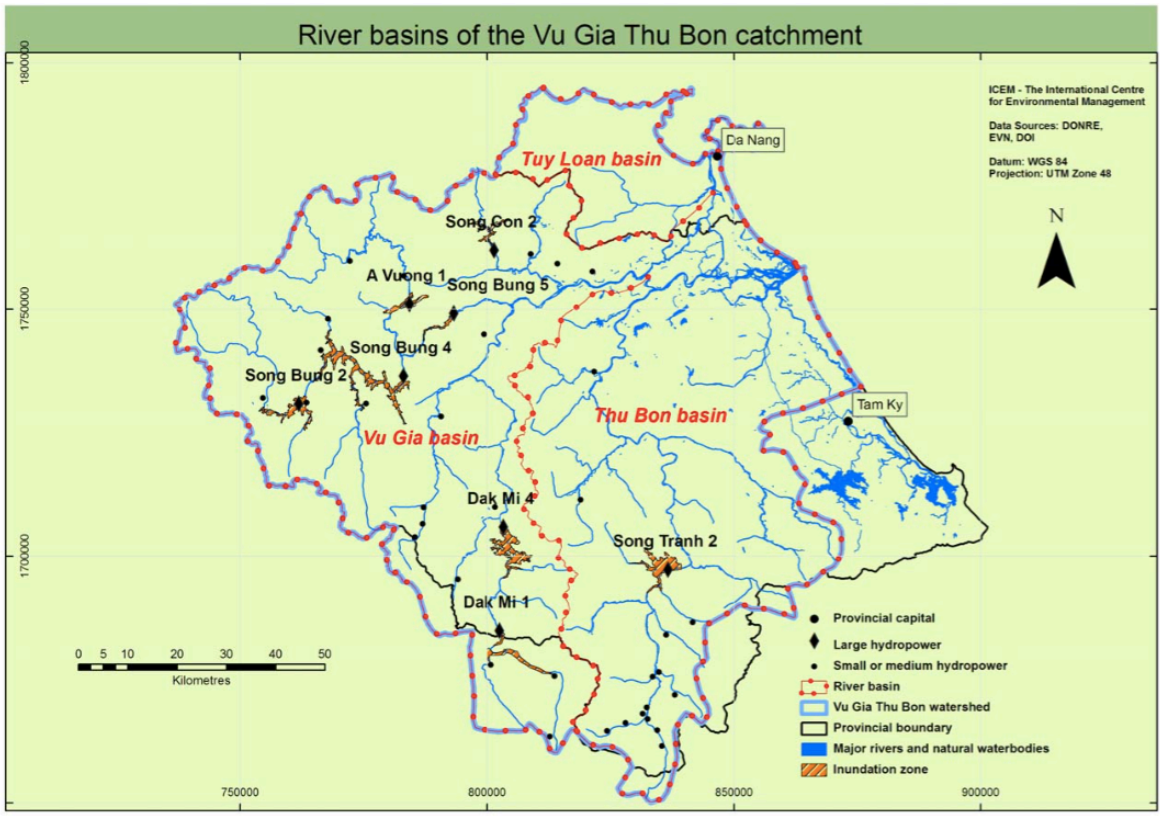


Figure 10: River basins in Quang Nam

Thu Bon river originates at the border of 3 provinces: Quang Nam, Kon Tum and Quang Ngai at the elevation of 2000m. It runs from south to north direction then later diverts to South-West to East-North and finally to West to East before meets the sea at Dai estuary (Hoi An town, Quang Nam). The course length of Thu Bon to the river mouth is 152 km. [19, p. 17] [7]

At downstream there are two inter-connection between the two rivers: Through Quang Hue River, part of water of Vu Gia river is transfer to Thu Bon river and the vice verse through Vinh Dien River located 16km from Quang Hue River.

The topography of the basin decrease in altitude from the West to the East, sectioning the area into three major distinct landscapes: Highlands, midlands, and lowlands (See Figure 11: Vu Gia - Thu Bon River Basin [33]). Three main mountain ranges of the highlands are: Bach Ma mountain range to the North, South Truong Son mountains to the West and Kon Tum mountain mass to the South [29]. The highest point in the basin is in Ngoc Linh mountatin (2598 m).

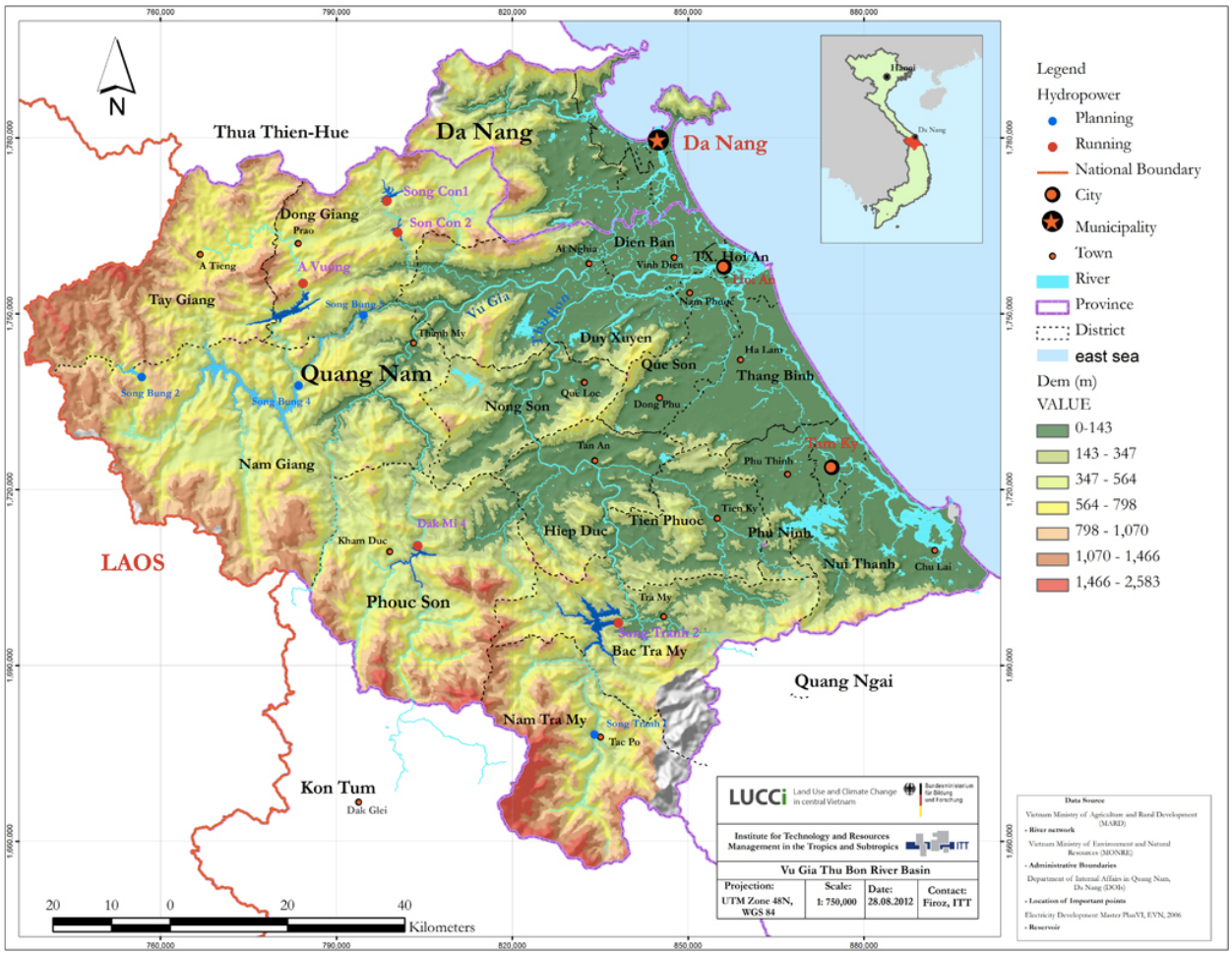


Figure 11: Vu Gia - Thu Bon River Basin [33]

Main characteristics of the are summarized as: Steep inclining, small and short slopes; many waterfalls and rapids; small storage capacity. Together with high rainfall, these conditions make the basin considered highly potential for hydropower [7, p. 10] as well as annual floods occur very quickly and severely.

Song Bung topography

Being one of the largest tributary of Vu Gia river, Song Bung has total catchment of 2500km^2 and length of 130km from the upstream at Laotian border to the confluence with Song Cai near Thanh My townlet of Nam Giang district. After the confluence the river is called Vu Gia river. The upstream elevation of Song Bung reaches near 1,800m a.s.l and the downstream reaches 1,200m a.s,l. The basin area of Song Bung up to the dam site of Song Bung 4 is 1,477km^2. Song Bung has A Vuong river as a large tributary to its north just 3km downstream of Song Bung 4 dam site. [21, p. 18].

3) *Rainfall:*

There are 12 rainfall stations in the basin area recorded since 1977. The basin is within seasonal wind tropical climate. Rainfall ranges from 2000mm on the delta and increase to 3000-4000mm in the upper part of the basin. Map of station in Figure 12: Rainfall and Gauging stations in the Basin. The average annual rainfall for period 2000-2013 in 4 stations in the basin area is presented in Figure 13: Annual precipitation in 4 stations [19].

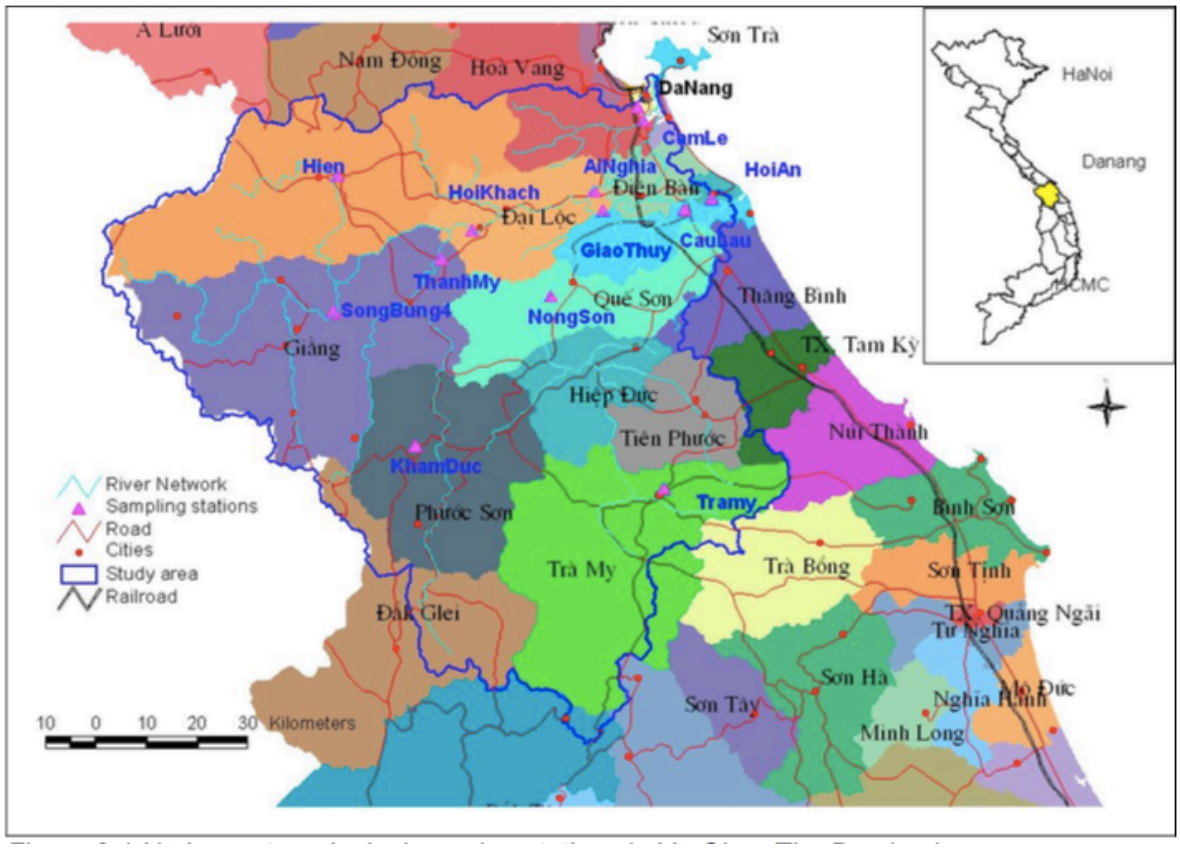


Figure 12: Rainfall and Gauging stations in the Basin

On the whole basin there are normally a monsoon season and a dry season every year although the mountainous areas starts the monsoon season earlier than the coastal areas. The monsoons season are from September to December with the highest rainfall is in October and November in the whole basin. The dry season is usually from February to April, receiving only 3-5% annual rainfall. See Figure 14: Average monthly precipitation of 4 stations.

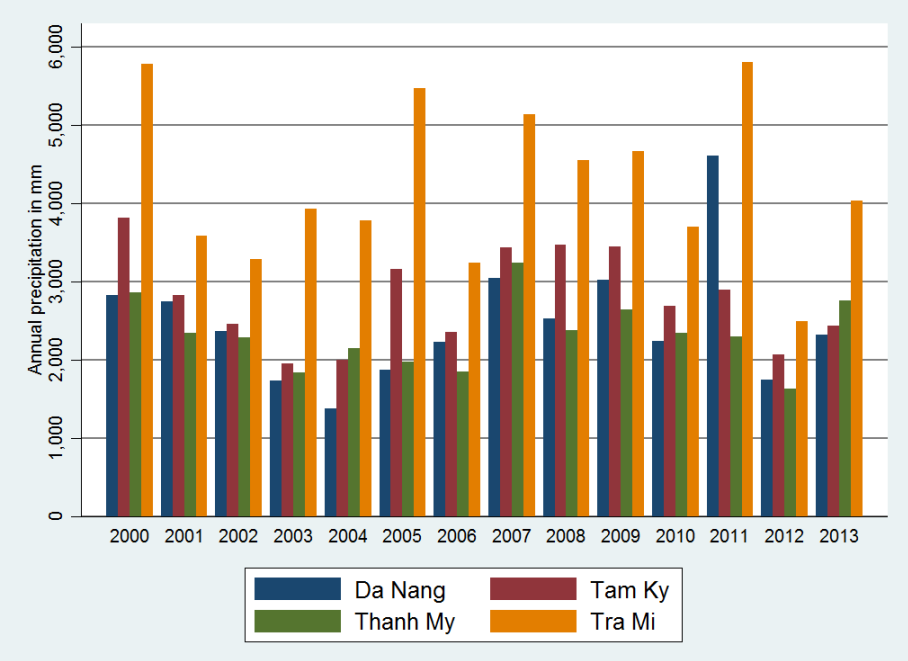


Figure 13: Annual precipitation in 4 stations

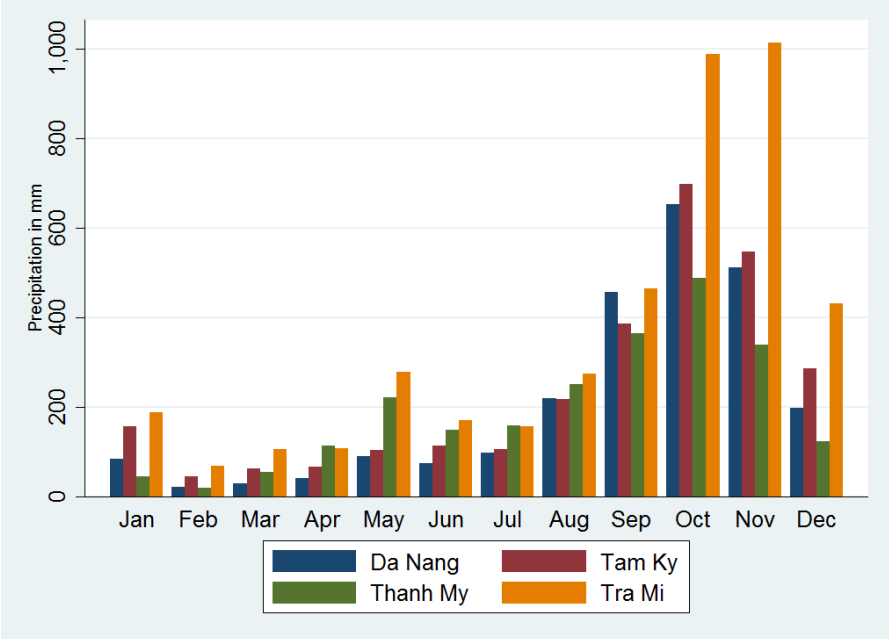


Figure 14: Average monthly precipitation of 4 stations

Rainfall in SB4 site was calculated for the period 1977-2004 in the EIA report [21, p. 21] to have annual precipitation of 2271mm and the highest rainfall falls in September-November, with only in October the precipitation accounts for 552mm or near one forth of the total annual precipitation (Table 2: Monthly and annual rainfall at Song Bung 4 dam site, Figure 15: Mean Monthly Rainfall at SB4 Site, Source: [21]). Season with light rains occurs before the rain season, from May to August. Dry season at Song Bung 4 dam site is usually from January to April. Compared to the monthly rainfall in 4 station, the rainfall in SB4 is closet to Thanh My station due to the dam site and Thanh My station are both within Nam Giang district.

Table 2: Monthly and annual rainfall at Song Bung 4 dam site

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
36	19	37	86	205	183	132	181	313	552	400	128	2271

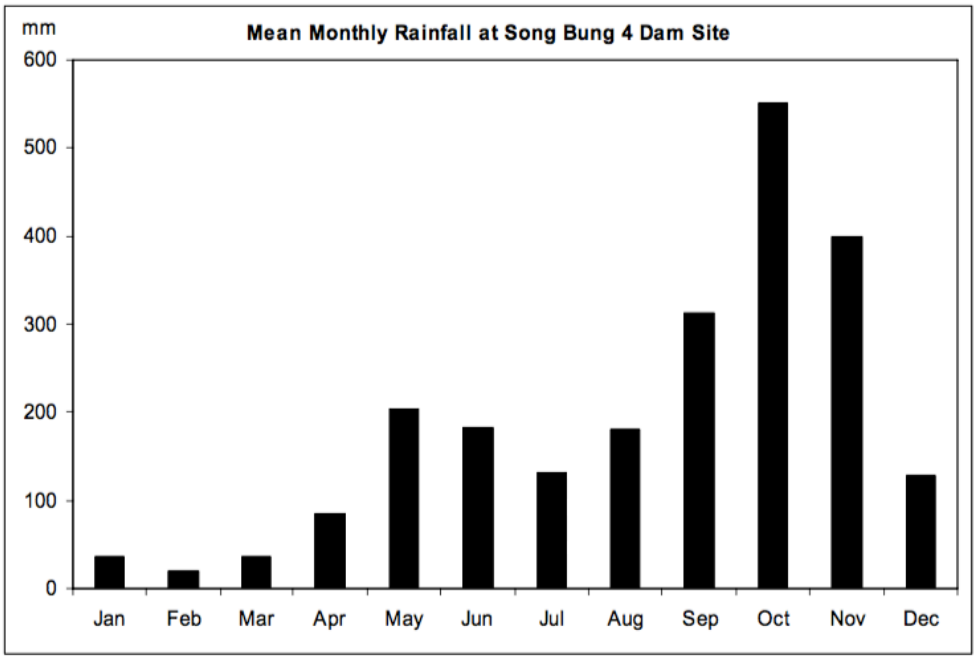


Figure 15: Mean Monthly Rainfall at SB4 Site

4) *Temperature*

Temperature at the site of Song Bung 4 that were recorded daily in 2003 to have hottest months are June and July of around 26-28^{o}C (mean monthly temperature) and coldest months are in December and January of around 19^{o}C. [21, p. 23]

5) *Terrestrial Habitats, Species and Threats*

Central Greater Annamite

Forests to the west side of basin is within the Central part of Greater Truong Son (Annamite). The Greater Annamite is a mountain range of 1,100km lying between Lao and Vietnam border. This central part of the range supports diverse habitats due to the great variation in altitude, from sea level to high mountain of over 2500 m [30]. Tordoff and colleagues in their report *A Biological Assessment of the Central Truong Son Landscape* [30] published in 2003 generalized the natural forests in the Central Annamite based on altitudinal distribution. It was found that 20.2% of the forest in the area was lowland forest (<300 m altitude), 71.3% is lowland hill forest and lower montane forest (300-1,200 m) and 8.5% upper montane formations. The area is characterized by evergreen forest communities. However, the forest cover percentage and vegetation types have probably occurred many changes since their research due to many social and natural factors: Commercial logging, illegal logging, change of land use for agriculture and irrigation, mining and construction and recently Ngoc Linh Ginseng plantation. The change is still continued.

The Greater Truong Son mountain are a hotspot for diversity with many endemic or near-endemic taxa such as saola (Pseudoryx nghetinhensis), large-antlered (giant) muntjac (Muntiacus vuquangensis). Asian elephant (Elephas maximus) and tiger (Panthera tigris) of highly threatened species are also found in the ecoregion. [30]

As other forested areas of Vietnam, there is the fragmentation of forest caused forest loss and infrastructure developments. Fragmentation has has caused ecological disconnection of forested path for the dispersion of plant species or movement of animals [30]. Highway 1A (Ho Chi Minh or North-South) passes the south corner of Song Thanh Natural Reserve.

The greater cause of declining biodiversity of the region is the logging of precious timber and hunting for lucrative bushmeat. The root cause of this wildlife hunting and extensive logging are escalating wealth and demands in urban areas in the condition of improved transport infrastructure.

In Vietnam legislation, special-use forest includes Natural Reserve (NR), National Park, Species-Habitat Conservation Area. Quang Nam has two protected areas classified as

Natural Reserves: Song Thanh and Ngoc Linh (Quang Nam) and one Species-Habitat Conservation Area: Quang Nam Sao La. One protection area is in Phu Ninh district of Tam Ki town (Figure 16: Reserves map in Quang Nam).

Figure 16: Reserves map in Quang Nam

Song Bung Project Area

Before construction of Song Bung 4 HPP, it is reported [21, p. 74] that the vegetation type in the Project area from the stream banks to altitude of 300-350m is mainly scrubs and grasslands. This type of vegetation is not natural and primary in this region but due to practice of slash-and-burn cultivation for many generations and logging in some parts, the primary vegetation of the site which is the closed evergreen broad-leaved lowland (0-700 m) forests on silicate rocks have disappeared. The primary forest had majority of indigenous flora species.

Land cover of each area by vegetation percentage is summarized from [21, p. 65] is given in below table:

Area	Total area (ha)	Main vegetation types

Reservoir	1653.8	34.5% of Vegetation type 4; Vegetation types VEG 6, 5 and 4 are dominant representing 238 ha (70%)
Roads (Access roads and Highway 14D)	83.8	Veg 2 and 3 are dominant type (49%). Veg 1 covers 8.9% of total area.

In which: VEG 1- Undisturbed closed forests. Cover of trees from 0.75 and more.
VEG 2- Disturbed closed forests. Cover of trees from 0.5 to less than 0.75
VEG 3- Woodlands. Cover of trees from 0.2 to less than 0.5.
VEG 4- Scrubs with scattered trees. Cover of trees from 0.1 to less than 0.2
VEG 5- Scrubs. Cover of trees less than 0.1.
VEG 6- Grassland and annual crops. Cover of trees 0.1 or less, and /or of shrubs 0.2 or less. Annual crops here usually consist of small scattered shifting agricultural plots within the landscape. Banana clumps or single papaya trees growing within the grassy-shrub landscape are also included here.
VEG 7- Bare lands. Cover of grasses or/and shrubs 0.1 or less; no trees occur here

Fauna of both project area and watershed were surveyed in the final EIA in 2007 [21, p. 75]. The method used for the survey were "direct opportunistic observation, vocalization, tracks and traces in the forest, interviews with key informants in villages and survey of results from previous studies".

According to this survey, in total, the project area and watershed area contains 164 species of 61 families among which 89 species are in the project area. The project area has few faunal activities and species which were explained through the heavy presence of human with different agricultural and forestry activities and poorly tree covered land. 5 species in the Project Area are of Threaten species are: Reshus macaque, *Macaca mulatta*; Asian water dragon, *Physignathus cocincinus*; Radiated rat snake, *Elaphe radiata*; Indochinese rat snake, *Ptyas korros*; Wattle-necked softshell turtle, *Palea steindachneri*. They are all found in reservoir area and abundant in the forest of the areas. All these species were found to be hunted or trapped for food or selling at the point of the survey.

6) *Aquatic Ecosystem*

Migratory species in Song Bung river have representatives from both Anadromous species (species that live in the sea and migrate to river for spawning), Catadromous species (species that live in the river and migrate to the sea for spawning) and Potamodromous species (species that migrate within the river every year, either for spawning or preying. An Anadromous fish species in Song Bung that is important for coastal and estuarine fisheries is *Clupanodon thrissa* (Chinese gizzard shad). They are said to migrate to Vu Gia upstream to spawn and the small offspring are caught and sold in Thanh My market and other markets along Vu Gia river. [21, p. 56]

An example of an important and highly priced Catadromous migrant fish in Song Bung is *Anguilla marmorata* (Giant mottled eel). They cost up to 250,000 VND/kg (more than 10 Euro/kg) (in 2006). [21, p. 56]

Clupanodon thrissa

Anguilla marmorata

Source: *Fishbase.org*

Potamodromous species can migrate at long or shot distance within the river and spawn at different locations depend on species. Important fish species for food in Bung river of upstream (at rapids) spawning migration are *Bangana lemasson* and *Bagarius yarrelli*.

Offshore of Quang Nam locates Cu Lao Cham Ocean Reserve with the tourist sites of seeing coral reefs.

7) *Demographics*

Nam Giang district has population of 24.469 in 2012, of which 2.218 was in Ta Bhing [31]. Ethnic minority groups account for the major population in the district: Co Tu (56% of the district population), Gie Trieng (21%), Muong, Thai and Tay.

The Reservoir and Project lands affected areas are almost entirely inhabited by Co Tu ethnic minority people. The downstream areas in Dai Son Commune and further downstream in Dai Loc District locate villages with mostly Kinh (Vietnamese) majority population.

C. Values of the Local Biodiversity

River basins have been cradles of civilization and cultural heritage. They support ranges of activities: agriculture, commerce, livelihood and ecological functions.

1) *Ecological and Environmental Values*

At upper stream of Vu Gia-Thu Bon basin are large area of protection forests and vegetation which slows flood water and retain soil preventing from erosion. The effect of flood would be more devastated without these protection mechanisms when the basin's topography is characterized with narrow valleys (small cross-section means water level raises faster) and steep riverbank. Rapid and large flood causes damage to human lives as well as houses, farms at the downstream and leads to erosion. Erosion means loss of land for houses near by river and soil for more vegetation. This is a chain cycle with magnifying effect when erosion causes more loss of land which cause more loss of vegetation and larger flood. Large flood and erosions occur every year in Quang Nam and Da Nang city in wet season. In the coastal area closet to the sea, the flood situation is higher as the superposition of river discharge and high tide at the same time [19, p. 31]. In addition, mangrove forests in the coastal land helps to reduce the effect of typhoons by 20-70% and protect dykes.

2) *Economical Values*

In the area of SB4, forests are also a source of cash for ethnic local people when wild animals and fishes are hunted and sold, and NTFP such as mushroom, fruits and plants are collected for household use and medicine. Rattans, bamboo shoots and palm leaves are

sold in markets with good road access. Timber with high values are also logged, though mostly by people from outside, not the local people. [21, p. 89].

In project area, fish is a staple food, the major protein source for Co Tu villagers [21, p. 90]. Other aquatic species such as small shrimp, snail, frogs are also caught in the project area watershed. In addition, woman also can raise small fish caught in streams for family consuming or selling for additional income.

Fishery is the main source of income of high percentage of people living in coastal area as Da Nang.

In addition, utilizing the advantage being adjacent to the sea, the basin also hosts 2 coastal economical zones with fast growing rate, contributing to the development of the Central Vietnam: Lien Chieu of Da Nang and Chu Lai of Quang Nam.

3) *Socio-cultural Values*

Tourism is also an important service industry in the basin area though the coastal area attracts more tourists due to more developed infrastructure and service due to the nature of low land than the high mountain on the west. Quang Nam's main attraction sites are Hoi An ancient town (World Cultural Heritage Site), Cu Lao Cham marine reserve area, My Son sanctuary (UNESCO World Heritage). Da Nang are also one of the main attraction place of Vietnam with Son Tra peninsula, Marble Mountains, My Khe beach, Ba Na eco-tourism area...

D. Other hydropower projects in the Basin

Currently operating large hydropowers (>30 MW) are: A Vuong, Song Bung 2, Dak Mi 4, Song Con 2, Song Bung 4, Song Bung 5, Song Tranh 2. They are within the cascade hydro plan approved by Decision No. 528/QĐ-NLDK dated in 2005.

	A Vuong	**Song Tranh 2**	**Dak Mi 4**	**Song Bung 4**	**Song Bung 4A**	**Song Bung 5**
Basin area at dam (km^2)	682	1 100	1 125	1 448	2 276	2 369
Full fuel supply (m)	380	175	258	222.5	97.40	60.0

Dead/minimum storage level (m)	340	140	240	205.0	95.40	58.5
Gross storage (Mm^3)	343.55	729.2	312.38	510.8	10.6	20.27
Active storage	266.48	521.1	158.26	233.99	1.58	2.45
Installed capacity (MW)	210	190	148	156	49	57
Mean annual energy				586.25 MWh		

VI. INTERVIEW LOGS

This chapter presents Questions and Answers of interviewees. The questions and answers presented here were shorten but kept authentic to the original in meaning. Both interviews were conducted in Vietnamese.

Ms. Tu:

Hydrology:

Q: How is environmental flow implemented? Is it opened daily in dry season?

A: Environmental flow channel was designed but not operated this season due to draught and there is a small stream on the left side of the dam and there is of course after-turbine flow.

Q: How is sand filter gate implemented?

A: It was not included in the design.

Aquatic Ecology:

Q: Is there an unexpected appearance of a (new/foreign/invasive) aquatic species in reservoir/vicinity of project area? If yes, what are they?

A: Nowadays more anabas and snakehead in the reservoir.

Q: What is fish productivity now and before in reservoir?

A: People at Pah Dih resettlement area around the reservoir now can catch more fish than before.

Q: Who can fish in reservoir and what is limit/day?

A: Anyone, people of resettlement programme and downstream citizens.

Terrestrial Ecology:

Q: Why are productive forest not mentioned and are special-use forest area reduced to half in Decision no.2334? Whether or not has compensation for protection forest implemented?

A: After People's Committee revised 3 types of forests, protection forest was not required and special-use was half.

Q: How was community-based forest management done?

A: Before 2011, forests were given to some households to protect forest and they can exploit bamboos, rattans. Now, environmental protection service fee was paid by Song Bung 4 to government, 22vnd/kWh electricity produced each month. The money was later paid to rehabilitated people to cover the living, around 500,000vnd/month/household.

Q: Are there any impacts that have not been included in EIA 2007 but occurred in the practice of the project? What are they and how the company have solved them?

A: Disadvantage on too dry hydrology. Flood situation was analyzed and modelled in the EIA while draught was not. Overall, the EIA covers well all impacts. Erosion was not that significant.

Mr. Phong:

Q: What is exact figure of rehabilitation for Song Thanh Nature Reserve (area, vegetation types?)

A: I don't know the exact figure, can be found in documents and 3 types of plants were planted lat hoa, sao den, lim xanh.

Q: Can you identify some terrestrial species that are directly affected by Song Bung 4 and how? (e.g, Turtle, macaque)

A: It is found that some deers were drown while trying to drink water in the reservoir and the bank of reservoir is pretty steep. It was water resource that are most effected.

Q: Are Project Management Unit of STNR content with rehabilitation programme and implementation progress of Song Bung 4?

A: Pretty content, Song Bung 4 sent money on time and planted as the approved plan.

A. Hydrology(Flow)

1) *Identified Impacts*

At the reservoir, due to filling period, the water level increases gradually from MOL in August to FSL in December. In dry season from January to July, the water level decrease gradually to reach MOL due to discharge for energy generation. This typical variation of water level in the reservoir is depicted in Figure 17: Typical annual water variation in the reservoir. [21]

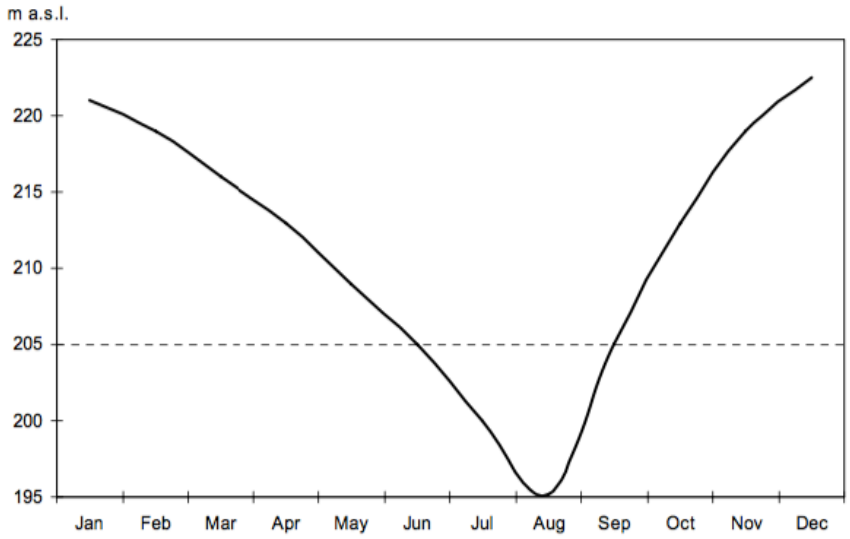


Figure 17: Typical annual water variation in the reservoir

Before 07 September 2015, the operation of dams is independent and there have been floods after floods situation created by the discharge of series of dams. The decision to discharge flood flow is completely by the dam owner and only 2-3 hours needed to notify the downstream [32].

After the Decision 1573/QD-TTg dated on 07 September 2015 about process of operating cascade reservoirs on Vu Gia - Thu Bon basin, the discharging procedure of 6 plants: A Vuong, Dak Mi 4, Song Tranh 2, Song Bung 4, Song Bung 4A and Song Bung 5 are regulated according to this decision. The decision regulates common regulations on operation of these HPPs and rules on operation during flood season and during dry season. It is required in the Article 1 of the Decision that the operation of the HPPs must follow a preference order: (i) Must ensure hydropower complex's safety in both dry and wet season;

(ii) To contribute to flood reduction, must supply minimum flow on rivers and minimum water use at downstream; (iii) Must ensure power generation.

Flow between the dam and the plant is dry to the bed. Very little water was opened (or leak out) from the dam at the visit time. There is not enough water in pool right after the dam to supply for the river after the dam. See Figure 18: River bed right after the dam and Figure 19: River bed further downstream before the plant.

Figure 18: River bed right after the dam

Figure 19: River bed further downstream before the plant

2) *Mitigations and Progress*

Song Bung 4 Operation Board has been compliant with policy of operating the reservoir in accordance with operation procedure of SB4 reservoir and operation procedure of reservoirs in catchment Vu Gia –Thu Bon basin [33]. In this year when draught is significant, threatening agricultural lands and drinking water downstream, Song Bung 4 as well as other reservoirs has been opened sometimes to supply water for irrigation and push salinity away.

Environmental flow is operated unregularly and no recordings are found in monitoring reports.

3) *Criticisms*

Environmental flow was not implemented enough. No big fishes have been observed in stream between the dam and power house.

The situation of prolong draught due to El Nino as this year were not mentioned in EIA. Due to this, contradiction between water resource use as the filling period might at the same time occur when there is still draught. However, the operation of cascade projects ensure that the downstream flow is properly supplied through compliance of reservoirs' operation board.

After turbine, the river is filled with water that is habitat for aquatic species and water source for terrestrial species.

One point of operation of the project is that the filling period of reservoir (water level increases) (August to December) is also the rain season at Song Bung 4; the generation period is the same as the dry season (See Figure 20: Rainfall and water level of reservoir at Song Bung 4). This might help mitigate the magnitude of draught and flood, however, this also change the natural flow regime of the river after power house.

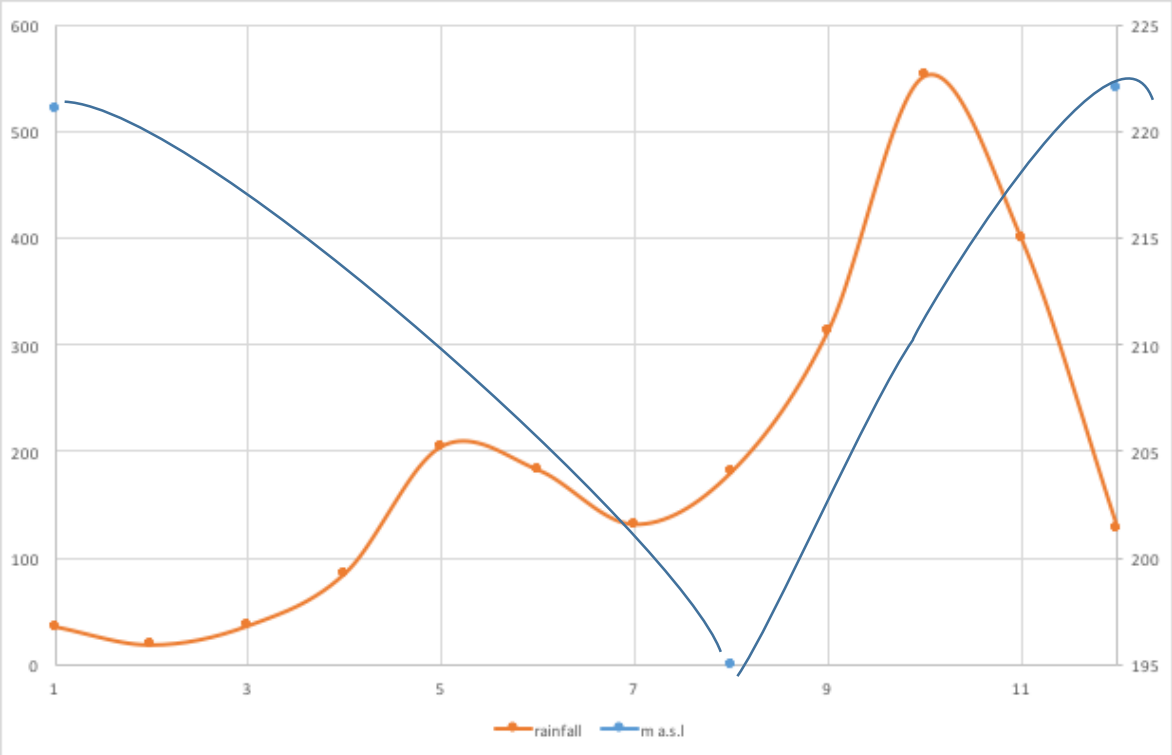


Figure 20: Rainfall and water level of reservoir at Song Bung 4

B. Terrestrial Ecosystems

1) *Impacts*

To prepare reservoir bed for inundation purpose, vegetation and forests was cleared up to the 222.5 m a.s.l. line (also FFS line) by contractors and economically important forest products were also collected in the clearance site. About 47 543 ton of biomass was cleared in the reservoir area before the reservoir impounding period in August 2014. The choice of clearance method was approved with Decision 617/QD-GENCO2 by GENCO 2 on Approval of documents of Technical Design and Cost Estimates for reservoir clearance - Project: Song Bung 4 Hydropower Project [34, p. Annex 2]. There are no documents on the mass and values of valuable trees collected.

The area of special-use forest (also Song Thanh NR's area) that are affected was 65.057ha after the change in forest types in Quang Nam.

2) *Afforestation Program*

To compensate for the lost of forest, an afforestation and rehabilitation program was established for all the areas affected by Song Bung HPP, including Song Thanh Natural Reserve. Decision No. 2334 of Quang Nam PPC dated on 26 July 2007 on Approval of Afforestation Plan replacement for Forest areas to be transferred by purpose serving for Song Bung 4 hydropower which is revised and replaced with Decision No.4030/QD-UBND dated December 18th 2014 [35] regulated afforestation plan for each of 3 types of forest (special-use forest, protective forest and productive forest [36, p. 20] [37] :

Affected protection forest area	141.5 ha	6.134 billion VND
Special-use forest area (also on STNR)	65.05 ha	10.920 billion VND
Sum	**206. 557 ha**	**17.055 billion VND (683 819.50 EUR)**

Although in Decision No.2334, 182.9 ha productive forest was included in the afforestation plan, the Decision No.4030 regulated only protection forest and special-use forest as in table above. The area of special-use forest now is also almost halved, from 128.5ha in Decision No.2334.

3) *Progress*

The Annual Environmental Monitoring Report 2015 reported that the afforestation has been completed before the end of 2015:

Protection forest	141.5/141.5 ha was replanted in Cha Vai Commune (Unit 337) and Ta Po Commune (Unit 284) with local plants Lat hoa (scientific name is Chukrasia velutina), sao den (Hopea odorata). Completed in December 2013.
Special-use forest area	(65.05ha): 65.05/65.05 ha were planted at site. Three kinds of local tree will be replanted: lat hoa, sao den, lim xanh (scientific name is *Erythrophleum fordii*). Completed in December 2015.

There have been many revisions on location and area of replanting for special-use forest recorded through decisions of Quang Nam PPC:

	Decision 2334/ QĐ-UBND dated 26/7/2010	**Decision 656/QĐ-UBND dated 29/02/2012**	**Decision 2663/QĐ-UBND dated 03/9/2014**
Special-use forest area	Cha Vai commune, Sub-area 342; Ta Po commune, sub-area 299	Ta Po commune, sub-area 304	Ta Bhing commune, sub-area 304
Area	128.5 ha	128.5 ha	65.057 ha

(Source: Decision 2663/QD-UBND dated 03 September 2014 of Quang Nam PPC)

4) *Criticisms:*

The project has achieved the area and progress required in the latest Decision approving the plan. The slow in replanting the special-use forest was due to the change in affected area by Quang Nam PCC.

It is inevitable that when replacing the primary with only 2-3 types of plants, the biodiversity is not rich anymore, might not create new sustainable ecosystems. The net loss would be the decline in quality and resilience of the forest in the functions to provide habitat for many species and prevent erosions.

It is calculated that 206 ha of forest of special-use and protective forest have been changed to generate 156MW, which means 1.3ha forest/MW electricity.

C. Aquatic Ecosystems and Species

1) *Impacts to Biodiversity:*

It was estimated in [21, p. 110] that the diversity of fish species would be reduced by at least 30% due to only some species can adapt to the lake life. However, precise impacts were not determined due to no exhaustive previous survey on aquatic life.

Some types of fishes, more fish in reservoir was caught due to more water and nutrients in the reservoir.

Migrant species *Anguilla marmorata* will be decreased in population.

2) *Mitigations*

Fish stocking in the reservoirs improved fish productivity of species that are adapted to the reservoir environment.

Smooth procedure is practice during start/stop to protect slow moving bottom animals.

In monitoring program of aquatic ecology and water quality (Annex 5, [21]), fish meat mercury content was proposed for monitoring during operation phase, however, results of the monitoring could not be found in environmental monitoring reports.

3) *Criticisms*

While water quality parameters are monitored, fish yield in reservoir as well as before and after dam and power house and fish meat mercury content monitoring was found whether has been implemented or not.

D. Ecological and Environmental Values

More erosions are induced due to the loss of vegetation along river and protective forest is less mature when Quang Nam has been often attached by floods and erosions.

Loss of timbers for clearance means lose of economics in the near future.

Destruction of forests and habitats might make a bad image for tourisms to the region, but there might be an encouragement for tourists to visit dam and powerhouse sites.

Migrant species with high economical values as *Anguilla marmorata* when be decreased in population will affect the livehood of many fishermans' family.

E. Indirect Impacts

1) *Impacts*

The first indirect impacts can be identified is due to losing land for growing rice and other staple plants, some people has to come back to the uncut forests to collect timbers and NTFP to increase income.

2) *Mitigations*

Capacity program was given to the staff of Song Thanh Natural Reserve as well as controlling guard and small boats were provided for guarding purpose.

Each affected household are also compensated with 1.5ha of productive land, 400m^2 of residential land and 600m^2 of garden land and 10ha of improved rice field. Training and inputs for productions also were provided. In additions, schools and medical stations are also opened to ethnic community.

Monthly environmental protection fee is practiced as follows: For each kWh of electricity produce, the Song Bung 4 project owners pay 22vnd or 0.1$cent to local goverment, the money is used to support daily protection activities for the forests.

From monitoring reports, all physical parameters on air, water, noise quality are good, under the limits.

Due to initial low valued vegetation at construction sites, direct loss is estimated to be not significant.

Impacts of 1 hydro dam might be small, however, contribute cumulatively to the whole area. The impacts at the further downstream plain thus results from these cumulative results and there are not yet analysis on the share of impact of each hydropower dam due to complexity. The cumulative effects might be unsustainable as shown in the conclusion of ICEM [19]. The impacts found here, thus are mainly upper stream at the reservoir, up to the plant.

Under the law, natural reserves are required to maintain intact ecosystems of national importance and unlike National Parks, extensive infrastructure for tourisms are not allowed [19]. However, Song Thanh Nature Reserve has been invaded in the buffer zone for construction of Song Bung 4 hydropower.

To make situation better, hydropower plants have been requested to supply water to downstream in the situation of prolonging salinity intrusion and draught due to El Nino to save rice fields.

Some impacts that EIA has not identified: Drowning of deers; Lack of simulation of hydrology for draught situation.

With design of no sediment release gate, sediment will be accumulated in the reservoir. In the future, sediment gate should be included in the design.

Controlling of illegal logging and wildlife hunting is improved through capacity building for staff of Song Thanh Nature Reserve. In this way, the project is beneficial to wildlife animal situation and forests.

Ethnic people are compensated well, they have opportunity to access to training, education and electricity and medication or a better life.

Operation of Song Bung 4 project contribute to solve electricity demand of the country. With better management in every aspect both of environment and society, the project might balance economic growth and sustainability.

However, the life of wild animals might be worse off by the project due to already very damage living environment.

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