ANNEX 1: TERMS OF REFERENCE

Package GEF-CPMU-CS-QCBS-03: River training and erosion protection in Mekong delta
Project: the Viet Nam mekong delta integrated climate resilience and sustainable livelihoods project (GEF-ICRSL)

(Attached to Decision No 413/QĐ-CPO-TĐ dated 14 December, 2021 of General Driector of CPO)

I GENERAL INTRODUCTION

1. The Government of Vietnam has received a credit from the International Development Association (IDA) of the World Bank (WB) to finance the Mekong Delta Integrated Climate Resilience and Sustainable Livelihoods Project (ICRSL).The project started in the third quarter of 2016 with the goal of "enhancing tools for climate-smart planning and improve climate resilience of land and water management practices in selected provinces of the Mekong Delta in Vietnam".

2. Project Technical Assistance for Mekong Delta Integrated Climate Resilience and Sustainable Livelihoods Project (GEF-ICRSL) approved by the Ministry of Agriculture and Rural Development (MARD) in Decision No. 4694/QD-BNN-HTQT dated November 16 2017 uses the Global Environment Facility (GEF) grant through the World Bank to aims to help research and innovation capacity for research institutions to develop and apply natural resource management; agricultural, forestry and fishery practices to adapt to climate change in selected provinces in MD including: delta plains (An Giang, Dong Thap); coastal & estuarine areas (Ben Tre, Tra Vinh, Vinh Long, Soc Trang) and peninsulas (Ca Mau, Bac Lieu, Kien Giang) to improve the effectiveness of the ICRSL Project.Total project fund is 6,237,281 USD, of which 6,090,831 USD is granted by GEF and 146,450 USD is the counterpart fund from the Government. The project took effect in October 2018 and ends in December 2022.

The project is designed in accordance with the respective supporting ICRSL Project Components including 05 components:

Component 1: Enhancing Monitoring, Analytics, and Information Systems ($1,540,831).

Component 2: Managing Floods in the Upper Delta ($1,450,000 USD).

Component 3: Adapting to Salinity Transitions in the Delta Estuary ($1,450,000).

Component 4: Protecting Coastal Areas in the Delta Peninsula ($1,450,000).

Component 5: Project Management and Implementation Support ($346,450).

3. The Mekong Delta is located at the end of the Mekong river and includes 13 provinces and cities: Long An, Tien Giang, Ben Tre, Dong Thap, Vinh Long, Tra Vinh,

Soc Trang, An Giang, and Kien Giang, Hau Giang, Bac Lieu, Ca Mau and Can Tho city. With an area of about 4 million hectares, accounting for 13% of the country's area and a population of 21, 5 million accounting for 18 % of the national population, the Mekong Delta plays a very important role in food security in Vietnam. It annually provides 90% of rice exports and 60% seafood exports, in addition to being a special area for growing fruit trees for domestic and export purposes.

The delta has a dense system of rivers and canals, with a density of over 4km/km2. The area of the Mekong River basin in the territory of Vietnam is 65,000 km2, accounting for 9% of the total area of the basin (795,000 km2). The two main streams of the Tiền and Hậu rivers and the systems of small rivers and canals have strongly dominated the development of the Mekong Delta. In particular, the Tiền River plays an important role, right after its distributive from the Mekong mainstream in Phnom Penh, thanks to its wider riverbed, it transports a larger amount of water than the Hậu River. After the Tiền River changed its flow to the Hậu River through Vam Nao, the two rivers created a balance. After My Thuan, the Tiền River is divided into 4 branches and flows into the sea by 6 estuaries: Tieu estuary, Dai estuary, Ba Lai estuary (constructed sluice gate), Ham Luong estuary, Co Chien estuary and Cung Hau estuary. The Hậu River flows relatively straight and only splits into two before emptying into the sea about 30 km through Dinh An and Tran De estuaries (Cau Bat That has been filled). After Vam Nao, both Tiền and Hậu rivers are wide and deep, with an average width of about 1,000-1,500m, with an average depth of 10-20m, some places over 40m deep. However, when reaching the estuary, the river is widened and the river bed is raised and many islands exist. Along the main rivers there are many deep scour holes. (*Figure 1. Location of erosion holes and deep creeks on Tiền and Hậu rivers)* The complex morphology of the channel is one of the factors causing the erosion of river banks and islets.

Based on management and information from local authorities, the Southwest region has been reported 690 erosion points/865 km (river banks: 608 points/590 km, coast: 82 points/275 km) since 2018. According to the classification criteria for riverbank and coastal erosions specified in the Prime Minister's Decision No. 01/2011/QD-TTg dated January 4, 2011 of the Prime Minister, the above-mentioned erosion locations include: Extremely dangerous erosions: 80 locations/140 km (which are urgently needed to be handled to ensure life safety and protect state and people's properties);

Regarding measures for erosion prevention and protection: according to reports of local authorities, regional provinces and cities in the Mekong Delta have implemented the following works by national and local funds as well as other grants from international organizations:

- Construction of riverbank and coastal erosion prevention works/structures: Since 2016, 142 projects have been implemented, with the total length of 128 km and the total cost of 7,127 billion VND (of which 112 projects are for river bank erosion

prevention accounting for the total length of 80 km and the cost of 5,762 billion VND). Among these, 17 projects have been implemented with the total length of 73km and the budget of 2,777 billion VND by ODA and SP-RCC funds (in which 5 projects are for riverbank erosion prevention with the total length of 10.5km, costing 1,081 billion VND).

- Migration or Relocation and Resettlement:

+ In performing Decision No.1776/QD-TTg dated on November 21, 2012 of the Prime Minister on "*Residential Layout of Regions: natural disasters, particularly difficult, borders, islands, free migration, forest-specific forests of 2013-2015 and oriented up to 2020* ", 62 projects / 21.000 households have been relocated, of which 9 projects / 8,000 households located in riverbank and coastal erosion areas have been relocated.

+ The program on residential and housing development in flood plains of the Mekong Delta was approved by the Prime Minister in Decision No. 173/2001/QD-TTg dated November 6, 2001 (for the period of 2001 – 2008). Additional investment projects were approved in Decision No. 1151/QD-TTg dated August 26, 2008 (for the 2nd period of 2008 - 2015), in which the projects of migration and relocation of households out of riverbank and coastal erosion areas has currently completed for both periods. 982 alignment clusters of housing and residential embankments have been built for the period of 2001 - 2015, ensuring safety for 191,000 households/ 1,000,000 people.

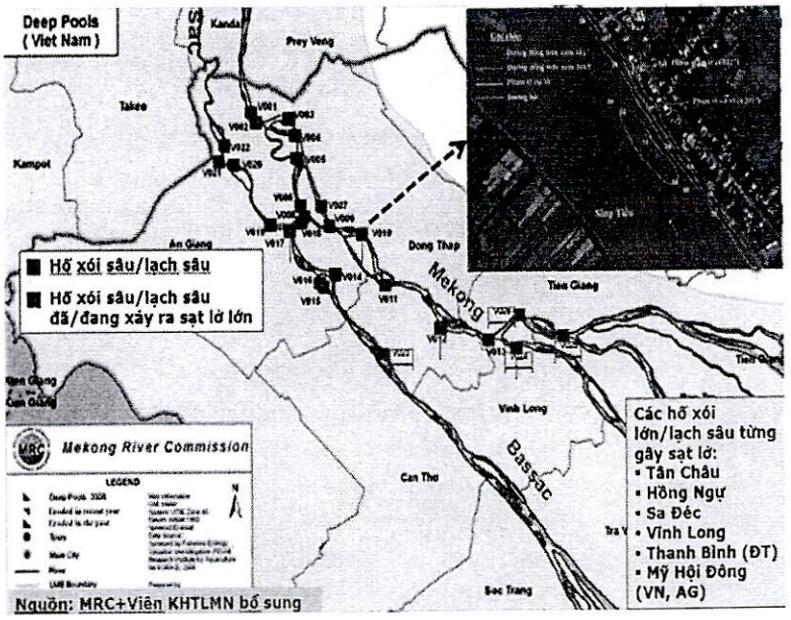

Figure 1. Location of erosion holes and deep creeks on Tiền and Hậu rivers

4. The package is under Component 4. This component aims to address challenges related to coastal erosion, groundwater management, sustainable aquaculture and improved livelihoods for communities living in coastal provinces of Ca Mau, Bac Lieu and Kien Giang. The scope of the research will be expanded to deal with river training possibilities and riverbank protection solutions on the main river routes of the

Tien rivers and Hau rivers, ensuring instant and long-term stability for the river. Rural household livelihood, infrastructure in the riverside area, improving the capacity of riverbank management in the Mekong Delta.

5. Implementation arrangement

The Central Project Office (CPO) of MARD is the Project Owner. The CPO is a Client of consulting services under this Term of Reference. The CPO will sign the contract, monitor the performance of the contract and the output of the consulting services.

During implementation of service, the consultant shall report to CPO and Vietnam Disaster Management Authority under MARD regularly in order to promptly address difficulties and issues. The main report/deliverables shall be consulted and agreed by CPO/VDMA before carrying out next steps or acceptance.

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II PROJECT OBJECTIVES

II.1 Main Objective

The main goal of this consulting service is to identify river training measures and river bank erosion management solutions along the Tiền and Hậu rivers, securing short and long-term stability of local livelihoods, riverine infrastructures and enhancing river bank management capacity in Mekong Delta.

II.2 Specific Objective

Study the main causes of riverbank erosion in the Tiền and Hậu rivers and classify them into archetypes, and connect them to the system-wide behavior of the river delta. Assess the key driving forces that may alter (increase) the erosion problem in the future. Subdivide the two rivers in upper, middle and lower reaches for classifying the erosion issues.

Identify and map current and future main high-risk areas or locations for riverbank erosion. This includes both identifying the hazard (bank-line forecasts based on bank erosion rates and associated physical processes) and the exposure (human habitation, future residential areas etc., along with boundary lines of permissible erosion). The mapping should present a corridor or zoning that has been identified to have specific risks for bank erosion.

Analyze and develop both structural and non-structural measures to control river erosion, including nature-based solutions, for each of the classified types. Propose potential measures for the areas of interest under this assignment, in which specific measures should be proposed for selected pilot sites.

Prepare guidelines for river training for bank erosion management in the Mekong delta, based on the research results. Provide guidance trainings on river training for bank erosion management to build up capacity at both national and local level

Deliver simulation models; Provide relevant training and capacity building programs for river bank erosion management.

III PROJECT AREA AND IMPLEMENTATION TIME

The project will focus on the main branches of Mekong Delta River System, i.e. the Tiền and Hậu rivers along with their main estuaries: Tieu, Dai, Ba Lai (constructed sluice gate), Ham Luong, Co Chien, Cung Hau, Dinh An and Tran De estuary. The project and model should also include some of the connecting branches (mostly in the upper zone, such as Kenh Chau Doc – Tan Chau, Song Vam Nao) as these will cause an exchange of water and sediment between the main rivers. They are not completely disconnected.

Based on previous studies on riverbank erosion in the Mekong Delta, 11 areas have been defined with high risk of bank erosion (see Figure 2). Within the scope of this project a detailed (modelling) analysis for three of the most at-risk areas will be done which are considered representative for the entire Mekong Delta. The choice of these three locations have to be substantiated in detail, for instance based on variations in hydro-morphodynamic conditions and type of erosion, and agreed with VDMA.

The implementation time: 10 months from the dated of signed contract.

Table 1. List of 11 locations in the project area with high potential erosion risks

No	Locations
1	Tân Châu – Hồng Ngự, Đồng Tháp
2	Châu Đốc –National Road 91, An Giang
3	Vàm Nao –Tiền River, Hậu River; An Giang and Đồng Tháp
4	Long Xuyên, An Giang
5	Cù lao Tân Mỹ - Cao Lãnh City, Đồng Tháp
6	Sa Đéc City – Mỹ Thuận, Đồng Tháp and Vĩnh Long
7	Thốt Nốt, Cần Thơ
8	Cần Thơ City
9	Mỹ Tho City
10	Hoà Minh islet, Trà Vinh
11	Dung islet, Trà Vinh, Sóc Trăng

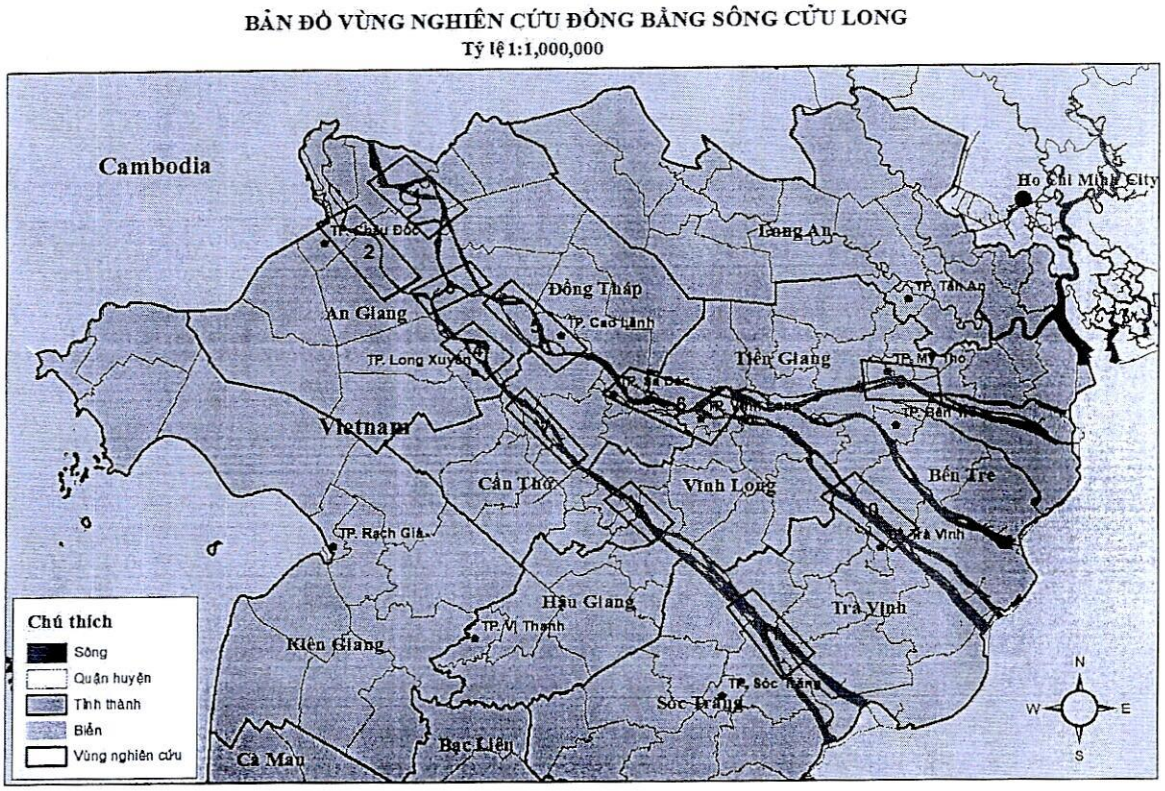

Figure 2. Mekong Delta and locations of 11 high potential erosion risk areas

IV DETAILED SCOPE OF PROJECT's TASKS & ACTIVITIES

Task 1: Inception phase

Task 1.1: Review (previous) existing studies and documents on riverbank erosion

During the Inception Phase relevant recent existing studies and documents on riverbank erosion in the Mekong Delta will be collected. These documents include: studies and projects on erosion in the Mekong Delta that have been/are being implemented, reports on erosion situation in the locality, reports on the situation of erosion prevention solutions, damage...Based on this material, a review of the knowledge (understandings of erosion problems til present) will be written, with appropriate reference to these studies. This review will include theories and evidence of causes, consequences and impacts as well as an overview of previously used methods to control erosion. Outstanding issues (gaps and inadequacies) in knowledge and data should be discussed. A special chapter will be devoted to international best practices that could be useful for the erosion problem in the Delta.

Special attention should be given during the Inception Phase to other ongoing Mekong Delta River studies on the issue of sediments and river morphology, including the ones in the framework of the WWF project "Drifting Sands: Mitigating the impacts of climate change in the Mekong Delta through public and private sector engagement in the sand industry". A plan for information exchange between these studies and the

VMDA study needs to be made based on communication between the contractors, the VMDA and other relevant authorities.

It is requested to clarify necessary documents to implement 4 main tasks (simulation modeling; analysis of trends and causes of riverbank erosion and classification; assessment of potential solutions and develop guidelines; develop databases and maps) as a basis for identifying documents needed to be collected and demands for additional surveys.

Task 1.2 Collect relevant data

Data collection should focus on the tasks of this project. First an overview of data needs will be prepared, with an inventory of where and how the data should be acquired. Collect relevant existing data, i.e. needed for general understanding and modelling. The data should be collected based on previous projects and studies executed by Vietnam Disaster Management Administration, provincial departments and/or authorities (Department of Agriculture and Rural Development, Department of Natural Resources & Environment, Department of Irrigation Management, Project Management Unit/Office ...) and research institutes.

Data should be collected on river hydrology, tides (including for instance tidal components and tidal excursion), bathymetry/topography, hydraulics, sediment transport (bed load, suspended load), grain-size distribution, previous riverbank erosion sites, deep scour holes, sand mining, navigation, geology, meteorology, subsidence, base map of river system, salt intrusion, geotechnical information of banks, etc. The data should cover the full system with both the Hau River and Tien River.

Select three sites for detailed assessments: Based on the outcomes of previous studies, assessment of existing data, and review of the previously mentioned 11 priority sites (figure 2), a selection will be made of 3 sites that will be considered for detailed modelling and analyses. The purpose of these sites is to demonstrate the full cycle of detection of causes and risks up to the feasibility of possible solutions. Therefore the 3 sites must be chosen such that they cover the wide range of causes and conditions that occur in the 11 sites in figure 7.

Early in the inception phase, an expenditure plan will be prepared for the surveys needed to collect the primary data at the 3 pilot sites. Measurements for this project must be carried out according to best international practice. This survey plan should include details for the execution of the survey, such as:

- Preparation of benchmarks and positioning system, coordinates, etc.

- Details for the equipment to be used, including calibration and testing procedures

- Details on the software to be used for data analysis and corrections

- Details on quality assurance and expected accuracy, such as references and experiences of surveyors, type and characteristics of equipment, calibration procedures, content of survey report, uncertainty handling, data quality assurance methodology, etc.

- Work plan for the survey, including a travel plan, vessels to be used, logistics, contingency plan for bad weather conditions, safety procedures, etc.

The survey plan will be discussed with Project Investor / VDMA and relevant agencies for survey execution. The data collection is input to the development of the high-resolution models and should therefore start as soon as possible to allow sufficient time to cover a range of conditions (e.g., high and low river flow).

Task 1.3: Topographic/bathymetric survey

- Topographic/bathymetric survey: the minimum requirement for the hydrometric surveys will be a recent topography of river bed and river banks of the river sections covered by the high-resolution models. Still the most commonly used instrument for measuring river-bathymetry in Vietnam is the single-beam echosounder (SBES). The surveys will therefore be carried out with SBES.

+ The hydrometric surveys will cover the model-area upstream and downstream of the erosion site to simulate erosion waves and other (large-scale) morphodynamic features connected to the cause and impacts of bank erosion. For the area close to the erosion site, i.e. 5 km upstream and 5 km downstream of a site, the tracks should be more dense to allow accurate interpolation and capturing of potential scour holes (coverage of about 10 km river length). For the adjacent sections upstream and downstream, which are considered for run-in and run-out of long-term features and impacts of boundary conditions, distances between the (cross-section)-tracks can be taken larger. Total survey length per pilot site will be in the order of 25 km.

+ Repeat the survey of two specific longitudinal sections after a short period to assess dune migration for net bed-load estimates. The tracks or paths of two consecutive surveys should be more or less identical. The duration between the surveys will be chosen such that dunes have moved sufficiently to use a dune-tracking method or similar.

+ Alternatively to the SBES surveys, it will be possible to consider to use multi-beam echo sounding (MBES) equipment if this is comparable or better cost-wise and in terms of data quality.

+ Topographic mapping of the river banks of the three modelling sites (from shore line to a reasonable distance landinward, e.g. to level of flood defense) will be carried out by using a proper leveling method

+ All topographic data (from leveling and bathymetric survey) has to be referenced to a fixed datum.

+ Line data from SBES and leveling will be interpolated to a Digital Elevation Model that can be introduced to the model (high-resolution gridded data), and which

can be introduced in GIS to produce elevation maps of the river bed and banks for the 3 pilot sites

Task 1.4: Hydraulic survey

- Hydraulic survey: flow and water-level measurements for a reasonable number of cross sections at the 3 pilot sites will be carried out, preferably using an acoustic doppler current profiler (ADCP) or similar. The minimum number of cross sections at each site is two (upstream and at the erosion site). Each cross-sectional survey will cover the period of (at least) one tidal cycle of the semi-diurnal tide (i.e. by multiple runs at the cross-section during the tidal period). The surveys will be repeated for 2 periods: at flood season, and dry season. Water levels will be referenced to the same fixed datum of the topographic maps.

Task 1.5: Water quality measurement and river bed composition sampling

Sediment concentration measurement: suspended-sediment concentration will be measured during the hydraulic surveys at each flow-measurement section. According to TCVN12636 – 11:2020 standard - Measurement of suspended sediment discharge in river under tidal influences, the sampling mode should be identified as follows:

+ Range of survey area is about $300<B \leq 1000$, the measurement location should be as same as flow velocity profiling, so the number of water sampling profiles should be 3.

+ The river width in the survey area is quite deep, so the number of measurement points per vertical profile should be at least 3 at 0.2h; 0.6h; 0.8h

+ Quantity of water sampling: the survey area is greatly influenced by tidal regimes, so the water sampling should be taken at least 4 times/day (every 6 hours).

+ Total number of samples per 1 station: 3 vertical profiles x 3 samples x 4 times/day x 5 days = 180 samples/day.

Bed composition sampling: based on the site conditions and availability of existing data, additional sampling of bed-sediment composition at some of the proposed modelling sites will be necessary. The sediment samples will be taken by grabs or similar, at 25 locations distributed over 2 stations at the 3 pilot sites. The sampling will be carried out twice, once during flood period and once during dry period. Samples will be sieved for sand fractions, and characteristics of silt and clay fractions will be determined.

Task 1.6: Geological surveys

Geological surveys: survey of the riverbanks (at risk of erosion) in the three pilot sections will be required with a minimum of 6 expected geological boreholes. These surveyed data will be processed for preliminary analysis to find the causes of bank erosion occurring in these areas and secondary used for model simulations. Depth of boreholes is 30 m. For half of the borehole samples experiments are required to

determine the physical and mechanical parameters of soil samples for separate layers: density, moisture content, plastic limit, elastic limit, grain size distribution, shear strength on flat cutters, compaction and settlement in non-expansion condition, volumetric mass (density). A small number of experiments will be added to determine physical and mechanical parameters of at least 3 undisturbed soil samples (shear, compression by triaxial methods). At the borehole sampling sites a small number of Field Vane Tests (for undrained shear strength) are foreseen, as well as about 10 Standard Penetration Tests

- ***Deliverables of Task 1:*** *Reports: inception report, detailed outline report and report for hydrological survey, topographic survey, geological survey, water quality, suspended sediment and river bed sediment composition.*

Task 2: Modelling

Task 2.1: Prepare a computational model to simulate the whole delta river system

Prepare a computational model to simulate the hydrodynamics and morphodynamics of the system, covering the considered river branches Tiền River and Hậu, and the connecting branches, at least from the Vietnam/Cambodian border to the river mouths. The main purpose of these models is to be able to simulate long-term responses to measures, and to evaluate the potential future erosion risk under changing boundary conditions (sea-level rise, and upstream development and climate change scenarios). This integral model must be based on a 2D depth-average numerical modelling system, or a combined (hybrid) 1D and 2D modelling system. The latter combines 2D models for sections with specific interest and complexity with 1D models for more uniform large-scale reaches.

As a minimum, the following scenarios and cases need to be run: current status scenario, sea level rise and climate change scenarios, sand extraction scenarios, upstream sediment shortage scenarios and combined scenarios of all negative/ unfavorable factors.

Task 2.2: Develop morphodynamic models for pilot sites

Prepare 2D or 3D high-resolution morphodynamic models for the pilot sites with current erosion problems for a deeper understanding of the causes and mechanisms of erosion at the pilot sites and for analyzing the effectiveness of erosion control solutions (see Task 5).

The models will be used to assess the effectiveness and the side effects of solutions for riverbank erosion, in particular sediment nourishment, local dredging and river widening. Furthermore, the models may provide design conditions for solutions based on structural solutions such as revetment.

Model simulation scenarios should be included:

- Floodplain discharge scenarios;

- Typical climate year scenarios;

- Upstream change scenarios (Building dams, reservoirs, sediment sources degradation);

- Sand extraction/mining scenarios;

- Scenarios of climate change and sea level rise;

- Scenarios of extreme weather (flood, drought);

- Combined scenarios: a combination of typical climate year scenarios, sand mining scenarios up to 2030 and climate change + sea level rise by 2030.

- ***Deliverables of Task 2**: Report on mathematical simulation modelling of global systemic responses and detailed mathematical modelling report for pilot study sites.*

Task 3: Analysis of trends and causes of riverbank erosion and classify

Task 3.1: Identify riverbank changes over the past two decades

The Consultant should make use of state-of-the-art tools for analyzing the satellite imagery. Relevant satellite sources are Sentinel, LandSat and possibly other sources recommended by the Consultant.

The method to process, visualize (mapping) and analyze the imagery should be automatized as much as possible and delivered as a product of the task, including a training session for officers working at national and local disaster prevention agencies. Detailed guidelines (or standard of procedures) should be descried in a specific report by a easy-to-use and easy-to-understand approach to assist VDMA and to be part of future operations by.

Task 3.2: Identify and classify main causes for riverbank erosion

The methodology should consider physical conditions as causes of erosion: for instance, different causes of local scour, including erosion of heterogeneous subsoil (scour holes in exposed sand pockets in clay bed), bend scour causing toe erosion, scour near structures such as at the end of a revetment or near groynes and bridges, confluence scour, etc. Possibly identify separate sections where tides are critical forcing for erosion, and sections where river floods are critical forcing (and transition regions). Also consider anthropogenic forcing, e.g. sand mining, encroachment (new embankments, urban expansion), or increased shipping. Internal changes, such as subsidence and migration of channels and sand bars (unstable bifurcations) need to be handled too when dealing with erosion issues. Therefore, this classification should be based on at least the following criteria:

- Cause of the bank erosion (e.g. shift of flow distribution at bifurcation, wave action, local sand mining, subsidence, etc.);

- Type of bank failure (mass failure, seepage erosion, sheet erosion, etc.);

- Geotechnical and physical characteristics (cohesive versus non-cohesive, vegetated, stratified layers of cohesive and non-cohesive material, piping processes, etc.)

- Also identify possible links of the erosion sites to specific large-scale system behavior (e.g., degrading channel sections, meandering). The purpose of such a classification is to support the selection of potential measures and to prioritize these measures.

Task 3.3: Evaluate (future) trends in changing boundary conditions

One of the key questions in this project is to unravel the underlying causes and processes that could explain why the erosion problems have increased. It could be related to river functions, navigation, water supply, safety against flooding, drought, (think of changing groundwater levels and salinization in estuary reach, changing tidal excursion length, etc.).

Changes in boundary conditions: consider the system-wide impacts on river morphology (predict trends in river bed evolution) from climate change, impacts of upstream dams, impacts of upstream flood-plain embankments notably the Plain of Reeds, sea-level rise.

Determine the river training alignments and propose the scope of area for residential/household relocation, riverside infrastructure works in areas at potential high erosion risks within simulation/estimation domains, especially at 3 pilot sites..

- ***Deliverables of Task 3:*** *Report on identifying riverbank changes, report on riverbank erosion classification, report on riverbank erosion trends under changing conditions.*

Task 4: Assessment of effectiveness (pro vs con) for deployed riverbank protection structures in Mekong Delta

An assessment of riverbank protection measures that have been applied worldwide, in national scale in Vietnam and in areas which have similar characteristics like the Mekong Delta should be implemented. The assessment should analyze the advantages and disadvantages of applied measures, including the impact assessment of increasing erosion due to unconformable or illogical designed structures.

- ***Deliverables of task 4:*** *Report on Effectiveness Assessment for deployed riverbank protection structures in Mekong Delta.*

Task 5: Identify potential solutions

Task 5.1: Identify possible solutions for the pilot sites

The Consultant should review a wide range of structural and non-structural solutions for riverbank erosion at the three pilot sites, including but not limited to:

- Traditional revetments and other (semi-) hard structures for bank protection

- Nature based solutions, which may involve natural material / vegetation for bank protection; use of natural forcing to modify flows; etc. Sediment nourishment as a solution for stabilizing the river channel
- Measures to influence the river flow direction and dimensions
- Set-back lines and relocation of houses
- For each of the solutions the experiences from both Vietnam and international best practice should be used in order to evaluate them on the following criteria:
- Effectiveness
- Technical feasibility and durability; Flexibility and robustness to climate change and other future changing conditions;
- Economic efficiency (costs, including capital investment, operation and maintenance)
- Social acceptability; social impacts, impacts to living habitats and livelihoods…;
- Environmental impacts (energy efficiency, water quality, biodiversity)
- Other issues related maintenance to sustain the solutions.

Task 5.2: Analyze solutions on costs and effectiveness using mathematical model

The models that are developed under Task 2.2 for the study sites will be used to analyze potential solutions (at least 3 different solution types for each site).

Task 5.3: Assess environmental and social side-effects of solutions

For each of the potential solutions for the riverbank erosion at the pilot sites, a high-level environmental and social side-effects assessment will be done. This assessment should use quantification of effects as much as possible. Expert judgement may be used for non-quantifiable effects.

Task 5.4: Develop guidelines for selection of solutions, depending on location and type of problem

Based on the knowledge gained from the previous tasks, the consultant will develop a set of practical guidelines that can be used by river practitioners at the regional and local level. These guidelines should be set up as a decision tree so that potential solutions can be easily found by answering questions on location characteristics and type of erosion problem.

Guidelines should also be made for an appropriate monitoring program focused on hotspots and other likely (future) erosion sites. Such monitoring program could include:

- Hydrometric monitoring that complement the existing hydrology monitoring system. That means that if additional stations are needed, they should comply

with the existing system, and become embedded in the present system (including station maintenance, update of ratings, and database connection)

- Procedures for bathymetric surveys with high resolution and reasonable frequency (e.g. annually) should be implemented, at least near existing and potential erosion sites (hot spots), but ideally for the entire river. In modern river management the use of multibeam echosounders is considered best practice. Potential scour problems near banks can be derived from GIS.
- Monitoring should include proper measurement of sediment concentration and sediment classification at proper sites, adding to existing monitoring.

The consultant is encouraged to propose additional state-of-the-art and innovative techniques, such as aquatic or airborne drone surveys, optical survey methods, etc. to support the monitoring of relevant parameters.

- ***Deliverable of Task 5**: Report on identifying possible solutions for the pilot sites; report on cost and effectiveness/benefits analysis of possible solutions using mathematical models; report on environmental and social impact assessment of possible solutions; report on developing guidelines for selection of solutions.*

Task 6: Database and maps

Task 6.1: Identify current and possible future hotspots of riverbank erosion risk

Based on the increased knowledge on the river erosion in the Tiền and Hậu rivers an update of the current river erosion locations will be prepared. Also maps for future potential hotspots will be prepared, based on scenarios for extreme events, climate change/sea level rise, upstream developments, sediment mining and increasing urbanization at the Mekong Delta.

In previous studies, SIWRR has derived a zone (or corridor) of bank-erosion risks based on extrapolation of observed bank-erosion rates at existing erosion sites. The zones can be used to prevent building activities or other economic activity. The lines of bank-retreat can be determined from aerial photographs or satellite imagery (when dealing with resolution). However, this approach does not involve consideration of (among others) changing physical conditions, the heterogeneous state of the river bank, and development towards a possible stable equilibrium state. Furthermore, it is only applicable for banks that have been eroding for some time already.

In this task, the approach of determining zones for bank erosion risk or safety zones will be extended further including and beyond the above-mentioned extrapolation method for existing banks. Although accurate predictions of future bank erosion are not feasible with the existing (numerical) tools, and limited availability of very detailed data (flow, morphodynamics, geotechnical), the map of potential (future) hotspots can be used to improve the zoning based on possible scenarios and estimated risks. A mapping approach will be developed that cater for the high uncertainty of the zones (e.g., color scaling of potential risks).

Developing printable maps on A0 size for 11 locations with the current occurrence of deep scour holes as mentioned above (including 3 selected pilot sites) and other areas identified at high potential erosion risks from modelling simulation, in which the following elements should be paid attention: existing erosion prevention structures; category of erosion areas by classification; river training alignment and boundary areas of residential/household relocation and infrastructures.

Developing printable maps on size 2A0 along the Tien and Hau rivers in the Mekong Delta, showing the current erosion status, existing erosion prevention structures, and trends in shorelines changes as well as velocity field corresponding to the scenarios.

The hotspots need to be defined according to the criteria for classification of river bank and coastal erosion as stipulated in the Decision No. 01/2011/QD-TTg dated January 04, 2011 of the Prime Minister ("high or extremely dangerous", "medium or dangerous", "low").

Task 6.2: Prepare maps and interactive Web-GIS application and database

The maps prepared in Task 6.1 should be made available in a user-friendly interactive Web-GIS application. Data/application should be compatible, synchronized and interoperable with database and information infrastructures. For each river stretch the application should be used to map (1) historical bank-lines; (2) current bank-lines; (3) bank-line forecasts (e.g. after 5 years); (4) boundary lines of permissible riverbank erosion; (5) classes of assets threatened by bank erosion (embankments, roads, human habitation, etc.); (6) riverbank training alignment lines. Based on this information, potential erosion risk locations (hotspots) should be made visible including their classification and an indication of potential solutions that are appropriate for that river stretch. Both digital and paper maps need to be prepared in scale 1:10,000 and 1:25,000 alternatively for the whole regional map and local maps for every prioritized area.

The web-GIS application should have the following key functionalities:

- Covering the entire Tiền and Hậu rivers, from the border of Cambodia to the ocean.
- Enable selecting different background maps (e.g. Google Earth, Google Maps, OSM)
- In zooming up to 1:1000
- Show river cross sections at hotspots
- Pop-up window for each hotspot with type of problem and potential solution
- Create calculation function: after selecting a solution for each hotspot in a river reach, the total costs for that reach will be calculated. Also totals for the entire Tiền and Hậu rivers will be shown.

- Enable importing .shp layers with urban, industrial, tourism, river training alignment and erosion (mentioned above) etc. land use plans
- Enable overlays between hotspots and current or future land use plans and show potential conflicts / problems with erosion (number of hotspots, length).
- Result of task 6: Erosion maps: current status, forecast, solutions; River training maps, digital maps and databases for Web-*GIS systems.*

Task 7: Dissemination of results and knowledge transfer

Task 7.1: Organizing seminars / workshops / training sessions

Dissemination of results and knowledge transfer is a key goal of the project. Therefore, the Consultant is expected to organize at least 2 workshops or seminars, for high-level decision-makers as well as for provincial river managers. The workshop will be held in the midterm and the end of the project for reporting and consulting scientists project results to scientists and managers.

Task 7.2: Reporting

In total the following reports will be delivered:: Inception Report, Detailed outline Report, Report on identifying riverbank changes, report on riverbank erosion classification, report on riverbank erosion trends under changing conditions, Report on mathematical simulation modelling of global systemic responses and detailed mathematical modelling report for pilot study sites; Report on Effectiveness Assessment for deployed riverbank protection structures in Mekong Delta, Report on identifying possible solutions for the pilot sites and Integrated Synthesis Reports and Executive Summary Report.

Besides, for the Web-GIS application a user documentation / manual will be written. The Final Report will contain an Executive Summary for policymakers, Conclusions and Recommendations (incl. remaining knowledge gaps and suggestions for further study), Workshop and Training Evaluation Reports.

The ***Practical Guidelines*** should be issued separately as a handy booklet, well-illustrated and with a nice lay-out. The guidelines will be delivered to administration agencies and local authorities along Tien and Hau Rivers.

Details of the project timeline and deliverables are shown in Table 2 and Table 3.

Task 7.3: Publications

The Consultant is expected to write and submit one or two scientific article based on the research, in a peer reviewed national/international journal. The manuscript should be included in the Final Report.

Task 7.4:Data archiving

The Consultant is responsible for accurately archiving all data and reports that have been used for the research, including all meta data. All data, following proper data storage procedures, have to be delivered to VDMA.

V Deliverables and timeline

V.1 Project timeline

Table 2. Project implementation timeline

	Description	Month									
		1	2	3	4	5	6	7	8	9	10
1	**Task 1:** Inception phase										
	Additional survey of 3 pilot sites in 2 periods										
2	**Task 2:** Modelling										
	2.1. Prepare a computational model for global systemwide responses										
	2.2. Develop river morphodynamic models for 3 prioritized hotspots (pilot sites)										
3	**Task 3:** Analysis of trends and causes of riverbank erosion and classify										
	3.1. Identify riverbank changes over the past 2 decades										
	3.2. Identify and classify main causes for riverbank erosion										
	3.3. Evaluate (future) trends in changing boundary conditions										
4	**Task 4:** Assessment of effectiveness (pros & cons) for deployed coastal protection structures in Mekong Delta										
5	**Task 5:** Identify possible solutions										
	5.1. Identify possible solutions for 3 prioritized hotspots (pilot sites)										
	5.2. Analyze solutions on costs and effectiveness using mathematical model										
	5.3. Assess environmental and social side-effects of solutions										
	5.4. Develop guidelines for selection of solutions, depending on location and type of problem										
6	**Task 6: Database and maps**										
	6.1. Identify current and possible future hotspots of riverbank erosion risk										
	6.2. Prepare maps and interactive Web-GIS application and database										
7	**Task 7:** Dissemination of results and knowledge transfer										
8	**Seminar**										
9	**Reports**	1				2				3	4

Timeline for main tasks
Timeline for task components

V.2 Deliverables

Timeline for deliverables submission are shown in Table 2, in which

(1): The following reports should be submitted within 1 month after signing the consulting contract:

Inception report, Detailed outline report

(2): The following reports should be submitted after 5 months since the date of contract signing:

Report on mathematical simulation modelling of global systemic responses;

Report on Hydrological, hydraulic and topographic surveys deployed in dry season.

Report on identifying riverbank changes over 20 years;

Report on Effectiveness Assessment (pros and cons) for deployed riverbank protection structures in Mekong Delta;

(3): The following reports should be submitted after 9 months since the date of contract signing:

Report on river morphodynamic models for 3 prioritized hotspots (pilot sites);

Report on Hydrological, hydraulic and topographic surveys deployed in wet season;

Report on riverbank erosion classification;

Report on riverbank erosion trends under changing conditions;

Report on identifying possible solutions for the pilot sites;

Report on cost and effectiveness/benefits analysis of possible solutions

Report on environmental and social impacts of solutions

(4): The following reports should be submitted after 10 months since the date of contract signing:

Guidelines for selection of solutions, depending on location and type of problem;

Final Report;

Executive Summary Report;

Web-GIS user manual

Table 3. Milestones and deliverables of tasks

	Content	Time	Results	Note
1	Task 1: Inception phase	02/2022	Inception report Detailed outline report	1 month
2	Task 2: Modelling	03/2022 - 10/2022	Report on mathematical simulation modelling of global systemic responses; Report on river morphodynamic models for 3 prioritized hotspots (pilot sites)	8 months
3	Surveys of pilot sites in 2 periods	04/2022; 10/2022	Report on Geological, Hydrological, hydraulic and topographic surveys deployed in dry and wet season	
4	Workshop to present preliminary results of tasks 1 and 2 and survey results	05/2022		1st Seminar
5	Task 3: Analysis of trends and causes of riverbank erosion and classify	06/2022 - 08/2022	Report on identifying riverbank changes Report on riverbank erosion classification Report on riverbank erosion trends under changing conditions	3 months
6	Task 4: Assessment of effectiveness for deployed coastal protection structures in Mekong Delta	07/2022 - 08/2022	Report on Effectiveness Assessment (pros and cons) for deployed riverbank protection structures in Mekong Delta	2 months
7	Task 5: Identify possible solutions	08/2022 - 11/2022	Report on identifying possible solutions for the pilot sites Report on cost and effectiveness/benefits analysis of possible solutions using mathematical models Report on environmental and social impacts of solutions	4 months

			Guidelines for selection of solutions, depending on location and type of problem	
8	Task 6: Database and maps	08/2022 - 11/2022	Erosion maps: current status, forecast, solutions;	4 months
			Web-GIS systems	
9	Final workshop	11/2022	Report of project results;	Last Seminar
			Knowledge Transfer	
10	Task 7: Dissemination of results and knowledge transfer	12/2022	Final report and executive summary report, Practical Guideline Notebook	1 month

VI CONSULTANT'S QUALIFICATION CRITERIA

VI.1 Consultant's qualifications

- The consultants should have full legal corporate capacity, financially autonomous, have at least 10 years of experiences in the fields of irrigation, water resources, natural disaster prevention. The Consultant should prove practical records in carrying out researches and design projects in irrigation / water engineering, especially projects in shoreline erosion prevention and protection funded by international organizations or co-sponsored by bilateral donors. Project experiences in the Mekong Delta is an advantage.
- Number of projects that have been implemented under the ODA funds: at least 03 projects/studies;
- Number of projects that have been implemented in the Mekong Delta: at least 03 projects/studies
- Number of projects on erosion: 2 projects
- The Consultants should have specialized equipment for surveying such as: ADCP for flow discharge and velocity measurements; GPS mounted echo sounder; turbidimeter, leveling equipment.
- The consultants should have modelling packages including: hydraulic model, rainfall-runoff model and water balance model.
- The consultants should have a team of experts to provide services that meet the expert's qualification requirements as described in Table 4.
- The international consulting firms are encouraged to form Joint Ventures or Corporations with Vietnamese companies to provide sufficiently professional skills and experiences for the overall success of the research and obtain project objectives.

VI.2 Expert's Qualifications

Table 4. Qualifications, Tasks and Number of project experts

	Position	Qualifications	Tasks	Quality (month/person)
1	**Key Staff** Team Leader/ Water Resource Engineering Specialist (Hydraulic) (1 people x 4.25 months)	• Candidate must have a Doctor of Science with specialization in civil engineering in Geophysics, Civil Engineering, water resource engineering, specializing in river erosion and sedimentation processes, river morphology or similar fields and has at least 15 years of experience, has participated in state research projects in the Mekong Delta region, Having experiences in similar projects in terms of scale and nature in the country, the implementation of projects in the Mekong Delta is an advantage • Proven track records as team leader / project managers of erosion prevention and river management projects/studies in the Mekong Delta: at least 2 projects/studies • Proven track records demonstrating their knowledge and experiences in design irrigation/hydraulic works. He/She must have experiences in effectively leading, coordinating and managing project resources (both in terms of time and quality) of a professional team of experts in complex projects. • Fluency in English, proficient in computing, designing software, and computer science	• Responsible for managing and directing all research activities, maintaining close relationships with CPO/MARD, donors, local (provincial) agencies and other stakeholders to ensure coordination and cooperation between the parties. • Responsible for managing project inputs & outputs, activities and reports of all experts including research thematic reports and concept designs. • Monitoring project progress against consulting service delivery and coordinate preparation and submission of inception reports, progress reports, thematic reports and other research reports; • Directly preparing final reports, executive summary report and thematic reports. • Taking responsibility and participate in all project tasks.	4,25

2	**Key Staff** Deputy Team Leader-Hydraulic engineering expert (1 people x 7 months)	• Candidate must have a Ph.D. or higher education level with specialization in engineering; • At least 12 years of working experience in hydraulic engineering / hydrology / water resource engineering / oceanography. • Having experiences in implementing similar projects in Vietnam, especially in the Mekong Delta; • Having experiences in effectively leading, coordinating and managing project resources (both in terms of time and quality) of a professional team of experts in complex projects; • Proven track records as team leader / project managers of erosion prevention and river management projects/studies in the Mekong Delta: at least 2 projects/studies • Working experiences in ODA projects is an advantage; and fluency in English	• Assisting Team Leader in managing and directing all research activities, maintaining close relationships with CPO/MARD, donors, local (provincial) agencies and other stakeholders to ensure coordination and cooperation between the parties. • Responsible for assisting the team leader to manage project inputs & outputs, activities and reports of all experts including research thematic reports and concept designs. • Instructing the team to guarantee that the (construction) work quality meets (up-to-date) present standards, in compliance with national Vietnamese laws, policies and strategies, as well as WB guidelines and requirements; • Taking responsibilities and participate in all project tasks • Directly preparing pre-feasibility study reports including thematic reports.	7,00
3	**Non-key Staff** Hydraulic engineering expert (1 people x 7 months)			7,00
4	**Key Staff** Hydraulic experts (mathematical modeling) (1 people x 3 months)	• Candidate must have a Ph.D. with 08-years experience or a Master with 10-years experience specializing in hydrology, hydraulics, river morphodynamics or similar. • Having experiences in mathematical simulation models for hydraulic processes, river morphology and riverbank erosion • Teamwork ability and able to go on field trips to the Mekong Delta	• Responsible for assisting hydrologists with necessary data for thematic studies as well as mathematical modeling; • Directly participating in task 2 and task 3: modeling and Analysis of riverbank erosion trends and causes and classification. • Assisting hydraulic engineering specialists in task 5. • Instructing the modeling group to perform the tasks. • Directly preparing thematic reports.	3,00
5	**Non-key Staff** Hydraulic experts (mathematical modeling) (4 peoples x 3 months)			12,00

6	**Key Staff** Hydrology Specialist (1 people x 3 months)	• Candidate must have a Ph.D. with 05-years experience or a Master with 10-years experience specializing in hydrology, water resource engineering / hydraulic engineering, oceanography; • Having experiences in implementing similar projects in Vietnam, especially in the Mekong Delta; • Having experiences in effectively leading, coordinating and managing project resources (both in terms of time and quality) of a professional team of experts in complex projects; • Having knowledge in natural resource management measures and impacts of climate change and sea-level rise on coastal areas; • Fluently in English skills, good computer skills and report preparation.	• Responsible for collecting data and information on meteorology (rain, wind), hydrology (discharge, flow, velocity, water level, sediment). Participate in deployment and implementation of additional hydrometeorological surveys to determine the necessary parameters for the thematic studies, including input data of hydraulic models. • Consulting on impacts of climate change on water resources, hydrological inputs for models, thematic studies. • Directly preparing reports.	3,00
7	**Non-key Staff** Hydrology Specialist (2 peoples x 3 months)			6,00
8	**Key Staff** Water Resources Engineering Specialist (1 people x 3 months)	• Candidate must have a Ph.D. with 3-years experience or a Master with 8-years experience specializing in hydrology, water resources engineering / hydraulic engineering, oceanography; • Having experiences in implementing similar projects in Vietnam, especially in the Mekong Delta; • Having experience in ODA projects is an advantage; and • Fluently English skills.	• Responsible for analyzing and evaluating the advantages and disadvantages of the shoreline (riverbank) protection works deployed in the Mekong Delta in Task 4. • Participating in task 5: Propose potential solutions • Directly preparing thematic reports.	3,00
9	**Non-key Staff** Water Resources Engineering Specialist (3 peoples x 3 months)			9,00

10	**Key Staff** Specialist of Construction of hydraulic/water resources works(1 persons x 3 months)	• Candidate must have a Master of Science or equivalent education in Civil Engineering or Water Resources Engineering specializing in river management. • Minimum 8 years of experience in the design and technical aspects of riverbank erosion control measures (including dike systems, dredging, sheet piling, etc.). • Recent relevant practical experiences with similar projects in Vietnam are required.	• Directly participating in task 5: identify possible solutions for 3 hotpots / pilot sites; • Assisting the analysis of solutions in terms of cost and effectiveness. • Directly contributing to reports.	3,00
11	**Non-key Staff** Specialist of Construction of hydraulic/water resources works(3 persons x 3 months			9,00
12	**Non-key Staff** Remote sensing expert (1 persons x 2.5 months)	• Candidate must have Master of Science or equivalent education in geography, remote sensing, cartography or similar. • Minimum 8 years of experience in using earth observation systems for hydrological and water resource management. • Proficiency with GEE or similar tools for remote sensing analysis is required. Recent relevant practical experience with similar projects in Vietnam is an advantage	• Directly participating in task 3: analyze and evaluate shoreline/riverbank changes using remote sensing images • Assisting in development of interactive maps	2,50

13	**Non-key Staff** Geodetic/ Geology expert (1 persons x 2.5 months)	• Candidate must have a Bachelor of Science in Geodesy or equivalents; • Having at least 10 years of experience in topography and marine bathymetry survey; • Having experiences in similar projects in Vietnam; • Fluently English skills	• Participating in topography surveys of riverbeds for hotpot areas. • Developing topographic maps for 3 hotspot areas. • Analysis and assessment of the topography of riverbed	2,50
14	**Non-key Staff** Geoscientist (1 persons x 2.5 months)	• Candidate must have a Bachelor of Science in Geology or equivalents; • Having at least 10 years of experience related to geotechnical investigation/survey, especially in shoreline protection works • Proficient in geological analysis software and tools; • Having experiences in similar projects in Vietnam; • Fluently English skills	• Participating in geological survey for 3 hotspot areas. • Analysis and Assessment of geology • Preliminary identification of erosion causes	2,50
15	**Non-key Staff** Economic/ environmental and social expert (1 persons x 2 months)	• Candidate must have a Master of Science or equivalent education specialization in economic or social sciences with a focus on environmental aspects and impacts. • Minimum of 8 years of experience in costs - benefits estimation of water infrastructures as well as assessment of potential social issues. Experiences with socialization processes and stakeholder engagement assessments are highly recommended. • Recent relevant practical experiences with similar projects in Vietnam is an advantage.	• Participating in cost estimation for alternatives, • Directly participating in the design of protection works. • Analyzing technical and economic conditions of areas of interest, proposing effective solutions for every area and every period • Directly contributing in reports	2,00
16	**Non-key Staff**	• Candidate must have a Bachelor of Science or equivalent education level specialization in river	• Initial environmental and social assessment with reference to all proposed interventions in	2,50

	Environmental management specialist (1 persons x 2.5 months)	ecology and water resource management or similar. • Minimum 8 years of experience in environmental impact assessment for river engineering solutions/measures. • Experiences with similar projects in Vietnam is an advantage.	compliance with regulated Guidelines of the Government and World Bank • Analyzing and evaluating the effectiveness construction works, • Analyzing and assesing the social & environmental impacts of the solutions on surrounding areas, and proposing mitigation measures. • The expert will contribute on social and gender aspects and reporting.	
17	**Non-key Staff** Information technology and data management specialist (2 persons x 2.5 months)	• Candidate must have a Bachelor of Science/or Technology or equivalent education level specialization in information technology in database management. • At least 5 years of experience related to machine learning, AI and image processing; • Proficient in Java, Python and Matlab programming languages; • Experience in big data processing; • Fluently English skills	• Assisting experts in processing data which will be collected and/or surveyed; • Translation, reporting, administration works • Data analysis, remote sensing image processing	5,00
18	**Non-key Staff** GIS Expert (1 person x 2.75 months)	• Candidate must have a Bachelor of Science/or Technology or equivalent education level with specialization in web design and GIS applications. • Minimum 8 years of experience in web design and GIS applications. • Recent experience with similar projects in Vietnam is an advantage.	• Assisting experts in using remote sensing images to analyze and develop maps. • Developing maps and interactive applications for Web-GIS	2,75

19	**Non-key Staff** Supporting staffs (20 persons x 7.4 months)	• Candidates must have a university degree in the right major of the proposed position and have less than 5 years of experience in consultancy. • Recent relevant experience with similar projects in Vietnam.	• Assisting experts in all project activities: data collection, additional surveys, data processing, document preparation, map processing, model calculation domain, result extraction, database development for Web-GIS, cost - efficiency calculation and processing, etc.	148