River Basin Master Plan Welang

Task C report - Solve and Innovate

Rijksdienst voor Ondernemend Nederland

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TABLE OF CONTENTS

1

INTRODUCTION

1.1 Background

The Welang Master Plan project is developed in close cooperation between Water Resource Department of the East Java Provincial Government and the Netherlands Ministry of Infrastructure and Water Management. The project is implemented under the Partners for Water Program, a program managed by the Netherlands Enterprise Agency (RVO), part of the Netherlands Ministry of Economic Affairs and Climate.

The project coordinator from East Java Province was Mr. Fauzy Nasruddin. The project was executed by a consortium consisting of:
- Lead consultant: Witteveen+Bos Raadgevende ingenieurs B.V. in cooperation with the Indonesian subsidiary PT Witteveen Bos Indonesia;
- Deltares;
- The Water Agency;
- Wetlands International;
- HZ University of Applied Sciences;;
- ITS University, Surabaya;
- Rebel Group.

The project structure: five tasks
The project has been divided into five Tasks:
- Task A: understanding the river basin: issues, mechanisms, physical and socio-economic aspects. This Task will lead to a Baseline Report where the underlying data collection which are relevant to the projects, such as water level, discharge, precipitation, etc. will be presented.
- Task B: preparing an Integrated River Basin Management Plan (IRBMP)
- Task C: select and detail a series of priority projects and support EJP and RVO in match-making. This Task leads to a series of designs with supporting information and a business case as well as a series of match making events.
- Task D: an inclusive development: include stakeholders, also in the river basin
- Task E: transfer of knowledge, training

This report presents the results of task (C) on ‘priority projects’. These projects are about developing solutions for urgent water management issues in the watershed. These urgent issues were identified in the Baseline Study (Task A), which is also the starting point for the IRBMP (Task B). The priority projects should be developed in such a way that international financing of a follow-up would be feasible.

This report details the criteria and considerations for the selection of these priority projects as well as a proposal for a set of priority projects.

1.2 Goal

To prepare conceptual designs for the desired hard and soft measures, based upon the thorough understanding of the river basin and incorporated in an Implementation Programme for the coming 5 years. These project packages are supported by stakeholders and subsequently can be used for acquiring (national and international) funding for the further design and implementation. EJP is inspired by and able to apply innovative technologies and approaches, such as Building with Nature (BwN).

2

METHODOLOGY AND MAIN ASSUMPTIONS

2.1 General approach

The workplan is aimed at 'funnelling' intervention options towards a small set of technically and socio-economically feasible interventions. We started with the most urgent issues identified in Task A (the Baseline Stusy) and explored a wide range of options. After a performing a Multi-Criteria Analysis, two priority issues remained, one in the downstream and one in the midstream section of the watershed. Next, we reduced solutions through a sensitivity analysis using hydrological and hydraulic modelling. In this initial stage we interacted with governmental stakeholders and local (community) leaders and representatives to better understand the local socio-economic conditions. The solutions were further evaluated in terms of effectivity, legislation, socio-environmental impact, and costs. Finally, the final preferred set of interventions were selected, based multiple criteria and these interventions were further detailed into conceptual designs together with cost estimations, cost-benefit analysis, outline business case and environmental and social evaluations.

2.2 Main assumptions

- Evaluation at conceptual pre-feasibility level (master plan level).
- The simulated water levels from the hydraulic model cannot be used as absolute levels and therefore effects of measures should also be evaluated and interpreted in terms of water level reduction in the main river only with the purpose to compare and select options.
- The existing Sobek model of the Welang can be used to simulate the effects of measures taken in the downstream part of the Welang.
- There are no water level/discharge observations in the Kali Sumber Pinang and therefore the model will be a rough first estimate at best. Verification of the simulated flood level will be performed by asking local people for their observation of the maximum water level in the river.
- DEMNAS (the national digital elevation model) will be used as the basis for the design of measures and excavation volume.
- The cross-sectional survey of the Welang from 2017 is used to determine the dredging volume of the dredging option.

3

C1: PRIORITISE MEASURES

3.1 Introduction

In this chapter we outline the selection and development process of the priority projects. In Chapter four, the selected priority projects and the designs are presented in more detail.

It is important to note that the Baseline study showed that developments in upstream land use are the most important drivers of floods. Changing these developments into a more sustainable direction (via spatial planning, soil conservation and sustainable economic planning) would also qualify as a priority project. However, this was beyond the defined scope of Task C, which focuses on physical interventions.

3.2 Priority issues

3.2.1 Priority issues in the river basin

The baseline study (Task A) [ref. 1] is the starting point for the Integrated River Basin Management Plan (IRBMP, Task B) [ref. 2] as this study outlines the main problems in the watershed, both physical and institutional. The priority projects are part of the identified issues in the IRBMP baseline study.

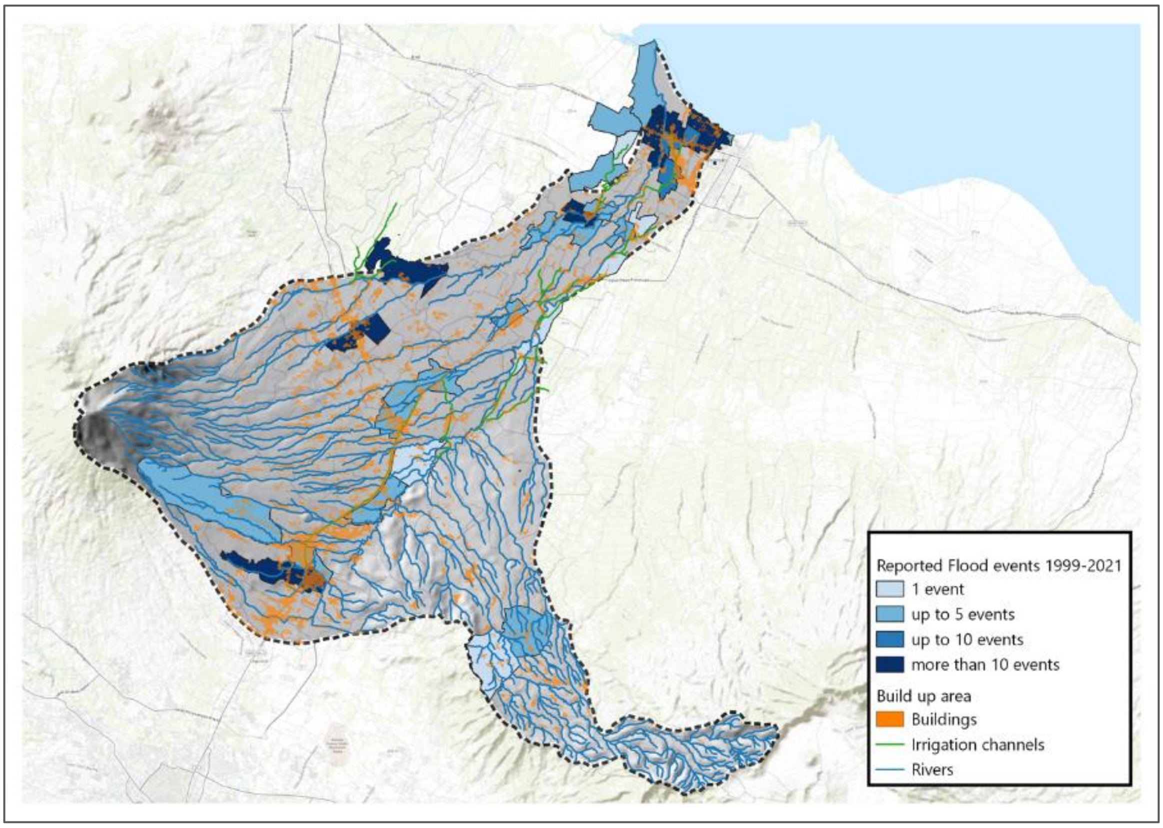
The IRBMP baseline study identifies as series of issues, summarized below:
- The **changing land use** is the main driver behind flooding, water shortage issues and water pollution. The mix of deforestation, urban expansion, non-sustainable agriculture practices, industrial pollution, littering and inadequate waste management and lack of waste water treatment created a multitude of problems in the watershed. A different, sustainable use of natural resources is required to fundamentally solve these problems.
- In more detail, water management issues are:
    - **Fluvial (river) flooding in the Kraton-Pasuruan area** (see figures below), caused by residential expansion into flood prone areas, combined with increased discharge from upstream sections (see also below this list);
    - **Pluvial (rainfall) flooding in several residential areas**, many in the Kraton-Pasuruan area caused by inadequate drainage systems. Sometimes old irrigation systems act as the drainage systems, but these were never designed for such purpose.
    - **Solid waste in rivers**, blocking drains, causing serious environmental issues in the riverine systems, seas and oceans.
    - **Poor water quality** due to discharge of untreated industrial and residential waste water. This pollution affects downstream users (intake drinking water and irrigation), contributes to waterborne diseases and affects the biological function of rivers.
- Solving these issues is hampered by:
    - A **strong focus on rapid economic development** without many environmental constraints to combat poverty rather than a more sustainable growth which takes environmental aspects into consideration;

- **Sectoral policy making**, where water management, development and spatial plans are prepared separately and do not automatically have a horizontal and vertical reach (e.g. influencing other sectoral plans and authorities);
- Industrial, urban **developers and residents do not contribute to solving water management issues** created by them. The 'polluter pays' principle is not applied, creating a burden to the state budget;
- **Water management is not an important steering factor** in strategic decision making (development plans, spatial plans). Flood plains, for instance, are not protected against (uncontrolled) urban and industrial expansion;
- **Weak implementation and enforcement of environmental and spatial laws**, thus allowing uncontrolled urban and industrial expansion and over-use of water resources.

Areas with frequent flooding

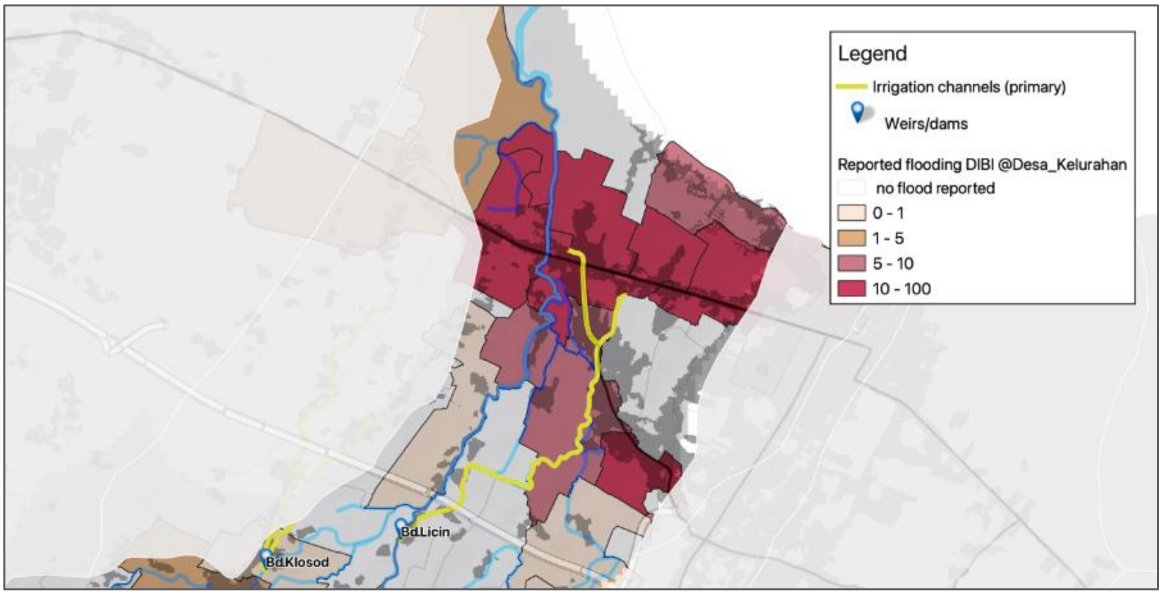
Although floods occur throughout the watershed, the Kraton-Pasuruan area appears to be the main area of flooding. See Figure 3.1 and Figure 3.2. In this area, the river transitions from a fast-flowing upstream river to a downstream river with lower water velocities. The urban density is also very high in this area, surrounding the river and canals. High water levels therefore frequently result in urban floods.

Figure 3.1 Reported flood events in the watershed between 1999-2021 [ref. 1]



The Kraton-Pasuruan area is affected in two ways:
- former irrigation systems are not designed for drainage purposes and this leads to pluvial (rainfall) floods in Pasuruan;
- the increased discharge volumes in the Welang river in combination with dense urbanisation (also in the floodplain of the river) create a high risk setting for floods.

Figure 3.2 Flood risks in the Kraton-Pasuruan area



3.2.2 Priority issues from the brainstorm sessions

The priority issues were also discussed in a meeting with EJP departments on 3 May 2021 and an internal workshop on 9 June 2021. These discussions provided more or less the same issues as identified in the baseline study (Task A), albeit sometimes in more detail or expressed differently.

The issues identified in these discussions were:
- Pluvial floods in the Pasuruan area.
- Fluvial floods in the Kraton area, due to increased water discharge.
- Soil erosion in watershed and sedimentation in the river.
- Solid waste in the river.
- Drought (albeit not discussed in detail).

Suggestions on projects:
- Request from BAPPENAS for a pilot project on improved institutional cooperation.
- Storage in the side channel of the Welang (between Kraton and toll road).
- Reconversion of upland agriculture in agroforestry.

3.2.3 Pre-selection

Although the identified problems and suggestions were valid (and included in the IRBMP), some of them were regarded as non-eligible for Task C:
- Upstream issues (erosion, land conversion) are regarded as problematic, but they are related to the impacts downstream and not being addressed as stand-alone issues which need to be addressed in isolation;
- Sedimentation is also regarded as a serious issue, but addressing this will require substantial fieldwork to better understand mechanisms and sources of sediment. Fieldwork is difficult under these COVID conditions. The impact of sedimentation on flooding in the downstream area and (potential) dredging as solution will still be considered;
- Solid waste is also a serious problem, but addressing this issue is mainly an environmental issue and would involve many stakeholders beyond the DPU and water management sphere, which presents practical problems;
- Droughts and excessive groundwater extraction are not part of the original scope of work for this project.

We therefore only consider the following projects to qualify for further selection:
- Reducing pluvial floods in the Pasuruan area.
- Reducing fluvial floods in the Kraton area, due to increased water discharge.
- Reducing fluvial floods in the Kraton area through storage in the side channel of the Welang (between Kraton and toll road).
- Reducing river flow from the upstream areas to the town of Sidogiri. The river flow has increased due to the reconversion of upland agriculture in agroforestry and other upstream interventions.

3.3 Priority projects

3.3.1 Focus on physical projects

The priority issues in the Welang watershed are both physical (conversion of land, sedimentation, flooding) and institutional (lack of effective, integrated policies and water management as policy priority).

Although the institutional issues are serious obstacles to a successful water management, they will not be eligible as priority projects. The ToR and the Inception Report focus on physical interventions with designs and business cases and this eliminates the institutional issues.

The institutional issues will be addressed under Task B, the IRBMP.

3.3.2 A longlist of priority projects

After eliminating the institutional issues as potential projects, the following potential projects remain:

Potential project 1: Improving the urban drainage of West-Pasuruan
The floods in Pasuruan are pluvial and most likely caused by rapid urbanisation in combination with poor drainage. The current drainage system is shaped to irrigation purposes which results in a different system (focussed on 'bringing water' rather than 'draining water').

The goal of this project would be: re-designing the drainage system of West-Pasuruan (on conceptual level) to reduce the floods in the current and future residential and industrial areas.

Note 1: this area will most likely be urbanized in the near future and any drainage system should be 'future-proof' (able to also drain future residential and industrial areas).

Note 2: making a final alignment of the project boundaries is required as first step. This alignment is based on topography, a system analysis and practical considerations like available modelling time and budget.

Figure 3.3 Indication of the study area under potential project #1

Activities:
- Scoping the project: defining boundaries, methodologies, and levels of detail
- Basic survey of the area: existing drainage channels (alignments, gradients, status)
- Evaluation of land development plans, spatial plans
- Building a hydraulic (Sobek) model
- Designing a conceptual drainage design, evaluation with Sobek
- Optimization and final evaluation with Sobek
- Stakeholder engagement
- Outline cost estimate
- Outline business case
- Screening of social and environmental impacts
- Reporting with conclusions and recommendations

A pre-condition to this project is the availability of some cross-section with GPS. This will allow to prepare a basic digital terrain model (DTM) which is required for Sobek modelling. The figure below presents an indication of such a grid of cross sections.

Figure 3.4 Indication of the cross sections

Potential project 2: Master Plan Kraton-Pasuruan

The fluvial (river) floods in the Kraton area are now being addressed by reinforcing the river embankments. With increasing water volumes (expected 10% increase in the coming 10 years), this might not be sufficient and additional interventions might be required. While further strengthening of the embankments may be considered, also other options may be effective:

- Dredging of the river (over different lengths) including re-use of materials (brick-making)
- Slowing down of upstream discharge by upstream retention, reservoirs or check-dams
- Widening of the river
- Side channels (downstream)
- Combination of these interventions

This evaluation should be done on Master Plan level, e.g. a high level evaluation of options in terms of hydrological/hydraulic potential, societal impacts and costs-benefits.

The goal of this project would be: evaluating the intervention options on a conceptual level to reduce the fluvial floods in the current (and future) residential and industrial areas of the Kraton area.

Figure 3.5 Indication of the study area under potential project #2

Activities:
- Evaluation of land development plans, spatial plans
- Evaluation of intervention option with Sobek
- Optimization and final evaluation with Sobek
- Stakeholder engagement
- Screening of social and environmental impacts
- Outline cost estimate and outline business case
- Reporting with conclusions and recommendations

Potential project 3: using the Kraton side-channel as retention area
The fluvial (river) floods in the Kraton area are now being addressed by reinforcing the river embankments. With increasing water volumes (expected 10% increase in the coming 10 years), this might not be sufficient

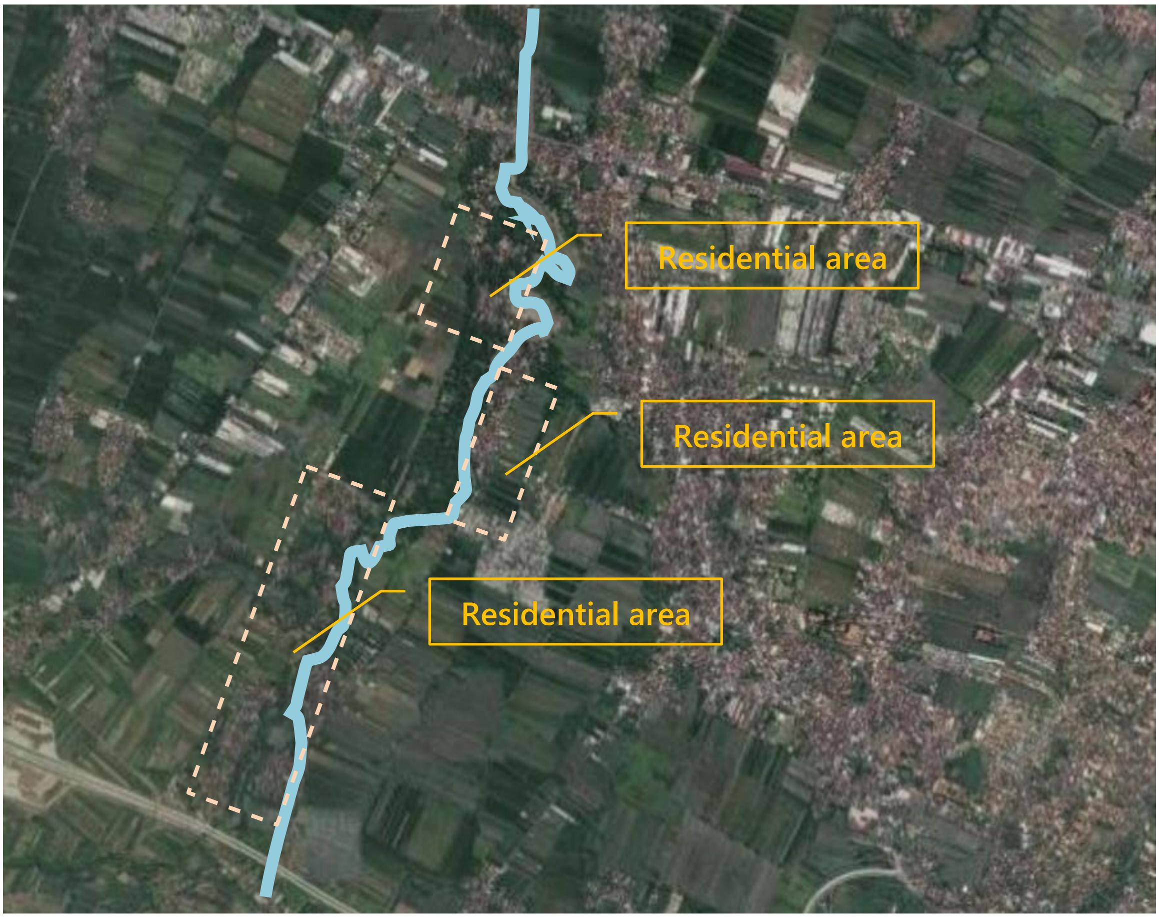
and additional interventions might be required. DPU is considering using a river arm parallel to the Welang river as storage channel. See figure below.

This area is partially in use as agricultural land, but already a residential area is built in the downstream section creating substantial restrictions to the use of this area as retention for large water volumes. See figure below.

The goal of this project would be: evaluating the use of the side-channel next to the Welang river to reduce the fluvial floods in the current (and future) residential and industrial areas of the Kraton area.

The evaluation would be both on the use as water retention area and as secondary drainage channel. The evaluation should not only be on technical aspects, but also on societal impacts (impact on agriculture and residents), multifunctional use and cost-benefits.

Figure 3.6 Potential retention area south of Kraton Bridge. This land is partially under agricultural use, partially residential



Activities:
- Evaluation of land development plans, spatial plans
- Develop retention options and a side-channel design, evaluation with Sobek
- Optimization and final evaluation with Sobek
- Stakeholder engagement
- Outline cost estimate and outline business case
- Screening of social and environmental impacts
- Reporting with conclusions and recommendations

Potential project 4: reducing the flow from upstream areas
The observed land conversion in upstream areas contribute significantly to the fluvial floods in the Kraton area and evaluating the upstream options would be useful:
- Reconversion of upstream sections (agroforestry, reforestation)
- Retention basins
- Reconstruction of irrigation reservoirs to check-dams. Irrigation reservoirs aim to retain water, while check dams aims to regulate (slow-down) water
- Check-dams in upper sections of the watershed

This evaluation should be done on Master Plan level, e.g. a high level evaluation of options in terms of hydrological potential, societal impacts, implementation issues, speed of implementation and costs-benefits.

The goal of this project would be: evaluating the upstream intervention options on a conceptual level to reduce the fluvial floods in the current (and future) residential and industrial areas of the Kraton area.

Given the size of the area and lack of good DTM, we would only be able to model the effectiveness of these interventions on a very global level (using the hydrological model Wflow, which is less accurate and versatile as Sobek). However, this assessment would provide insights in hydrological potentials, required efforts and socio-economic impacts.

3.3.3 Final selection

Pre-selection and short-listed projects
A pre-selection was made in the previous paragraphs:
- All non-physical interventions were excluded (ToR).
- All interventions which are beyond the sphere of influence of DPU were excluded (litter, waste).
- All interventions which will require substantial data collection and field work were excluded for practical reasons (erosion and sedimentation).

Four potential interventions remain:
1 Improving the urban drainage of West-Pasuruan.
2 Master Plan Kraton-Pasuruan.
3 Using the Kraton side-channel as retention area.
4 Reducing the flow from upstream areas.

Criteria
According to the ToR, these potential interventions should meet the following criteria:
- Must include conceptual designs.
- Must be part of the priorities in river basin and part of the implementation programme.
- Must be supported by stakeholders*.
- To be used to secure national and international funding.
- Application of innovative techniques (like BwN).

*The criteria 'must be supported by stakeholders' will be interpreted as 'must be supported by DPU' as this list of potential priority projects has not been discussed with all relevant stakeholders. Stakeholder engagement will be an important aspect of the implementation of the priority projects.

We will include these criteria in the full set of criteria. Other criteria with their justification will be:
- **Learning aspect:** this project is also on transfer of knowledge and the staff from DPU must learn from this priority project. Projects which focus on basic engineering designs have less 'learning potential' compared to more advanced, integrated projects;
- **Cooperation aspect:** a priority project with a large stakeholder involvement (governmental and non-governmental) will strengthen inter-agency and stakeholder cooperation and raise awareness for water issues with non-DPU stakeholders; the more concrete the project, the deeper the involvement;

- **Hydraulic urgency:** projects which are important and urgent will have more potential for follow-up and funding;
- **Societal impact:** one may argue that projects with a big potential impact on society (residents, farmers, industries) are more relevant in this project compared to projects which has limited impact. In this project we have the resources to support DPU in such complex settings and we can develop mitigating mechanisms which can be useful for future situations.
- **Practical implementation:** can this priority project be implemented within the given time, COVID restrictions and budget. Do we need additional field surveys (GPS-data) to make a DTM?

These aspects are valued by numbers ranging between:

1 No added value, not relevant.
2 Limited added value, limited relevance.
3 Some added value, relevance.
4 High added value, highly relevant.

The Multi-Criteria Table below shows the result of the application of the criteria.

Table 3.1 MCA priority projects

Criteria	Improving the urban drainage of West-Pasuruan	Master Plan Kraton-Pasuruan	Using the Kraton side-channel as retention area	Reducing the flow from upstream areas
TOR: Must include conceptual designs.	3 Designs are included	3 Designs are included	3 Designs are included	2 High level conceptual only
TOR: Must be part of the priorities in river basin and part of the implementation programme.	3 Is included in IRBMP and identified as important	3 Is included in IRBMP and identified as important	2 Is not as such included in IRBMP as the efficiency is in doubt	3 Is included in IRBMP and identified as important
TOR: Must be supported by stakeholders.	3 Is suggested by DPU	3 Is suggested by DPU	3 Is suggested by DPU	2 Is mentioned by DPU, but not regarded as urgent
TOR: To be used to secure national and international funding.	3 Feasible, will provide a good option for follow-up	2 Might provide some options for follow-up	2 Might provide some options for follow-up	1 Complicated to translate in tangible follow-up projects
TOR: Application of innovative techniques (like BwN).	0 Is basic engineering design	2 Might provide an integrated approach	2 Water retention and multifunctional use	3 Water retention, reforestation
Learning aspects	1 Basic engineering: limited learning experiences	3 Involves many (non-) technical aspects of water management	2 Involves several (non-) technical aspects of water management	2 Involves several (non-) technical aspects of water management
Cooperation aspects: the more concrete the project, the deeper the involvement	3 Deep involvement of local authorities, residents and users	2 Consultation of local authorities, residents and users	3 Deep involvement of local authorities, residents and users	1 Some consultation of local authorities and users
Hydraulic urgency	2 This is the area of frequent floods, albeit limited in impacts	2 Fluvial floods are potentially severe, but problem is addressed for short term	2 Fluvial floods are potentially severe, but problem is addressed for short term	2 This will reduce future floods
Societal impact	1 Limited impacts as this is about relative small drainage channels	3 May lead to interventions with major societal impacts	3 May lead to interventions with major societal impacts	3 May lead to interventions with major societal impacts

Criteria	Improving the urban drainage of West-Pasuruan	Master Plan Kraton-Pasuruan	Using the Kraton side-channel as retention area	Reducing the flow from upstream areas
Practical implementation aspects	3 Limited scope, limited complexity, is feasible. Might be combined with other light project when executed in a high level manner	2 Medium scope, medium complexity, feasible, will require all resources under Task C	3 Limited scope, limited complexity, is feasible, might be combined with other light project	3 Limited scope, limited complexity, is feasible, might be combined with other light project
Additional (GPS) data required?	yes	yes	yes	no
Totals	**22**	**25**	**25**	**22**

3.3.4 Conclusions and recommendations

Conclusions
The 4 potential projects do not differentiate much when using the unweighted criteria. The highest scoring potential projects are:
- Master Plan Kraton-Pasuruan.
- Using the Kraton side-channel as retention area.

The Master Plan for the Kraton-Pasuruan area will require all resources under Task C as different interventions must be modelled, individually and combined. Selecting this project implies that Task C will focus on this project only. This Master Plan may be interesting as it will include many potential interventions, ranging from dredging to upstream interventions. This wide-ranging evaluation will provide additional insights in the mechanisms in the Welang river and the potential of interventions.

If the Kraton side-channel is selected, then another small priority project may be selected as second priority project: upstream retention or urban drainage of West-Pasuruan (provided this project is executed on a high level of abstraction with limited modelling work). This project will provide useful insights in the functioning of mid-stream retention and the opportunities and constraints of this type of interventions. However, these insights are only applicable for this area specifically as the feasibility of retention is strongly related to the local circumstances.

A pre-condition for the first three priority projects is the availability of additional terrain data. This will require a field survey with GPS instruments. This additional field survey is not included in the current Scope of Work for this project.

Note: if two priority projects are selected, the GPS-based field survey may be necessary in 2 areas!

Recommendations
We recommend considering two options:

Option 1: Master Plan Kraton-Pasuruan. This Master Plan will include many different water management interventions (structural, non-structural, upstream and downstream), a MCA analysis and several stakeholder aspects. This Master Plan may lead to an interesting, integrated intervention package which could be eligible for financing and BAPPENAS involvement.

Option 2: undertake two priority projects 1) using the Kraton side-channel as retention area and 2) high level analysis of the urban drainage West-Pasuruan. This combination will still include many aspects of water management (drainage, retention, urban, rural, multifunctional use, spatial planning, stakeholders), while it also aims at solving concrete problems. Both projects have the potential of a follow-up.

Selection of the priority projects

After a series of discussions with DPU-EJP, two priority projects were selected in the workshop of 12 July 2021:
1. Revitalizing the old Welang river arm (Welang Lama) including an investigation of Room for the river type of interventions in the Kraton area to accommodate increasing water volumes (expected 10% increase in the coming 10 years) as a result of upstream land conversion.
2. Water retention in the Sumber Pinang catchment (upstream of Sidogiri town) to lower the flood hazard at the Islamic Boarding school.

3.4 Developed measures for priority projects

3.4.1 Priority project 1: Kraton area

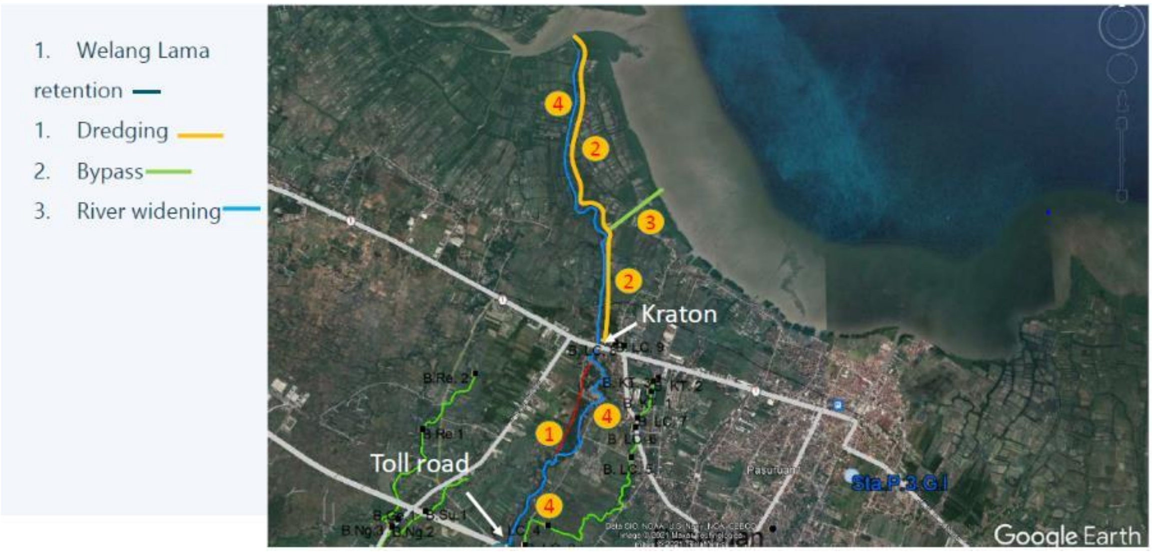
The fluvial (river) floods in the Kraton area are currently being addressed by reinforcing the river embankments (parapet). With increasing water volumes (expected 10% increase in the coming 10 years), this might not be sufficient and additional interventions might be required. DPU has indicated a wish to potentially use a river arm parallel to the Welang river as storage channel. See Figure 3.8 (nr 1).

The area to the west of the old branch is currently mainly used for agriculture, although the ownership is unknown. The area between the old channel and Welang river is forested and contains agricultural land and residential areas. The spatial plan of Kabupaten Pasuruan indicates that this area is designated to be developed into residential and industrial areas. It is very likely that the land is already bought by developers. The goal of this priority project is to evaluate alternative measures to reduce peak water levels in Welang river between Dhompo and (at least) the railway crossing.

We advocate to take more sustainable measures and steer away from expensive rigid physical protection measures (which are erected to provide protection there where they are constructed) towards cheaper flexible prevention measures which aim at the root causes leading up to the flood problems, such as:

1 Welang lama retention
2 Dredging
3 Bypass
4 River widening

Figure 3.7 Location of the measures in the Kraton area and downstream



The flood water level at the Kraton area may also be reduced by reducing the peak discharge by implementing measures the upper catchment to reduce and slow down and attenuate the flood wave such as:

- Reconversion of upstream sections (agroforestry, reforestation)
- Upstream retention (basins)
- Reconstruction of existing weirs at inflow locations of the irrigation channels
- Check-dams in upper sections of the watershed
- Terracing

- Avoid the additional run-off from the near future potential land-development by preparing a more sustainable spatial plan (zero-deltaQ policy[1])

The results modelling of the downstream and upstream measures are elaborated in Appendix I.

3.4.2 Priority project 2: Sidogiri

The village Sidogiri is located along the Kali Sumber Pinang which is a tributary of the Welang. The confluence of this river is located just upstream of the toll road at Dhompo.

In this project we investigate the cause of the flooding and evaluate several potential interventions in the catchment upstream of Sidogiri. The goal is to understand what feasible interventions are available to reduce the amount of river water (during floods) in the town of Sidogiri. If such feasible interventions exist, then these may be applied throughout the whole Welang watershed. This priority project can therefore be considered as a showcase.

As there is little data available on this section of the Welang watershed, a river cross section survey is carried out to obtain a basic set of levels and cross sections. The hydrological model is used to determine the discharge of the Sumber Pinang, which will give an indication on the effectiveness of interventions (a more detailed analysis using Sobek is not possible as the dataset is not sufficient).

The following interventions are evaluated:
- Regreening of slopes (agroforestry, reforestation);
- Terracing of slopes
- Check dams

The evaluation and selection of preferred measure is presented in the next section.

3.5 Evaluation and selection

The longlist of measures is evaluated using an MCA with the criteria listed in the table below.

Table 3.2 List of criteria to be applied in MCA

Main factor	Sub factor	Clarification
Hydraulic effect	Flood level reduction	The water level reduction during a 1/25 year flood at Kraton
	Effectiveness	The amount of water level reduction vs excavation volume (cm/1000 m3)
Technical	Constructability	Ease of construction and maintenance (availability construction materials and construction equipment, expertise of contractors)
	Robustness of the intervention	Resilience of the intervention (does it work in several scenarios and in the situation with a large degree of uncertainty?), the dependency on the 'human factor' (ease of operation), maintenance aspects, Redundancy options (spare materials for repairs)
	O&M	Requirements for staff, budget and knowledge
Financial	Costs	CAPEX and OPEX
Institutional	Impact on O&M, monitoring and planning in budget, capacity (knowledge and organisation)	Capacity (staff and knowledge) for implementation, O&M, monitoring and planning

[1] This concept aims to avoid or reduce the extra run-off due to surface hardening (buildings, parking places, roofs) by compensating the hard surfaces with (for instance) retention basins and infiltration boxes.

Main factor	Sub factor	Clarification
Hydraulic effect	Flood level reduction	The water level reduction during a 1/25 year flood at Kraton
	Effectiveness	The amount of water level reduction vs excavation volume (cm/1000 m3)
Technical	Constructability	Ease of construction and maintenance (availability construction materials and construction equipment, expertise of contractors)
	Robustness of the intervention	Resilience of the intervention (does it work in several scenarios and in the situation with a large degree of uncertainty?), the dependency on the 'human factor' (ease of operation), maintenance aspects, Redundancy options (spare materials for repairs)
	O&M	Requirements for staff, budget and knowledge
Environmental	Impact on nature and environment	Impact on natural habitats (on land and in water), impact on water bodies, water quality and morphology
Social (and culture)	Socio-economic impact	Adverse and positive impact of interventions on people and livelihood, including (reduced) flood and erosion risk, impact on transport, water supply, etc.
	Inclusivity	Involvement, impact and opportunities for women and minorities
	Poor people	Vulnerability: impact on number of people, livestock and subsistence farms
	Employment	Impact on regional employment focussing on the poor and vulnerable

3.5.1 Priority project 1: Kraton area

The table below presents the evaluation of the interventions on the criteria. The scoring is done among the alternatives and not against the autonomous development. This will be done for the selected priority measures (section 4.5).

The table shows that dredging scores best followed by the bypass and river widening interventions. The Welang Lama as a retention basin doesn't score well.

The Welang Lama as a retention basin doesn't score well because the effectiveness in reducing the flow level is small while a large excavation volume is required. The intervention is not very robust as the inflow should be designed properly to make sure the retention basin becomes active at the right moment during the passage of a flood wave. A large agricultural area needs to be converted into a retention basin and many landowners need to be compensated.

Dredging is an effective intervention and easy to realise but maintenance dredging (approximately every 5 years) will be required. The dredged sediment might be re-used which could create additional revenue. Adverse impacts are increase in salinity intrusion, decrease of (water levels) consequently lower groundwater tables and less inundation of floodplains, and reduced connectivity of the river and floodplains.

The bypass is very effective in lowering the flood level at Kraton. The excavation volume and maintenance (removal of vegetation and silt). It has some potential of creating an agro-ecological zone (a zone with limited agricultural use, but with ecological potential).

River widening is effective, but the hard embankment (parapet) prevents the realisation of this intervention and the area outside the 20 m zone of the river is not with jurisdiction of PU-SDA. Therefore, this intervention is considered not realistic.

The evaluation of the interventions was presented and discussed during workshop 7 on 27 October 2021. PU-SDA selected the bypass and dredging measures to be further detailed into conceptual designs.

We carried out a sensitivity analysis of upstream measures such as regreening, terracing and check dams. The results of the sensitivity analysis is presented in Appendix I. It is concluded that terracing and regreening parts of the catchment is an effective way to reduce the peak discharges and flood level at Kraton. Since these measures are outside the jurisdictional area of PU-SDA it was decided not to include them in the implementation programme for the coming 5 years.

Table 3.3 Priority project 1 (Kraton area) - Evaluation of interventions

Intervention	Water level reduction at Kraton bridge	Effectiveness (cm/1000 m3)	Technical	Cost	Institutional	Environmental	Social
Retention basin Welang Lama	- 8-14 cm	- ~0.1 cm/1000 m3 is not effective	- weir height should be designed at right height to assure the retention is effective in reducing flood level	- Large excavation volume. Construction of in-/outlet. Purchase of land	- outside jurisdictional zone of PU-SDA	0 area is mainly agricultural land, environmental impact is limited	- large area with many landowners need to be compensated
Dredging	+ 40-60 cm	+ ~0.5 cm/1000 m3 is relatively effective	+ relatively easy to realise	+ cost effective solution but frequent dredging needs to be carried out. Sediment can be used for brick making	+ within the jurisdictional area of PU-SDA	- impacts on all water levels salinity intrusion increases connectivity decreases	+ additional income and jobs can be generated
Bypass	+ 30-35 cm	+ ~0.4-0.9 cm/1000 m3 is very effective	+ easy to realise and no structures need to be built. Some maintenance is required (removal of vegetation and silt)	+ cost effective solution as excavation volume, maintenance and purchase of land is limited	- outside jurisdictional zone of PU-SDA	0 the bypass is active only at high flows so impact will be limited	0 the size of the area is limited, only a few landowners need to be compensated
River widening	+ 30-90 cm	+ ~0.2-0.8 cm/1000 m3 is very effective	- easy to realise and no structures need to be built. However, an embankment (parapet) structure has been built along the foreseen river banks preventing the river widening	- to realise the river widening the hard embankment should be removed and soil needs to be excavated	+ within the jurisdictional area of PU-SDA	+ better lateral connectivity between river and floodplain	- large area with many landowners need to be compensated

3.5.2 Priority project 2: Sidogiri

To gain understanding of the cause of the floods at Sidogiri and to model interventions, a hydraulic model of the Sumber Pinang is required. The 1-D hydraulic model (Sobek) requires, amongst others, a bathymetry as input. Since this data is missing, a cross-sectional survey of the main channel, riverbanks and structures like bridges and weirs was carried out. Using this data and information on the boundary conditions (upstream: discharge and downstream water level) the hydraulic model was established. Note that with this model only the flood from the river (fluvial flooding) can be simulated.

This model was validated by comparing the modelled flood level with visual observations made by residents of maximum flood depths and flooding frequency. From the modelling results it appeared that hardly any (fluvial) flooding occurs at Sidogiri, while residents indicated that Sidogiri experiences yearly flooding with a maximum inundation depth of about 0.5 - 1 m which lasts generally 30-60 min. Possible causes for this discrepancy may be:

- the floods are caused by heavy rainfall which could in combination with poor drainage (see next bullet) of the system result in pluvial flooding rather than fluvial flooding.
- there are several irrigation channels in and around Sidogiri which were not included in the hydraulic model as these were not surveyed. At the inflow locations often, a gate is present. It’s not clear how the gates are operated and how the irrigation system works during a high discharge. Flooding can occur in case of mismanagement of the irrigation system during high flows.
- the discharges prescribed at the upstream model boundary originate from the hydrological model Wflow and were not calibrated and validated because discharge measurements don’t exist. The simulated discharges may be underestimated resulting in too low flood levels.
- the water levels of the hydraulic model were not calibrated and validated in absence of water level measurements. A sensitivity simulation showed that the resistance number (Manning n value) needed to be set at an unrealistic high value to match the observed flood level. So, the uncalibrated water level alone is not the main cause for the underestimated flood level.
- observations made by the residents may not be accurate.

We conclude that the uncertainty of the hydraulic model is too high to determine the cause of the floods at Sidogiri and to model interventions and that discharge and water levels are required to reduce the model uncertainty. However, a sensitivity analysis was performed consisting of land management options upstream and check dams. The results of the sensitivity analysis are presented in Appendix I. It turns out that terracing and regreening are effective measures to lower the peak discharge in the Sumber Pinang and flood levels at Sidogiri, while check dams seem less effective.

Conclusion: No measures were further detailed into conceptual designs.

4

C2: DETAILING MEASURES INTO PROJECTS

4.1 Introduction

This chapter described the cursory conceptual designs of the selected measures including the cost estimate and impact. First the priority measure dredging is presented followed by the bypass measure.

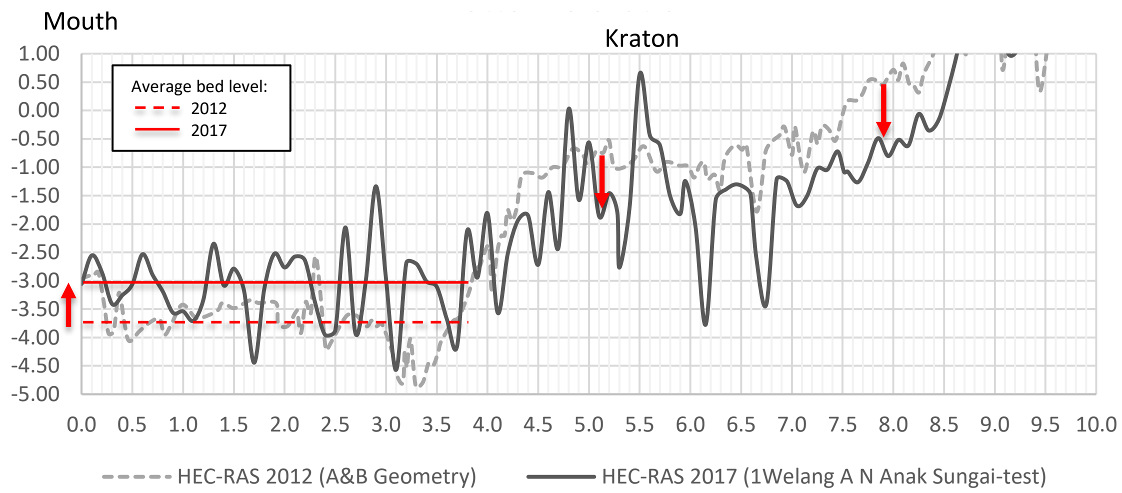
4.2 Dredging

4.2.1 Rationale

Figure 4.1 presents the longitudinal section of the river along the thalweg in 2012 and 2017. The riverbed lowered in the last 5 years due to erosion in the stretch upstream of km 4.0 while the riverbed increased in the downstream stretch due to sedimentation. In 2012 the average bed level along the thalweg is MSL -3.7 m while in 2017 it increased with 0.6 m to MSL -3.11 m. The riverbed slope seems to decrease towards a new equilibrium. The reason for this is not clear. It is estimated that the sedimentation volume in the section from the river mouth up to km 4.0 is approximately 31.000 m3 in 5 years (annually 6.000 m3), while from km 3.5 up to Kraton bridge the erosion volume is about 9.000 m3. The nett volume change in the reach from the river mouth up to Kraton bridge is therefore about 22.000 m3 (5 years). Note that the sediment transport load is much higher as a substantial part of the sediment is transported as wash load towards the river mouth and estuary. From Google Maps it is observed that significant sedimentation of the coast occurs just downstream of the river mouth.

It is concluded that the downstream reach of the Welang experiences strong sedimentation. Dredging the river aims at increasing the discharge capacity consequently lowering the flood level in the Kraton area.

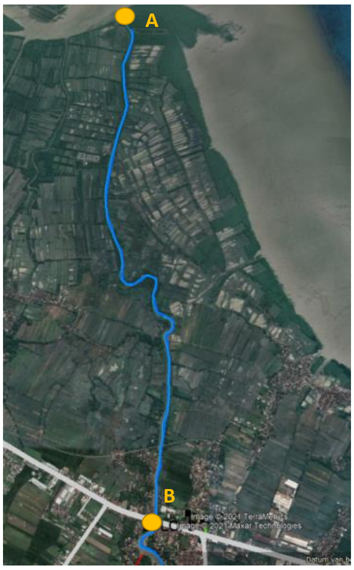
Figure 4.1 Dredging - longitudinal section of the riverbed (m MSL) along the thalweg



4.2.2 Location

The reach to be dredged runs from the Kraton bridge up to the river mouth as presented in Figure 4.2. The length of the measure is about 5.6 km.

Figure 4.2 Dredging location

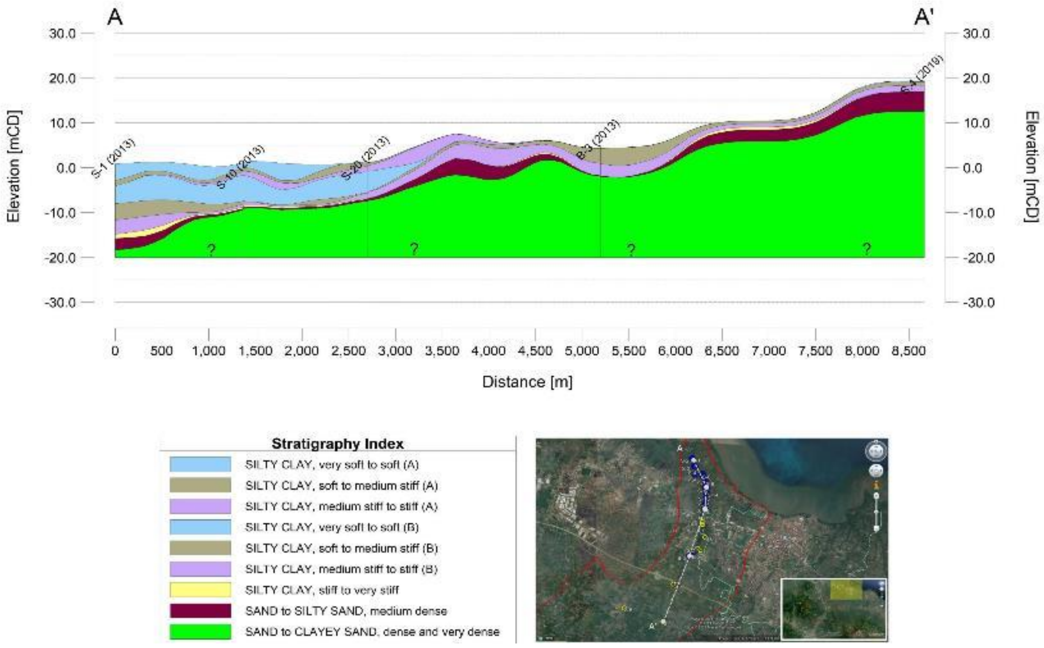


4.2.3 Soil conditions

In total results of 28 CPT tests and 3 boreholes/SPT (with depths of 2 to 20 m) were available and used for the analysis. The data shows that the thickness of the soft soil varies along the downstream section of the Welang river (Figure 4.3). Near the toll-road the thickness of the soft soil is with about 1 m. Further towards the river mouth, the thickness of the soft soil layer increases to a maximum of about 10 m. This is much less than what is found elsewhere along the north coast of Java where the thickness of the soft soil can reach 40-60 m.

The upper layers are of importance for the dredging operation since those are the ones that will be dredged/excavated. They mainly consist of silty clay.

Figure 4.3 Stratigraphy of downstream reach of the Welang



4.2.4 Design

Dredging depth and volume

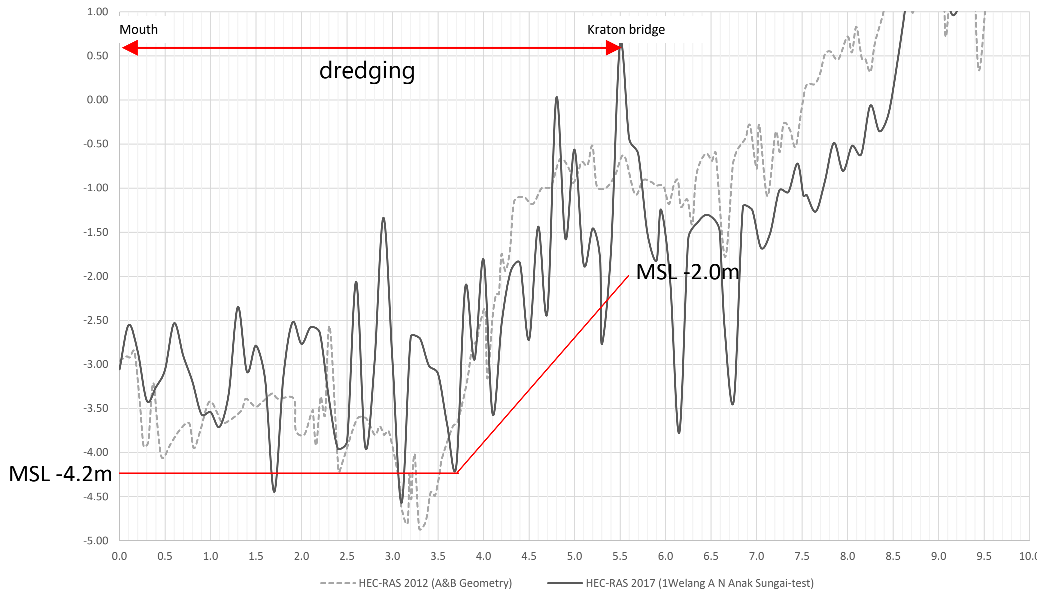
Figure 4.4 presents the longitudinal section of the riverbed with the indicated maximum dredging depth. We propose to dredge the sedimentation that occurred in the downstream stretch from km 3.6 up to the mouth between 2012 and 2017 including an additional dredging depth of 0.5 m to allow a certain amount of sedimentation before maintenance dredging is required. This means the maximum dredging depth in this stretch is MSL -4.2 m (average bed level in 2012 was MSL -3.7 m including additional dredging depth of -0.5 m). The stretch from km 3.6 - km 5.5 is dredged to remove the sediment using the 2012 average river slope from km 4.0 - km 9.0. The maximum dredging depth is summarised in Table 4.1.

Using this maximum dredging depth, the riverbanks remain stable and the salinity intrusion will be limited while increasing the discharge capacity of the river.

Table 4.1 Dredging depth

reach	dredging depth
km 0 - km 3.6	MSL - 4.2 m
km 3.6 - km 5.6	MSL -4.2 to -2.0 m

Figure 4.4 Longitudinal section of the riverbed from Kraton bridge up to the river mouth



Using the bathymetry of 2017 and assumed dredging profile the dredging volume is estimated at 80.000 m3. A more accurate assessment of the dredging volume should be carried out by carrying out a multibeam survey and further detailing the typical dredging profile.

The conceptual design is presented in Appendix II.

Maintenance

After completion of the works, the riverbed restores to its original bed level. An important part of this restoration process occurs by a propagating front governed by the bed load transport and moves from the upstream end of the dredging works in the downstream direction. Because of the increased depth a more diffusive deposition of fine silt (carried as wash load) is expected in the downstream dredged reaches. It is expected that the largest sedimentation will occur upstream end of the dredging works. Given the observed annual sedimentation rate of about 6.000 m3, the sedimentation at the upstream part could be in the order of several thousands m^3/year with a sedimentation thickness of about 0.1 - 0.2 m, which mainly deposits during the wet season.

These numbers are based on uncertain estimates of the annual sediment load, because reliable and validated data on the sediment balance for this reach are not available. Due to this uncertainty, we propose that the desilting volume and timing of the desilting operations will be based on a monitoring program. This program will involve periodic (e.g., monthly) measurements of bed level along the entire reach, and a digital comparison of subsequent bed-elevations to establish the trends in bed-level development and sediment balance.

Execution method and disposal

The dredging works can be executed by a backhoe on a pontoon or a suction dredger. For disposal of sediments dredged from the river three options are available:

- Spread the removed sediments along the left or right bank (business as usual scenario).
- Disposal of the sediments in the estuary. According to environmental legislation the disposal location should be at least 20 km from the river mouth. This option is therefore relatively costly and not recommended.
- Re-use the dredged sediment by:
    - filling geotubes which could be used as riverbank protection
    - making bricks for housing or blocks for river training works

The re-use options are further described in section 4.4.

Other considerations:
It is important that the gas pipeline crossing the Welang near the gas facility remains covered with a sediment layer sufficient thickness to capture sudden rapid erosion processes and passage of bed forms. It is recommended to keep a safety layer on top of the gas pipeline of about 2 m.

4.2.5 Cost estimate

The cost estimate is presented in the table below.

Figure 4.5 Dredging cost estimate (capital and maintenance dredging)

Activities		Length [m]		Unit price [USD]	Amount [USD]	Remarks [-]
1.0	Direct construction costs					
	A Mob-demob					
	- cutting section dredger Surabaya Pasuruan	1	ls	$ 37 143.0	$ 37 143	From Pasuruan to Surabaya
	- Buldoser	1	Ls	$ 714.0	$ 714	
	B stripping and shaping of dredged material at disposal area	80 130	m3	$ 5.0	$ 400 650	disposed by pipe from TSHD
	C Dredging	80 130	m3	$ 10.7	$ 858 536	
	2 **Direct costs to be detailed later (allowance)**		20%	$ 1 297 043	$ 259 409	other direct small components
	Direct construction costs				**$ 1 556 451**	
2.0	Indirect construction costs					
	2 Execution costs		12.5%	$ 1 556 451	$ 194 556	Restructuring charges, emergency maintenance expenses, Losses from discontinued operations
	2 General costs		0.5%	$ 1 751 008	$ 8 755	land preparation cost,
	2 Profit		3%	$ 1 759 763	$ 52 793	HSE
	2 Risk		2%	$ 1 759 763	$ 35 195	Administration
	Indirect construction costs				**$ 291 300**	
	Total Foreseen cost (direct and indirect cost)				**$ 1 847 751**	
3.0	Contingency and unforeseen		15%	$ 1 847 751	$ 277 163	delay to bad weather
4.0	Engineering, supervision, project management & insurance costs		12%	$ 1 847 751	$ 221 730	Design study (DED),
5.0	Rent of disposal area	50 000	m2	$ 35.7	$ 1 785 714	for disposal area 10 m at one side of river bank
	Total required investment				**$ 4 132 358**	

B. Maintenance cost (USD/ 5 year)						
Activities				Unit price [USD]	Amount [USD]	Remarks [-]
1.0	Direct construction costs					
	A Mob-demob					
	- cutting section dredger Surabaya Pasuruan	1	ls	$ 37 143.0	$ 37 143	From Pasuruan to Surabaya
	- Buldoser	1	Ls	$ 714.0	$ 714	
	B stripping and shaping of dredged material at disposal area	30 000	m3	$ 5.0	$ 150 000	disposed by pipe from TSHD
	C Dredging	30 000	m3	$ 14.0	$ 420 000	
	2 **Direct costs to be detailed later (allowance)**		20%	$ 607 857	$ 121 571	other direct small components
	Direct construction costs				**$ 729 428**	
2.0	Indirect construction costs					
	2 Execution costs		12.5%	$ 729 428	$ 91 179	Restructuring charges, emergency maintenance expenses, Losses from discontinued operations
	2 General costs		0.5%	$ 820 607	$ 4 103	land preparation cost,
	2 Profit		3%	$ 824 710	$ 24 741	HSE
	2 Risk		2%	$ 824 710	$ 16 494	Administration
	Indirect construction costs				**$ 136 517**	
	Total Foreseen cost (direct and indirect cost)				**$ 865 945**	
3.0	Contingency and unforeseen		15%	$ 865 945	$ 129 892	delay to bad weather
4.0	Engineering, supervision, project management & insurance costs		12%	$ 865 945	$ 103 913	Design study (DED),
5.0	Rent of disposal area	30 000	m2	$ 35.7	$ 1 071 429	for disposal area 6 m at one side of river bank
	Total required investment				**$ 2 171 179**	
	Total required investment (per year)				**$ 434 236**	

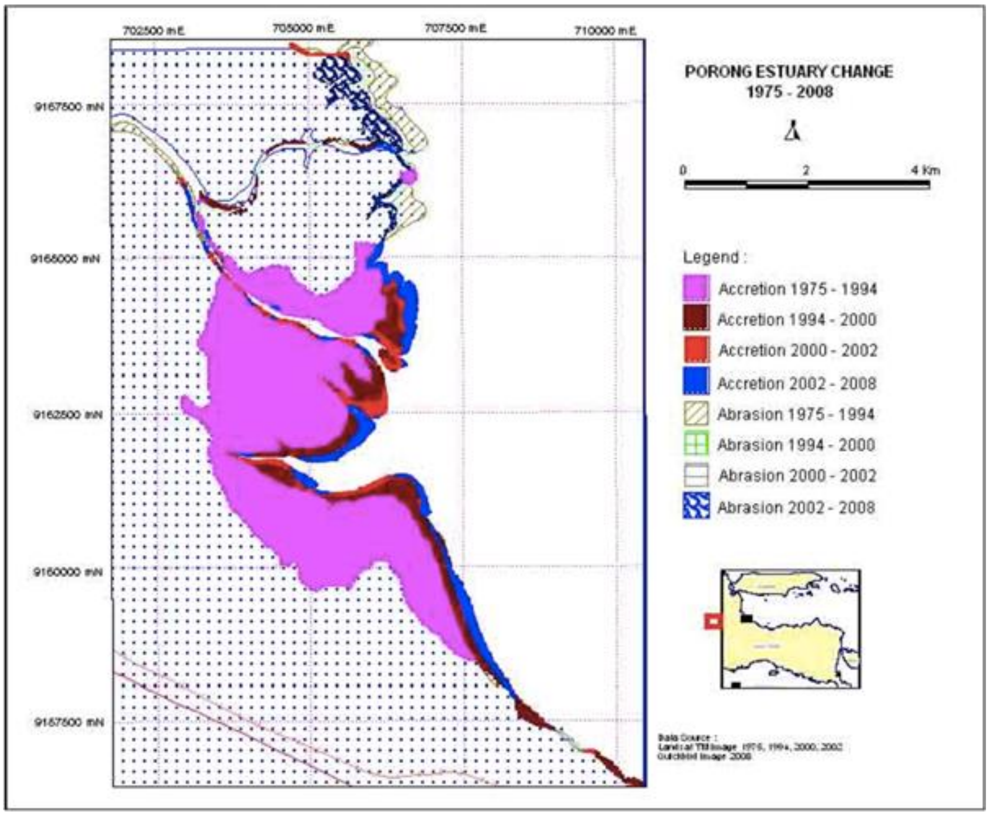
4.3 Bypass

4.3.1 Rationale

As described in task A report the coastline of the Welang river has seen significant sedimentation at least since the 1970s (Figure 4.6). The recent sedimentation and rapid development of the southern part of the Porong estuary has had major effects on the Welang river. Since the 1970s the Welang river has become some 2-3 km longer.

This priority measure entails the construction of a bypass (high water channel) near the gas terminal to create a shortcut towards the sea during high flows. This increases the discharge capacity of the river and lowers the flood level in the river reach upstream of the bypass.

Figure 4.6 Coastal development of the Porong Estuary (Hernawan, 2008)



4.3.2 Location

The length of the bypass is 1.1 km while the length of the Welang branch downstream of the bypass is about 4 km, consequently shortening the river with 2.9 km. The bypass runs through the right bank of the river and crosses several fish ponds before it enters the sea.

Figure 4.7 Location of the bypass

4.3.3 Design

Based on the sensitivity analysis we propose a width of the bypass of 50 m, a 1:2 slope and a bed level at MSL +1 m (Figure 4.8). The width and depth are sufficient to cause a significant lowering of the flood level. The relatively high bed level of the bypass ensures that it only becomes active during high flows limiting the adverse effects on morphology, salt intrusion and environment. The excavation depth varies along the bypass between MSL -1 m and MSL +6 m as shown in Figure 4.9). At the fish ponds the excavation level is higher than the existing surface level.

The excavation volume is about 52.000 m3. It is proposed to use the excavated soil to make embankments along both sides of the bypass.

The conceptual design drawings of the bypass design are enclosed in Appendix II.

Figure 4.8 Cross-section of the bypass

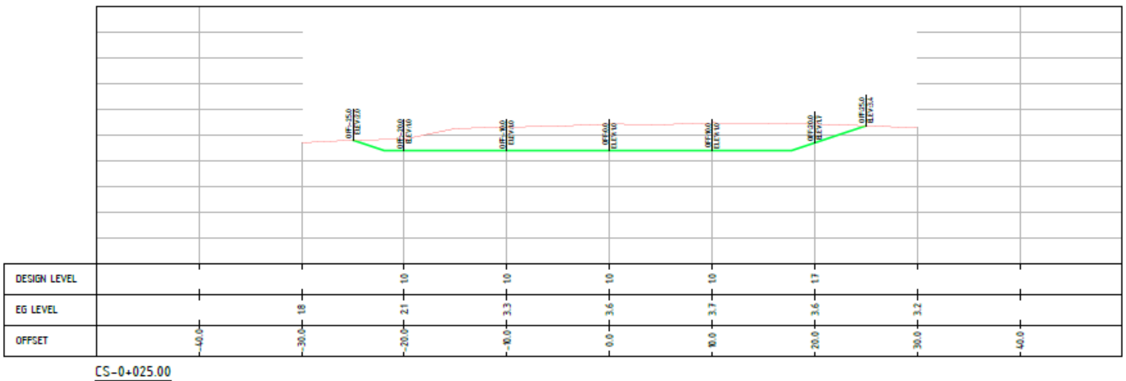
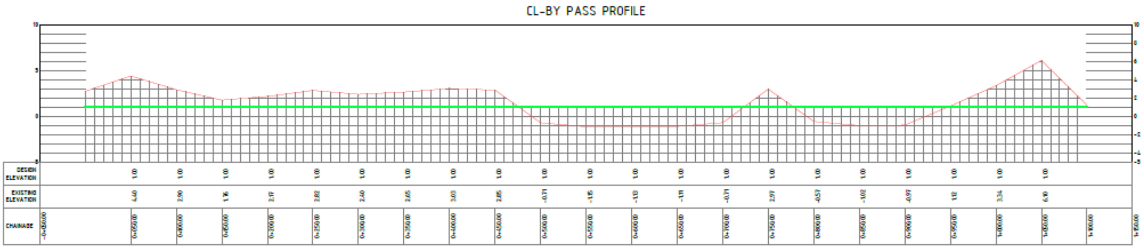


Figure 4.9 Long section of the bypass



Maintenance

Maintenance of the bypass consists of:

- Removal of vegetation to maintain the conveying capacity of the bypass. This should be performed regularly, at least before the wet season starts.
- Removal of sediment. Fine sediment (silt and clay) will enter the bypass from the river during high flows and through sea water entering the bypass at high tide, which will lead to gradual siltation of the bypass. It’s expected that siltation rate will be relatively small due to the relatively high bed level of the bypass.
- Removal of solid waste and debris after floods.

Execution method and disposal

Excavation of the bypass can be performed from land by e.g. excavators, bulldozers, etc.

For the disposal of the soil two options exist:

- Use the material to make embankments along both sides of the bypass (business as usual).
- Re-use the sediment by making bricks (see section 4.4)

4.3.4 Cost estimate

The cost estimate is presented in the table below.

Figure 4.10 Bypass cost estimate

Activities			**amount**		Unit price [USD]	Amount [USD]	Remarks [-]
1.0	Direct construction costs						
	A	Mob- Demob	1	ls	714.29	$ 714	based on productivity rate, time SF 1.5 due to delay
	B	Excavation bypass	52 700	m3	10.71	$ 564 643	
		Contingency	5 270	10%	10.71	$ 56 464	
	2	**Direct costs to be detailed later (allowance)**		20%	$ 565 357	$ 113 071	other direct small components
	Direct construction costs					**$ 734 179**	
2.0	Indirect construction costs						
	2	Execution costs		12.5%	$ 734 179	$ 91 772	Restructuring charges, emergency maintenance expenses, Losses from discontinued operati
	2	General costs		0.5%	$ 825 951	$ 4 130	land preparation cost,
	2	Profit		3%	$ 830 081	$ 24 902	mob-demob, HSE
	2	Risk		2%	$ 830 081	$ 16 602	Administration
	Indirect construction costs					**$ 137 406**	
	Total Foreseen cost (direct and indirect cost)					**$ 871 585**	
3.0	Contingency and unforeseen			15%	$ 871 585	$ 130 738	delay to bad weather
4.0	Engineering, supervision, project management & insurance costs			12%	$ 871 585	$ 104 590	Design study (DED), Site investigation (LARAP)
5.0	Land acquisition		77 000	m2	$ 35.7	$ 2 750 000	for dike, maintenance road, sempadan sungai
	Total required investment					**$ 3 856 913**	

B. Operation and maintenance cost (USD/year)					
Activities			Unit price [USD]	Amount [USD]	Remarks [-]
1.0	River and Retention (dredging)	10.0%	$ 3 856 913	$ 385 691	
Total				**$ 385 691**	

4.4 Sediment re-use options

In addition to the conventional disposal methods, sediment re-use options were investigated by Netics, a Dutch company specialized in re-use of sediments (Appendix III). Two reuse options were considered: geotextile tubes and brick production. The study shows that re-use of the sediment is a good way to generate additional revenues and jobs for the local community. It is recommended to further detail the study in a next project phase.

The results from the Netics study are summarized below.

Re-use of materials for brick making:
- The expected dredged volume is 80.000 m^3, the bypass could provide 27.500 m^3 , while river widening could produce 25.000 m^3. This is sufficient raw material to produce 35 million bricks, which is sufficient to build 3500-5000 houses, depending on the size;
- The sediment in the bypass and river widening is more suitable for brick making compared to the dredged sediment (too many fine particles). Using the material from the bypass and river widening will provide enough material to make 14 million bricks (which is the equivalent of 1400 houses);
- Dredging will produce the largest volumes of sediment, but the composition of this material makes it less suitable for brick making. The material is also wet and large air-drying area is required or a belt press. This affects the business case;
- Depending on the scale of the operation, a hand press can be used to make bricks (30 blocks/hour, investment USD 1500), or a mobile press (360 blocks/hour, USD 150.000);
- The bricks are made using a binding material (cement, lime or even burned rice husks can be used);
- The production costs are around USD 0,14 per brick, while the wholesale price is around USD 0,20-0,35 per brick. The brick production therefore seems to be a viable business (which is also why a lively, local brick making industry exists).

Re-use of materials for geotubes:
- Geotubes are textile tubes which can be filled with soil material. The tubes will hold the material together and have a typical height of 2 metres. Geotubes can be stacked to obtain higher walls;
- Depending on the fill height of the geotubes, 5-30 kilometres of embankments can be constructed using the 80.000 m^3 dredged materials;
- An initial calculation shows that building 5.611 meters river embankment with geotubes (2 metres high) using the 80.000 m^3 dredged materials would cost USD 101 per running metre.

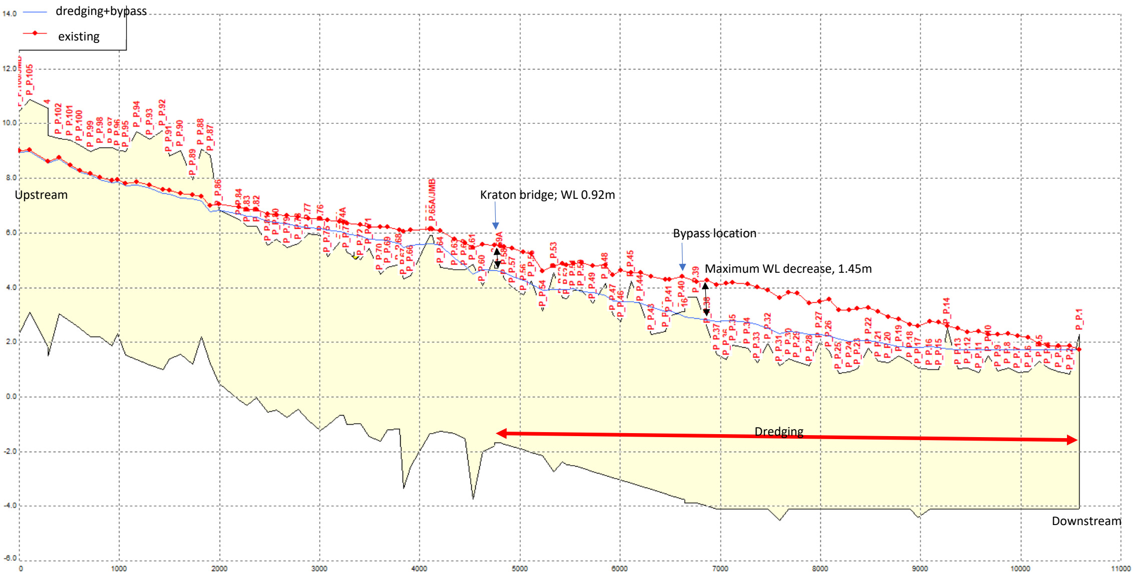
4.5 Impact assessment

4.5.1 Hydrodynamic and morphological impacts

The priority measures that have been formulated have been tested with the 1D hydraulic model Sobek 1 that was developed to analyse their efficiency in reducing the flood level with a return period of 1 in 25 years. Overall, the hydraulic effects of the measures are quite encouraging, the previously flooded areas would decrease considerably. It is noted that the flood wall (parapet) temporarily reduces the flood hazard in the Kraton area. If this wall is sufficient to prevent flooding in the future is still under investigation.

The simulations have been undertaken for the combination of the two measures. Hence, the effect of the measures in flooding reduction is the result of all measures combined. Therefore, the simulated results represent the situation at the end of an implementation period of a project that comprises all the measures. The project implementation period is approximately 5 years.

Figure 4.11 Simulated effect of the priority measures (bypass and dredging) on the 1/25 years flood level



The morphological effects are mainly caused by the dredging of the river. As described in section 4.1 the river bed will restore to its original profile; upstream by a sedimentation front which travels in the downstream direction and further downstream by diffusion of fine particles. Maintenance dredging needs to be carried out to maintain the hydraulic effect. During high flows a part of the flow and suspended sediment will be diverted from the river through the bypass to the sea and deposited at the coast.

4.5.2 Environmental and social impacts

The environmental and social impacts (E&S) can be described and compared in various ways. We will firstly opt for a qualitative evaluation which can be used for screening and scoping at a later stage in the project development.

We will also briefly describe the 'autonomous development' as impacts should also be considered in a relative way: how do the impacts of proposed interventions compare to the autonomous developments?

4.5.3 E&S aspects of the autonomous development

The benchmark for the comparative evaluation is the so-called 'autonomous development', also sometimes called 'zero-alternative' or 'do-nothing alternative'. This autonomous development can be summarized as follows:

- The downstream discharge will increase with 10 % in the coming decade due to changes in upstream land use, necessitating higher and stronger river embankments downstream;
- Despite river works, more downstream residential areas will be flooded, either by pluvial or by fluvial floods, or a combination;
- The heightening of river embankments will lower risks of floods, but at the same time also increase the potential impact. The impact on residents will be more devastating if embankments fail and breach as water levels in rivers are high due to the constraining of rivers within an embanked system. This is well illustrated by the image below;
- High river embankments close-off rivers from communities and, for instance, affect easy use of river water. The decreased lateral connectivity between the river and its floodplain results in less exchange of water, sediment, organic matter, nutrients, and organisms.

Figure 4.12 Residents may feel safe, but the potential impact of failing embankments is higher compared to unconfined rivers

4.5.4 E&S aspects of dredging

Social and environmental impacts of dredging-salt intrusion
Dredging in coastal zones facilitates discharge of river water during floods, thus lowering flood levels. However, during low-discharge conditions, sea water can intrude the system over a longer stretch compared to non-dredged rivers. This salt water intrusion is a major problem when river water is used for agricultural purposes.

According to the East Java Water Department (DPU-SDA), salt water already intrudes beyond the Kraton bridge and dredging will extend this impact. Although there is still substantial agriculture in the zone of influence (Figure 4.13), it is likely that farmers either rely on rainfall (rain-fed farming) or on water from upstream sources transported via irrigation channels. This aspect should be further investigated in a social and environmental assessment.

Figure 4.13 Three agriculture areas in the project area

Dredging will only lower water levels during floods, but also (to some degree) in periods of low-discharges in the dry season. While the lower flood levels may be considered a positive impact, lower dry season levels are to be considered a negative environmental and social impact as the availability of river water will be affected as well as groundwater tables next to the river.

Impact on brick makers, contamination, pollution, deforestation

In the Welang river basin, river sediments are a valuable commodity as they are used for brick making. Dredging will make more of this commodity available and this could be considered a positive development, provided some considerations are taken into account:

- Local brick makers will be affected by competition if the dredged materials are processed into a bricks on an industrial scale. On the other hand, this might also bring down the price of bricks and benefit consumers.
- Brick making is a fuel-intense process. Industrialisation may create substantial pollution and, when wood is used as fuel, may accelerate deforestation.
- The sediment may be contaminated (although the watershed is not known for having large chemical industries). Humans will be closer to this potentially contaminated materials, both during the brick making process and while using it in construction. In general, the health risks are considered low as the contact is limited and finished bricks also do not easily release contaminations.

Figure 4.14 Local brick making from river sediment

Groundwater lowering

The lower river levels will also affect the groundwater levels next to the river and this impact will be most noticeable during the dry season. This may affect the residential water wells close to the river.

Ecological impacts-loss of transition zone

Dredged rivers tend to have square cross sections and a smaller transition zone between river and river banks compared to non-dredged (and silted) rivers. Transition zones are important from an ecological point of view as, for instance, herons, fish in these zones. This adverse ecological impact will be highest in the downstream, rural parts while the impacts will be less in the urbanized section of the Welang river.

Safety levels and risk reduction

Dredging will lower flood levels which is intrinsically safer compared to higher embankments. Failure of high embankments, for instance, will create immediate crisis-situations while overtopping of river banks often is a more gradual process.

Maintenance
Dredging is a recurring activity as rivers will sediment and this will happen faster after dredging as rivers tend to return to a morphological equilibrium.

4.5.5 E&S aspects of the bypass

The bypass is designed as a high water channel: dry during low-water situations and flooded during extreme discharges. This will allow some combined land-use, although rainfed agriculture is not an option as this could coincide with rainstorms and the use as flood channel.

The environmental impacts are very limited as the river system is not fundamentally altered as the existing branch downstream of the bypass will not be closed off. The banks of the bypass will probably be covered in waste and debris after the water levels have receded, but this waste would otherwise end up in the sea and oceans or washed up elsewhere. In this sense, there is no real benefit or adverse impact.

The social impacts are more relevant as the by-pass will require land which is used as paddy fields. Local farmers indicated in interviews that much of the land is already acquired by property developers, but nevertheless, there will be a loss of land and income when the bypass is constructed.

The bypass, similar to dredging, will lead to lower flood water levels which is an intrinsically safe flood intervention. And safer compared to creating high embankments.

The maintenance of a dry by-pass is limited as this by-pass is only used during extreme circumstances. Some dredging and cleaning is to be expected after a flood.

When the by-pass is constructed as a dry channel, no real ecological benefits can be expected as such. Only some ecological benefits can be expected when this channel is kept free from agricultural or other use.

4.5.6 Summary of impacts

The pro’s and con’s of the various alternatives are presented in Table 4.2.

Table 4.2 comparison of alternatives

	Autonomous	Dredging	Bypass
Environmental impacts: pollution, CO2, resources	- Use of concrete, hard river banks	- Periodic maintenance dredging, requiring fossil fuel	+ Limited maintenance after construction
Social impacts: use of river by residents	- River is disconnected from residential areas, limiting use of the river	+/- No impact	- Land cannot be fully used for agriculture
Land acquisition	+/- Limited land is required	+ No land is required	- Land is required
Groundwater	+/- No impact	- Lower water levels during dry season	+/- No impact
Ecology	- Hard river banks	- Loss of transition zone	+/- or + No impact or positive impact when by-pass is natural zone
Salt water intrusion	+/- No impact	- Intrusion	+/- No impact
Flood safety	+/- Less floods, but higher risks of severe impacts	+ Lower water levels create intrinsically safer rivers	+ Lower water levels create intrinsically safer rivers

The table shows that all downstream measures have adverse impacts. The bypass has a slight edge on the positive impacts, mostly because of the combination of limited maintenance, the potential of creating a agro-ecological zone (a zone with limited agricultural use, but with ecological potential) and the lowering of water levels.

5

C3: DEVELOPING OUTLINE BUSINESS CASES

This chapter presents the results of the financial and economic analysis for two interventions: dredging and the bypass. We will assess the investment and maintenance costs as well as the potential for revenues.

As the soil material from dredging is not very suitable for brick making (fine particles, needs drying), we will only assess brick making as revenue source for the bypass. The dredging material is suitable for use in geotubes and we will therefore assess the use of dredged soil materials for building river walls with geotubes.

5.1 Cost-Benefit Analysis (CBA)

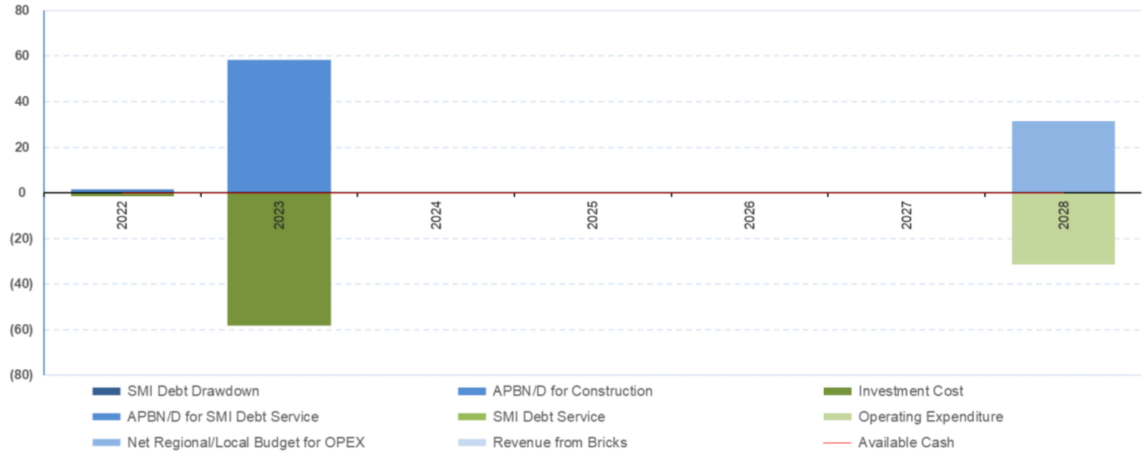
Dredging the downstream section of the river and the realisation of a By-pass, were identified as the most cost-effective flood mitigation measures for the Kraton priority project in the short- and medium term. However, due to the lack of reliable digital terrain model and subsequent inundation depths, it is not possible to present a CBA which reflects the monetized core flood mitigation benefits at this stage. Going forward, a more detailed economic feasibility analysis shall reconfirm the significant socio-economic returns of these investments in terms of prevented flood damages to assets and livelihoods and increased economic productivity. This analysis should also take into account the additionality of these measures with the flood wall which has been recently realised.

5.2 Investment planning

Dredging

The dredging of the Welang river - 5 km from Kraton bridge to mouth of the river- requires an initial investment of ~ US$ 4.1 mln (IDR 60 bln) and maintenance dredging should take place every 5 years with an expected cost of US$ 2.2 mln (IDR 31 bln). The graph below shows the project cashflow up to 2028. As a base case it is assumed that the initial capital dredging will be funded from APBN (DAK allocation). The 5 years recurrent cost of maintenance dredging is supposed to be covered from the APBD. In 2022, roughly IDR 1.5 bln will be spent on preparation costs.

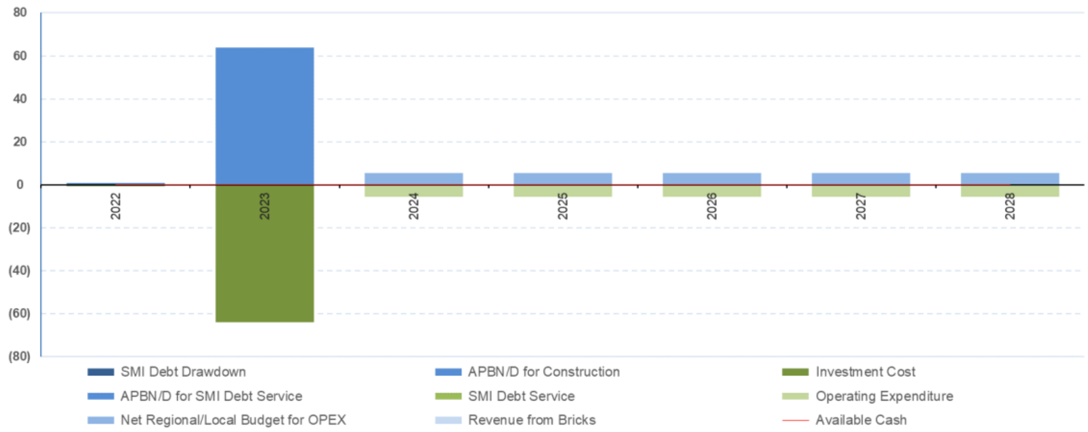
Figure 5.1 Dredging - cash flow up to 2028



By-pass

Developing a by-pass requires an upfront investment of roughly IDR 64 bln. which includes roughly IDR 40 bln. for land acquisition. The yearly operational costs (maintenance) are assessed at a figure of roughly IDR 6 bln. per year. The base case assumption is that funding of the initial investment will be furnished from the APBN (DAK allocation) and that the local/regional budgets will have to furnish the yearly maintenance costs.

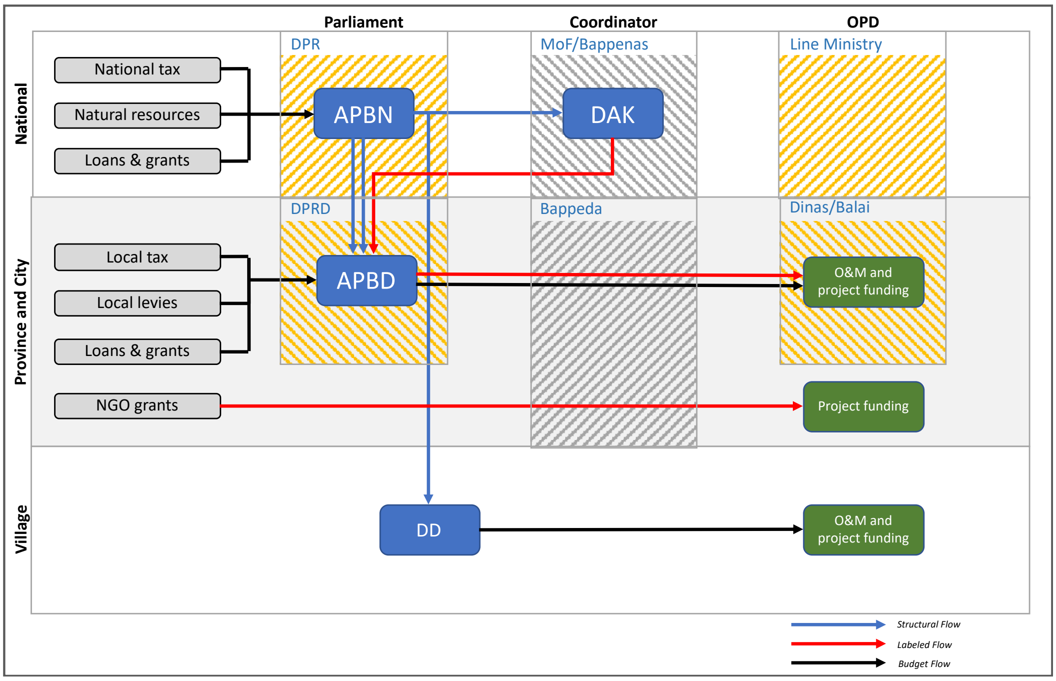
Figure 5.2 Bypass - cash flow up to 2028



5.3 Funding options

Although the measures are not that capital intensive, there is no structural budgeting for capital expenditures at the level of the regional governments which can cover the required investments. As such we assume a base case in line with the normal funding practices sourced from APBN and the APBD. The flowchart below sketches the usual flow of funds to cover regional infrastructure investment.

Figure 5.3 Usual flow of funds to cover regional infrastructure investment (Deltares 2018)



In a more detail, the funding of the respective components could be arranged for as follows:

Figure 5.4 Arrangement of the funding components

By-pass		Fund. Requirement (IDR bln)	Funding Source	GCA	Alt. Funding
	Land acquistion	40	APBN-DAK	PUPR-BBWSBS	APBN-LMAN
	Design & Construction	16	APBN-DAK	PUPR-BBWSBS	
	Maintenance (yearly)	6	APBD	Dinas PUSDA	
	Brick production plant	9	APBD-BUMD	BUMD	Private
Dredging					
	'Capital' dredging	60	APBN-DAK	PUPR-BBWSBS	
	Maintenance (5-yearly)	31	APBD	Dinas PUSDA	

The burden to these government's budgets can be 'eased' by means of cost savings, private (co-)investment and project financing. The following options were identified:

1. Cost savings by reusing sediment from the by-pass for brick making. This will reduce the costs for discharging the sediments and can result in a net revenue-stream from selling bricks in the local market. However, this is one-time activity as the by-pass will only function every 10-25 years and does not require maintenance dredging (which will produce soil material);
2. The respective measures (dredging and the by-pass) do not create options for commercially viable private investments. Only the re-use of sediments could be structured as a private business opportunity.
3. Financing may be obtained from the Regional Infrastructure Development Facility managed by PT SMI (a public infrastructure development bank). This allows to spread the investment costs over a longer period of e.g. 5 up to 10 years. Also LMAN may be approached to finance the land acquisition component of the by-pass.

Cost savings from reusing sediments

Brick making

Based on the investigation carried out by Netics (Appendix III) roughly 7 million bricks can be produced from the 27.500 m^3 excavated sediments from the by-pass. It is assumed that the average production costs of a brick is roughly US$ 15 cts. and its selling price is assumed at US$ 25 cts/brick. By facilitating (=investing in production capacity/facilities) the production of bricks in situ from the excavated sediments, a net revenue stream can be created which can be used to cover some of the investment costs. As the by-pass does not require maintenance dredging, no soil materials will be available after completion of the by-pass. However, the brickmaking factory could continue production with material for other sources.

The investment in the brick-production capacity requires an upfront investment of US$ 600,000 and is expected to generate a net revenue of IDR 5 bln/year (USD 350.000) for 2-3 consecutive years.

A different perspective is that the re-use of sediments can generate a net cash-inflow which can be valued at roughly US$ 0.1-0.45 mln.

Geotubes

Geotubes might lead to cost saving as the dredged material can be re-used to fill geotubes and to construct river embankments. Netics calculated the construction cost of USD 100 per running meter for a geotube river wall. This makes geotubes a competitive option as an earth filled dike costs USD 250 per meter and a concrete wall between USD 200-500 (exact price depends on wall thickness, use of rebar, type and depth of foundation, etc). While the footprint of a wide geotube (several metres) wall could lead to additional land purchase costs and potential relocation costs, geotubes are worthwhile option to consider, also as it provides a good alternative for dumping of dredged material.

Private investments

Eventually the brick making opportunity may be structured as a private concession, where a private party may be given the right to re-use the sediments in situ for brick production. It is then expected that this private entity will invest in the required production plants which roughly cost US$ 600,000.
Alternatively, this business may be developed through a regionally owned business entity (BUMD) which generates the net revenue stream and may be given the responsibility.

Project finance

Project finance options do not reduce the cost to the government's budget but can be used to spread the burden over a longer time period. Given the relatively small size of these interventions obtaining finance from international financing institutes (IFIs; World Bank, Asian Development Bank) is a less likely approach. It will take a long time to arrange it and there may only be lukewarm interest from IFIs for these kind of 'incidental' projects. As such one option for the government may be to attract financing from the Regional Infrastructure Development Fund (RIDF) which is managed by PT Sarana Multi Infrastruktur (PT SMI). Based on our research we have made a simulation where RIDF-SMI would finance up to 80 % of the Capex. The loan would be amortized over 5 years and the applicable interest rate is 6 %. Below we depict the resulting cashflow/burden to government budgets in case of project financing by PT SMI.

By-pass

Figure 5.5 By-pass with project financing

On Construction Period			
	Investment Cost	64,558	Million IDR
	Total SMI Debt	51,052	Million IDR
	APBN/D for Construction	13,506	Million IDR
On Operation Period			
	Regional/Local Budget for OPEX per year	5,593	Million IDR
	APBN/D for SMI Debt Service per year	12,120	Million IDR
less	Revenue from Bricks per year	5,040	Million IDR
	Budget Required per year	12,672	Million IDR
Budget for Construction + Operation			
	APBN/D for Construction	13,506	Million IDR
	APBN/D for SMI Debt Service	60,598	Million IDR
	Regional/Local Budget for OPEX	27,963	Million IDR
less	Revenue from Bricks	15,200	Million IDR
	Total Budget Required	86.867	Million IDR

This approach inclusive of financing, results in a total burden to the APBN/D of IDR 87 bln. equally spread over 6 years (~ IDR 14,5 bln/year).

Dredging

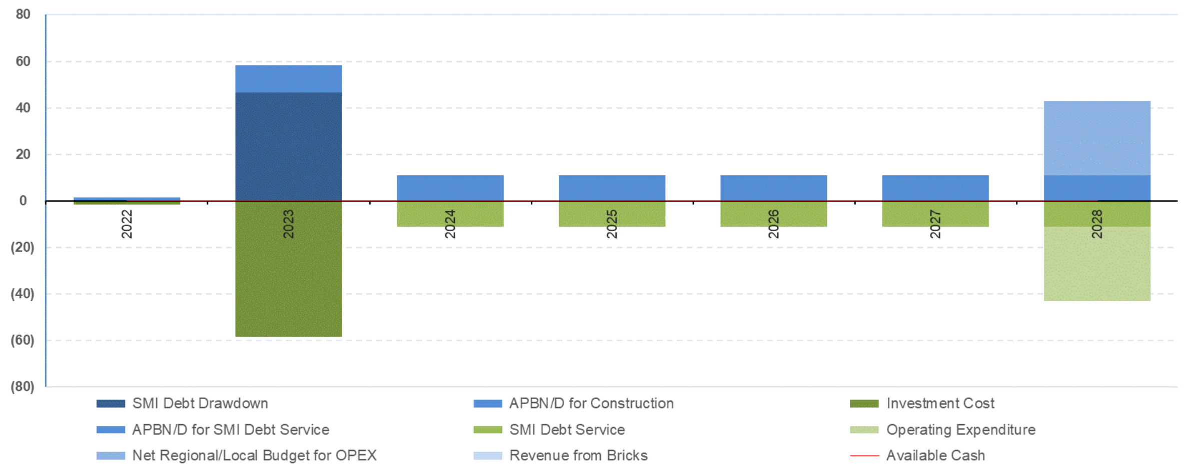


Figure 5.6 Dredging with project financing

On Construction Period			
	Investment Cost	59,920	Million IDR
	Total SMI Debt	46,650	Million IDR
	APBN/D for Construction	13,270	Million IDR
On Operation Period			
	Regional/Local Budget for OPEX per 5 year	31,900	Million IDR
	APBN/D for SMI Debt Service per year	11,074	Million IDR
	Budget Required per year	42,975	Million IDR
Budget for Construction + Operation			
	APBN/D for Construction	13,270	Million IDR
	APBN/D for SMI Debt Service	55,372	Million IDR
	Regional/Local Budget for OPEX	31,900	Million IDR
	Total Budget Required	100,543	Million IDR

With the financing option the initial burden to the government budget can be reduced from IDR 60 bln. to IDR 13.3 bln. in 2022-2023. Then the burden to the APBN/D will amount to IDR 11 bln for 5 years to repay the loan for the capital dredging. After this there is a burden to the APBD of IDR 31 bln every 5 years for maintenance dredging. This is a significant cost and stresses the importance to reduce sedimentation in the downstream by taking upstream measures.

The geotubes are not included in this financing scheme as they do not create revenues which can contribute to the financing of dredging itself. The use of geotubes, however, can contribute to lower construction costs of embankments.

5.4 Conclusions

The proposed priority measures/interventions are not very capital intensive, hence IFI (World Bank, Asian Development Bank) support and finance are less likely options to arrange the funding of these projects. Funding of the interventions is to be backed from the APBN and APBD (national and regional government budgets).

Brick making

The business development option of brick making is a modest cost recovery option for the by-pass development as it will allow a net revenue stream of a total of US$ 0.1 – 0,4 mln over a period of 2-3 years. The most straightforward option would be to invest in the required production capacity from the APBD. The revenue may then somewhat reduce the burden to the APBD for the investment costs. By using project finance options provided by RIDF-SMI, the burden to governments' budgets can be spread out over a 5-6 year period, making the interventions more affordable in the short/medium term.

Although IFI based funding seems not a viable option, bilateral arrangements and instruments like the Dutch D2B and Drive, may enhance the affordability of the interventions to the governments involved.

Geotubes

The geotubes are an economic and interesting application for dredged materials. Initial calculations show that the cost per running metre are lower than traditional dikes, but a more in-depth analysis of costs is required to further detail the business case (like need for and costs of purchase of land). Nevertheless, more and more geotubes are used by private investors, indicating that it indeed is an economic option.

Filling the geotubes requires as synchronisation of dredging works and building of embankments to avoid downtime and storage costs. This will create planning and budgeting challenges.

6

C4: APPLICATION FOR FURTHER SUPPORT

In this task we support EJP in application for further support or funding, comprising the following activities:

- Assessment of requirements for the further support or funding.
- Discuss with EJP for which activities specific support is required.
- Coordination and supervision of the activities.
- Evaluation.

The application for further support is still ongoing and the results will be included in a next (final) version of this report.

7

C5: MATCH MAKING PLATFORM

At the request of EJP, we have set-up a matchmaking process with the goal of bringing EJP in contact with Dutch companies and organisations that are interested in the Welang River project and may be able to provide solutions.

To support EJP's interest in this regard, we have undertaken the following activities.

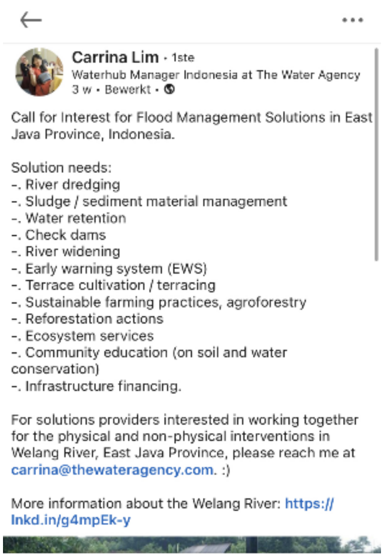
1. Indonesia Country Platform Meeting, 8 July 2021

TWA gave an introductory presentation about the Welang River project during the NWP Indonesia Country Platform meeting on 8 July 2021. This online meeting was attended by a broad range of companies and organisations from the Dutch water sector. We informed participants about the matchmaking process and offered an initial *Call for Interest*, which resulted in several companies/organisations contacting us for more information.

Program: https://www.netherlandswaterpartnership.com/events/indonesia-country-platform-meeting
Report: https://www.netherlandswaterpartnership.com/sites/nwp_corp/files/2021-09/Country%20Update%20Indonesia%20Sept%202021_%20FINAL.pdf

2. Call for Interest, 27 October 2021

A *Call for Interest* was published on the Indonesia Water Portal providing more concrete and specific information on the potential opportunities around Welang River. This *Call for Interest* was widely distributed through various channels, such as LinkedIN and the weekly Dutch water sector newsletter.



[Post on LinkedIN]

The *Call for Interest* was responded to by more than 15 companies and organisations (see list under (3) below)

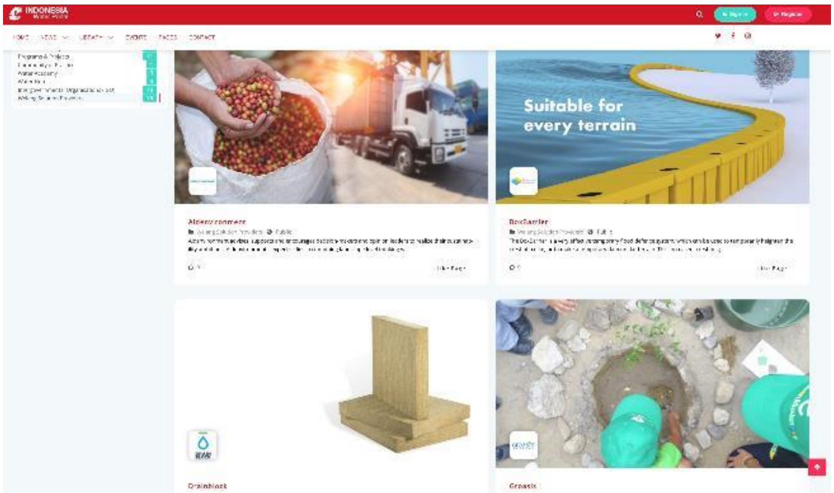
Call for Interest: https://www.indonesiawaterportal.com/news/call-for-solution-providers-to-work-together-in-welang-river-east-java.html

3. Introduction of Solution Providers, 25 November 2021

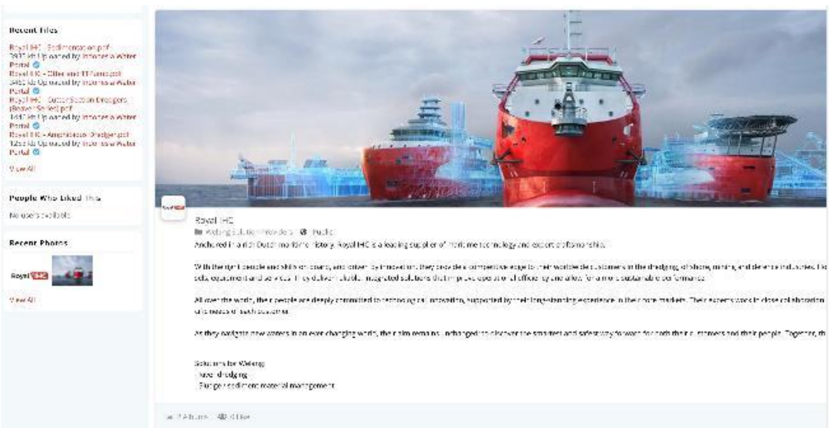
To introduce the interested companies and organisations to EJP, each of the solution providers has been offered a dedicated Page on the *Indonesia Water Portal* to introduce its organisation, activities and potential solutions.

The Pages have been designed in such a way that these can also be used for one-on-one matchmaking between EJP and individual companies. For this purpose, the pages can be made member-only to ensure confidential exchange of information.

Company introduction pages: https://www.indonesiawaterportal.com/pages/categories/welang-solution-providers/all/latest.html



[Directory of solution providers on the Indonesia Water Portal]



[Solution providers can share information on their own page]

4. Kick-off Matchmaking, January 2022 (TBD)

An online introduction meeting between EJP and the interested companies/organisations is being planned for January 2022 as a kick-off for more targeted matchmaking.

The *Indonesia Water Portal* remains accessible until this kick-off meeting to facilitate exchange of information.

8

CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The conclusions are as follows:

- The Terms of Reference for this project focused on physical interventions when it comes to priority projects, while the Baseline Study showed that also spatial planning, soil conservation and sustainable development would definitely qualify as priority projects;
- The baseline study (Task A) [ref. 1] and Integrated River Basin Management Plan (IRBMP) [ref. 2] outline the main problems in the watershed, both physical and institutional. After several discussions and meetings with PU-SDA the priority issues to reduce the pluvial flooding in Kraton area and flood level at Sidogiri by taking measures in the upstream as well as the downstream part of the catchment were selected.
- The sensitivity analysis showed that upstream measures to hold water like terracing and regreening an effective way to reduce the downstream flood level. Furthermore, downstream measures aiming at increasing the discharge capacity such as dredging, river widening, and bypass and thereby lowering the flood level at Kraton are effective.
- The cause of the flooding at Sidogiri was investigated with a 1-D hydraulic model (Sobek) using a cross-sectional survey of the Sumber Pinang. From the modelling results it appeared that hardly any (fluvial) flooding occurs at Sidogiri, while residents indicated that Sidogiri experiences yearly flooding with a maximum inundation depth of about 0.5 - 1 m which lasts generally 30-60 min. We concluded that there is insufficient data to calibrate and validate the model which makes it impossible to determine the cause of the flooding and model interventions.
- For the Kraton area the priority measures bypass and dredging were selected based on a evaluation and MCA. These were further detailed into conceptual designs including costs estimate, impact assessment, and CBA.
- The bypass and dredging measure have adverse impacts. The bypass has a slight edge on the positive impacts, mostly because of the combination of limited maintenance, the potential of creating a agro-ecological zone (a zone with limited agricultural use, but with ecological potential) and the lowering of water levels.
- Two alternative sediment re-use options were investigated: geotextile tubes and brick production. The study showed that re-use of the sediment is a good way to generate additional revenues and jobs for the local community. It is recommended to further detail the study in a next project phase.
- The socio-economic feasibility of the proposed interventions could not be determined because the accuracy of the elevation data is not sufficient for such an analysis.
- The proposed priority measures/interventions are not very capital intensive, hence IFI support and finance are less likely options to arrange the funding of these projects. Funding of the interventions is to be backed from the APBN and APBD. The business development option of brick making is a significant cost recovery option for the By-pass development, which allows to generate a net revenue stream of roughly US$ 0.8 – 1.0 mln. The most straightforward option would be to invest in the required production capacity from the APBD. The revenue may then reduce the burden to the APBD for the yearly maintenance costs.
- By using project finance options provided by RIDF-SMI, the burden to governments' budgets can be spread out over a 5-6 year period, making the interventions more affordable in the short/medium term.
- Although IFI based funding seems not a viable option, bilateral arrangements and instruments like the Dutch D2B and Drive, may enhance the affordability of the interventions to the governments involved.

- A matchmaking process has been set-up with the goal of bringing EJP in contact with Dutch companies and organisations that are interested in the Welang River project and may be able to provide solutions.

8.2 Recommendations

The recommendations of the study are:

- Have an in-depth, high-level conversation with East Java Province and the Ministry of Public Works on the political feasibility of dredging and re-use of sediments and construction of the by-pass. High-level commitments must be assured before a follow-up can be considered. The current river embankment at Kraton might provide a (false) sense of security which will reduce the willingness of the government to participate in the more complex planning of dredging/re-use and the by-pass.
- Any future project on physical interventions downstream should be closely connected to upstream soil- and land conservation as the upstream developments are the main driver behind the pluvial floods. Only focusing on downstream, physical interventions in follow-up projects would indicate that the upstream developments can be easily mitigated with some downstream interventions.
- Perform a LIDAR survey of the downstream part of the Welang and Sumber Pinang to obtain a more accurate digital terrain model. This terrain model should be the basis for a 1D/2D model to account for overland flow and designs of the measures.
- As a next step the socio-economic feasibility needs to be corroborated with a detailed analysis and quantification of the benefits from improved flood safety.
- To further develop the upstream land management measures to decrease the runoff and subsequently discharge wave together with the stakeholders and communities.
- Setup an inclusive design process and involve local stakeholders in the downstream area to further detail the conceptual designs of the bypass and dredging.
- Monitor the Sumber Pinang water levels and discharges to calibrate and validate the hydrological and hydraulic model with the aim to better understand the flooding at Sidogiri.
- Perform yearly bathymetrical survey of the Welang to assess the erosion and sedimentation patterns, sediment transport and sediment balance.
- Improve the legislation related to the re-use of sediment and further detail the business case of the brick making.

9

REFERENCES

1 Deltares (2021). Baseline assessment Welang: balancing development, and flood resilience (Task A report). Draft version 30-9-2021
2 Witteveen+Bos (2021). Integrated River Basin Master Plan Welang. Draft version.

Appendices

I

APPENDIX: MODELLING RESULTS OF UPSTREAM AND DOWNSTREAM MEASURES

RESULTS OF THE SENSITIVITY ANALYSIS OF UPSTREAM MEASURES

I.1 Introduction

As part of Task C - Solve and Innovate, hydrological and hydraulic modelling is carried out to assess the effect of measures to lower the flood risk of Pasaruan and Sidogiri (See Figure 1). To get a first impression of potential effects of measures, we carried out a sensitivity analysis using the models that have been setup by Deltares as part of task A (Understanding the river basin).

This section the results of the sensitivity analysis using the hydrological model Wflow.

I.2 Measures

In total 3 different measures to lower the flood risk in the catchment at the two priority project locations (Kraton and Sidogiri) were modelled. These interventions consist of terracing, check dams and reforesting.

By converting (sloped) agricultural areas to terraces, one reduces the natural slope of such an area to near 0. Precipitation falling on and draining to the terraces is then captured on each terrace, instead of discharged directly via the natural slope of the area. This process increases the infiltration of water into the soil, and thereby reduces river peak and increases river base flows. A downside of this method is that the stability of the slope may decrease when a lot of water infiltrates in the subsurface of the terraces, with possible collapse of the structure as a consequence. Terraces therefore need to be maintained.

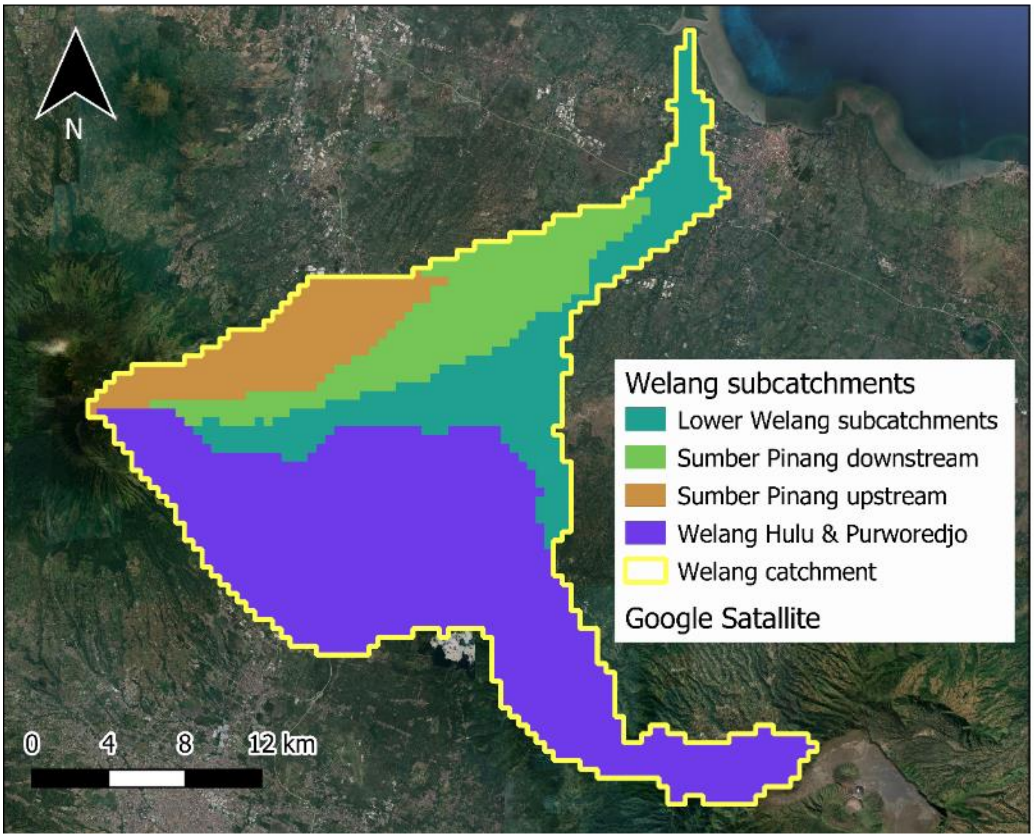
Checks dams are small structures in the streams of the basin, that increase the resistance of the river bed to flow. They are implemented as a set of dams at regular intervals in the smaller streams of a basin thereby reducing the flow velocities and hold water in these smaller streams. This decreases the peak discharge in the downstream part of the basin.

Reforestation has an effect on multiple hydrological processes in a basin. By converting cropland, grassland or shrubland into forest, the interception capacity of the vegetation is increased, which increases the amount in interception evaporation. Also, the transpiration of the vegetation is increased. Furthermore, trees increase the depth of the root-zone, meaning that the soil is able to store more water. The root-zone also contains much more roots and vegetative material, which increases the surface roughness, and thereby the flow velocity of the water.

I.3 Method

During the sensitivity analysis of the Wflow model of the Welang catchment, the focus will be on two subcatchments. The first subcatchment is the (upstream and downstream part of the) Sumber Pinang and second subcatchment consists of the Welang Hulu and Purworedjo subcatchments, which are located in the upstream part of the Welang river basin (see figure below). Interventions related to land use management are more effective in the upstream part of the basin. Interventions in each subcatchment are modelled separately.

Figure I.1 Subcatchments defined in the Welang river basin



To model the potential effect of terracing the slope with Wflow model, the slope has been artificially modified using raster operations. The slope of raster cells within a subcatchment having an agriculture landuse (globcover code 14, 20 or 30, see Figure 3.2 and Table 3.1) were decreased. The slope within these raster cells was replaced by slopes of 90, 75, 50 and 0 % of the original value. See Figure 3.2 for the original slope map of the model.

The influence of check dams is simulated by changing the Manning n-values of the river branches in the two subcatchments. Increasing the Manning n value dampens the discharge wave. The river branches are ranked using the streamorder parameter, where the main branch gets the highest order, a tributary of the main branch one order lower and so on. In Figure 3.6 the streamorders of the river branches within the wflow model (from 2 up to 5) are presented.
The Manning n-value is coupled to a streamorder within the conversion tables in the Wflow model. The streamorders of the branches within the two subcatchments were decreased to impose higher Manning n-values. In addition, also a run was performed with a "new" defined streamorder to test a completely different Manning n-value.

Reforesting was modelled by replacing the land use codes of cropland areas to vegetated areas or forest areas, within the two subcatchments.

Figure I.2 Landuse map of the Welang river basin of the year 2020

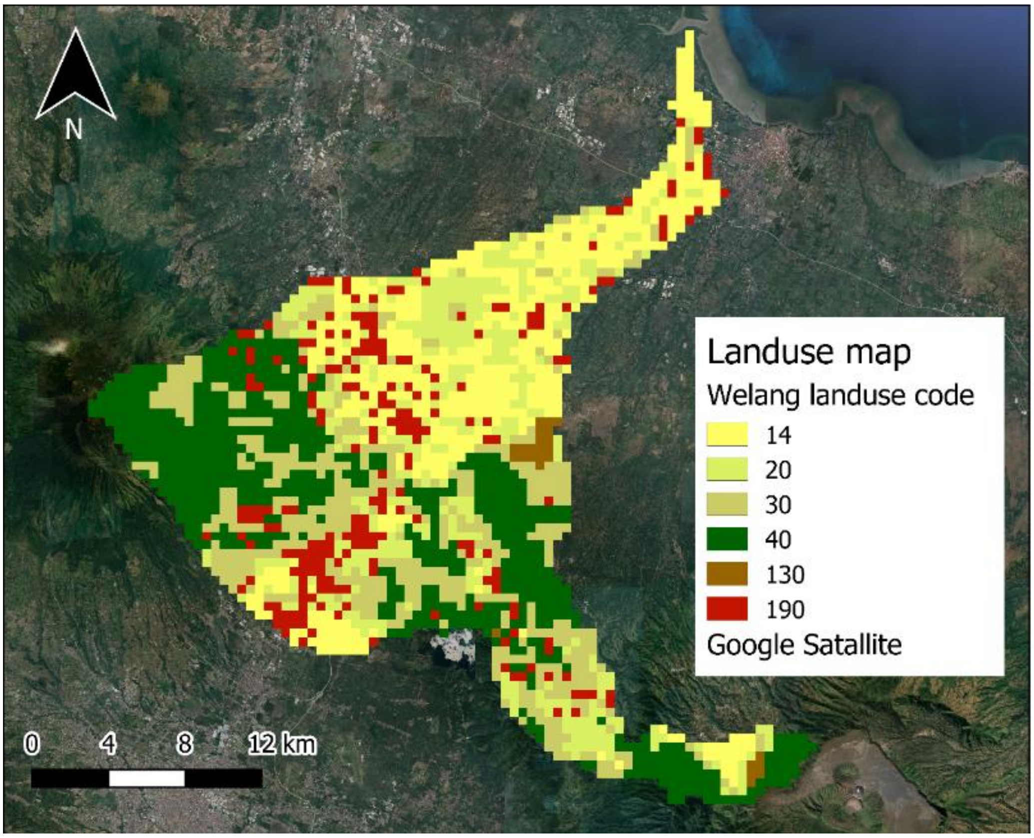


Table I.1 Land use codes corresponding to the landuse map in Figure 3.2.

land use code	description
14	rainfed croplands
20	mosaic cropland (50-70%)/ vegetation(grassland/shrubland/forest) (20-50%)
30	vegetation(grassland/shrubland/forest) (50-70%)/ mosaic cropland (20-50%)
40	Closed to open (>15%) broadleaved evergreen or semi-deciduous forest (>5m)
130	Closed to open (>15%) (broadleaved or needleleaved evergreen or deciduous) shrubland (<5m)
190	Artificial surfaces and associated areas (Urban areas >50%)

Forcing data

All forcing data that was used in this model comes from the E2O (EartH2Observe) dataset from Deltares. This dataset contains precipitation (P), potential evapotranspiration (PET) and temperature (TEMP) data that is used in the model. The model runs for 4 years, from 01-01-2011 till 30-12-2014 on a daily timestep and starts from a cold state (empty reservoirs). The resolution of the model and the input data is 0.5 x 0.5 km.

I.4 Results

In Table I.1, an overview of the results of all variants for both the Sumber Pinang and Welang Hulu + Purworedjo subcatchments is given.

Table I.2 Overview of the effect of all variants for both subcatchments on the peak discharge

Measure	Variant	Effect on peak discharge Sumber Pinang [%]	Effect on peak discharge Welang Hulu + Purworedjo [%]
Terracing	slope in agricultural areas to 90% of the original value	-7	+1
	slope in agricultural areas to 75% of the original value	-9	+4
	slope in agricultural areas to 50% of the original value	-13	+8
	slope in agricultural areas to 0% of the original value	-63	-53
	slope in areas with land use code 20 to 0% of the original value	-35	-20
	slope in areas with land use code 30 to 0% of the original value	-20	-39
Check dams	replace streamorder 3 by streamorder 2	-4	0
	replace streamorder 3 and 2 by streamorder 1	-5	0
	replace streamorder 3 and 2 by streamorder 1 and streamorder 4 by streamorder 3	-5	0
	replace streamorder 3 by streamorder 7	-7	0
Reforesting	replace land use code 14 by land use code 30	-17	0
	replace land use code 14 by land use code 40	-9	0
	replace land use code 14 and 20 by land use code 30	-20	+1

I.5 Conclusions

From the sensitivity runs using the hydrological model it is concluded that terracing seems to be the most effective intervention to reduce the peak flow in the Welang river. However, it should be taken into account that terracing is a costly measure and that it is unrealistic to transform all agricultural areas in a subcatchment into terraces. Nevertheless, it has been shown in this study that large reductions in peak flow can already be achieved if between 10 and 30% of the area in a subcatchment is transformed into terraces. In the Sumber Pinang, the most effective intervention is to transform areas with land use code 20 (mostly mosaic cropland, 20% of the catchment) into terraces, while the most effective intervention in the Welang Hulu and Purworedjo subcatchments is to transform areas with land use code 30 (mostly vegetation, 28% of the catchment) into terraces.

Constructing check dams in the smaller branches of the Welang river has a small reducing effect in the Sumber Pinang, but almost no effect in the Welang Hulu and Purworedjo catchments. It is however concluded that the effect of should be verified in a hydraulic model, like Sobek.

Reforesting of agricultural areas has a large reducing effect of peak flows in the Sumber Pinang, but a small increasing effect on peak flows in the Welang Hulu and Purworedjo catchments. Like for terracing, the total area that is reforested is important for the effect on peak flows. In the Sumber Pinang, this area is larger (32% of the catchments for land use code 14, rainfed croplands), than in the Welang Hulu and Purworedjo subcatchments (9% of the catchments for land use code 14) in the simulations, which explains the large differences between the results. Reforesting may be a cheaper and more sustainable solution to reduce peak flows compared to terracing, and should therefore also be considered for the Sumber Pinang catchment.

RESULTS OF THE SENSITIVITY ANALYSIS OF DOWNSTREAM MEASURES AT KRATON

Task C started with a sensitivity analysis to show the potential effect of measures on reduction of the peak discharge and -water level at the two priority areas. The upstream measures focus on reduction and slowing down of the flood wave while the measures in the mid/downstream part focus on increasing the discharge capacity. This section presents the results of the sensitivity analysis of downstream measure at Kraton mid/downstream using the 1D- hydraulic model Sobek. The hydraulic effect was determined for the T = 25 years condition for the year 2020.

The sensitivity analysis is only to show the mechanisms and potential effect of measures. The flood level decrease at Kraton vs excavation volume was used as a measure of the effectiveness of the measure.

The following downstream measures were investigated with the 1-D hydraulic model (Figure @@):
1 Revitalise old Welang branch
2 Dredging
3 Bypass
4 River widening

Figure I. 3

1. Welang Lama retention
2. Dredging
3. Bypass
4. River widening

The modelling results of the alternatives and different variants are presented in the table below. Effective variants are indicated with a green colour (the greener the ore effective a variant is). Effective measures and variants are:
- Bypass (1c)
- Dredging (a)
- River widening (f)

Table I. 3 Summary of the effect of measures on the flood level and approximate effectiveness (cm/1000)

Alternative	Description	Excavation volume (m3)	Wl decrease at Kraton [m]	Effectivity cm/1000 m3
Bypass variants				
1a	Bypass permanently flowing, existing Welang reach from the bypass to downstream is closed.	74800	0.16	0.22
1b	Bypass, keep the existing Welang reach from the bypass to downstream (bed level of bypass at MSL +0)	55000	0.27	0.50
1c	Bypass, keep the existing Welang reach from the bypass to downstream (bed level of bypass at MSL +1	27500	0.24	0.88
1d	Bypass, keep the existing Welang reach from the bypass to downstream (bed level of bypass at MSL +1), river width 50m - location at gas terminal	55000	0.25	0.45
2e	Bypass, keep the existing Welang reach from the bypass to downstream (bed level of bypass at MSL +1), river width 50m - location at upstream gas terminal	70000	0.37	0.52
Dredging variants				
a	Dredging v1, lower thalweg with 1 m	80000	0.41	0.51
b	Dredging v2, lower the bed 1m, adjust the embankment	140000	0.66	0.47
Retention at old Welang's branch variants				
a	Retention area of 10 ha (1 km length, 100m width) with 2 m depth	200000	0.08	0.04
b	Retention area in existing Welang Lama branch of 0.75 ha (1.5 km length, 5m width) with 2 m depth	0	0.003	
c	Retention area of 10 ha with 3m depth	300000	0.14	0.05
River widening variants				
a	From Kraton to 2 km length downstream (Alt 1), lowering 1m	40000	0.28	0.71
b	From Kraton to 2 km length downstream (Alt 1), lowering 2m	80000	0.47	0.58
c	From toll road to mouth, lowering 1 m	100000	0.50	0.50
d	From toll road to mouth, lowering 2 m	200000	0.84	0.42
e	River widening from Kraton to train station- 250m with storage	125000	0.19	0.16
f	River widening from Kraton to train station- 50m no storage	25000	0.19	0.76

Figure I. 4 Bypass variants

Figure I. 5 Bypass variants Dredging alternative

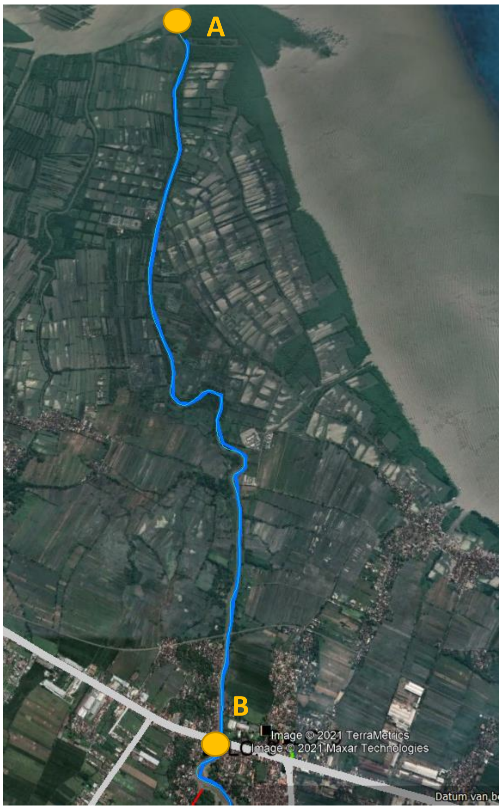


Figure I. 6

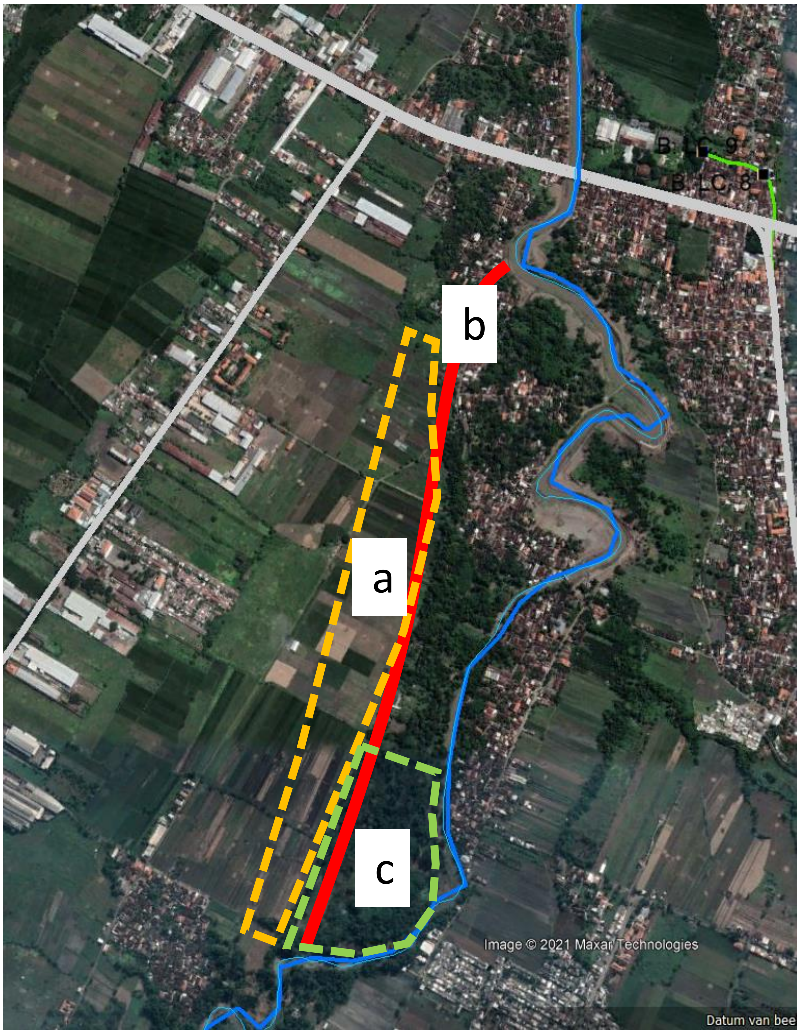


Figure I. 6 River widening variants a and b (left), c and d (right)

Figure I.7 River widening variant e and f

RESULTS OF THE SENSITIVITY ANALYSIS OF MIDSTREAM MEASURES SUMBER PINANG

It was concluded in the wflow sensitivity analysis, that a hydraulic model like Sobek is more suitable to assess the effect of check dams in a river compared to a hydrological model like Wflow. In Wflow, the check dams are schematised by using different Manning roughness values for the river cells of the model, while in a hydraulic model, the actual energy loss caused by an overtopping structure is calculated.

To assess the effect of check dams in the Sumber Pinang, a large tributary of the Welang, a Sobek model was developed of the main branch of the Sumber Pinang using the cross-sectional survey. With this hydraulic model, the effect of several check dam scenarios on river discharge and subsequently water level at Sidogiri, was assessed.

I.6 Method

To set up the hydraulic Sobek model of the Sumber Pinang, a survey was carried out in which a total of 43 cross sections of the bed profile of the river were measured over a length of 16.8 km. This survey also includes all main structures (weirs, bridges and sluices) in the Sumber Pinang, so that these could be included in the Sobek model.

A Sobek model of the Welang river itself was developed by Deltares. This model was extended with the Sumber Pinang branch. This model is forced with a set of lateral discharge locations as boundary conditions, obtained from the Wflow model. Unfortunately no discharge and water level measurements exist. Therefore, the model couldn’t be calibrated and validated. Hence, the model can only be used to determine the effect of a scenario compared to a baseline scenario (being 2020).

I.7 Model scenarios

7 model scenarios were developed for this sensitivity analysis. The model scenarios are described in Table I.4.

Table I. 4 Check dam scenarios

Scenario	Description
Baseline scenario (no weirs)	This scenario forms the baseline or reference scenario. In this scenario, no weirs are placed in the Sumber Pinang.
Weirs 1m 200m	In this scenario, weirs with a crest level of 1 m above the bed level are placed at every 200 m of the Sumber Pinang between cross sections STA 8+000 and STA 16+800. This results in a total of 41 check dams.
Weirs 2m 200m	In this scenario, weirs with a crest level of 2 m above the bed level are placed at every 200 m of the Sumber Pinang between cross sections STA 8+000 and STA 16+800. This results in a total of 41 check dams.
Weirs 3m 200m	In this scenario, weirs with a crest level of 3 m above the bed level are placed at every 200 m of the Sumber Pinang between cross sections STA 8+000 and STA 16+800. This results in a total of 41 check dams.
Weirs 4m 200m	In this scenario, weirs with a crest level of 4 m above the bed level are placed at every 200 m of the Sumber Pinang between cross sections STA 8+000 and STA 16+800. This results in a total of 41 check dams.
Weirs 2m 400m	In this scenario, weirs with a crest level of 2 m above the bed level are placed at every 400 m of the Sumber Pinang between cross sections STA 8+000 and STA 16+800. This results in a total of 18 check dams.
Weirs 2m 200m upstream	In this scenario, weirs with a crest level of 2 m above the bed level are placed at every 200 m of the Sumber Pinang between cross sections STA 12+500 and STA 16+800. This results in a total of 19 check dams.

These 7 model scenarios were ran with boundary conditions representing both a T1 and a T25 flood wave, which were extracted from the wflow model ran with a T1 and T25 precipitation event.

I.8 Results

The results of the scenario simulations are presented in the table below. It can be seen that the reduction of the peak water levels is very small. We conclude that in order for this type of intervention to become effective, a large number of check dams or gully plugs need to be built in the streams at the upstream part of the catchment.

Table I. 5 Maximum water levels (Max. WL) and discharges (Max. Q) at Sidogiri for all model scenarios for the T25 flood wave

Check dam scenario	Max. WL at Sidogiri [m AD]	Diff. w.r.t. baseline [m]	Max. Q at Sidogiri [m^3/s]	Diff. w.r.t. baseline [m^3/s]
Baseline (no weirs)	25.41	-	64.49	-
Weirs 1m 200m	25.41	-0.00	64.48	-0.01
Weirs 2m 200m	25.40	-0.01	64.42	-0.07
Weirs 3m 200m	25.39	-0.02	64.33	-0.16
Weirs 4m 200m	25.37	-0.04	64.32	-0.17
Weirs 2m 400m	25.41	-0.00	64.44	-0.05
Weirs 2m 200m upstream	25.40	-0.01	64.42	-0.07

II

APPENDIX: CONCEPTUAL DESIGNS

KEY MAP

SCALE 1:40000

LEGEND

CENTER LINE

DREDGING AREA

0 20 40 60 80 100m

SCALE 1:2000

PROJECT MASTERPLAN WELANG RIVER

DREDGING WELANG RIVER
LAYOUT DREDGING

G	
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Revisions	
Scale	1:10000
	122683.5000
Size	A1

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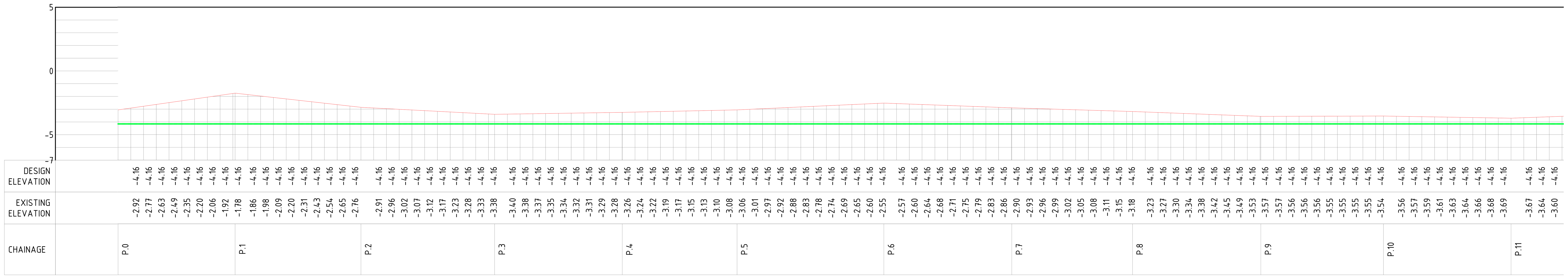
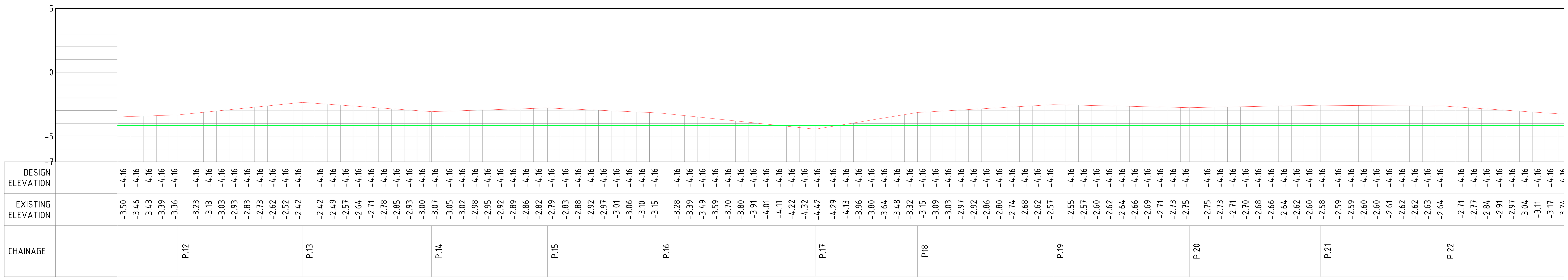
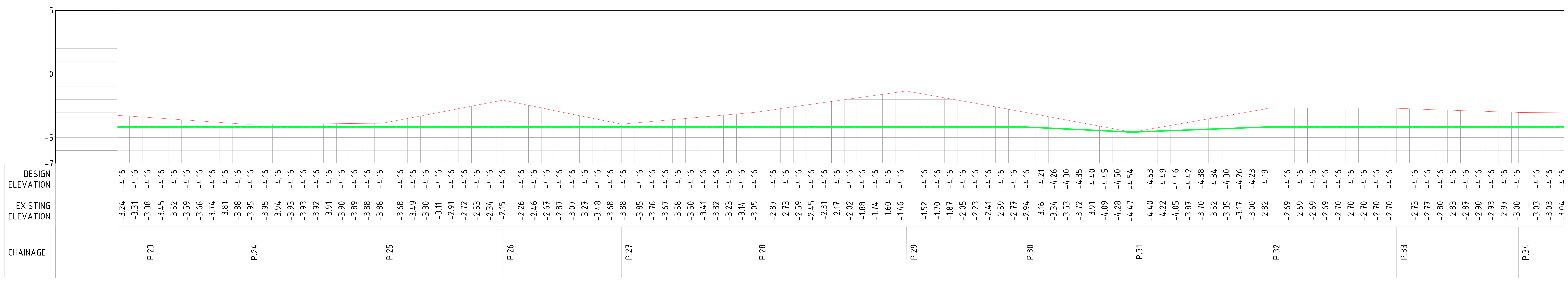
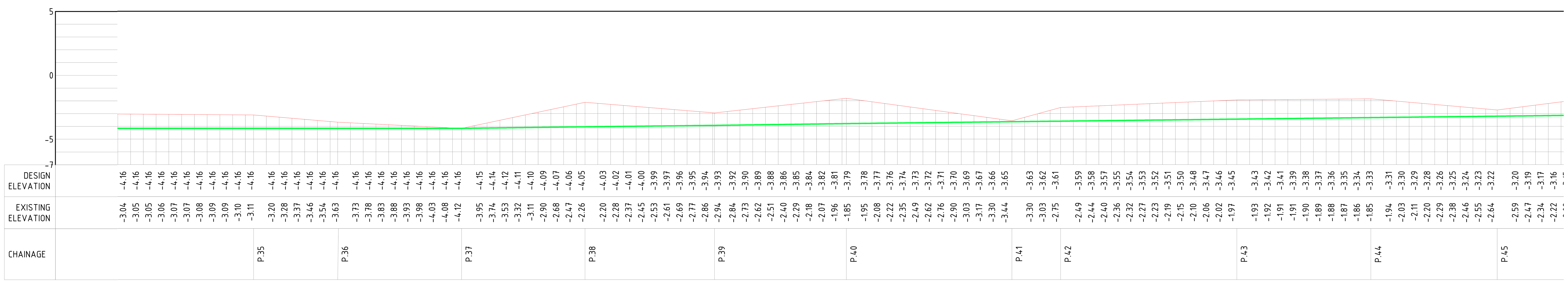
Plot date: 9 Desember 2021





CL-WELANG RIVER PROFILE





KEY MAP
SCALE 1:40000

LEGEND

EXISTING GROUND
DREDGING

0 20 40 60 80 100m
SCALE 1:2000

PROJECT MASTERPLAN WELANG RIVER

DREDGING WELANG RIVER
LONG SECTION

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Authorized	
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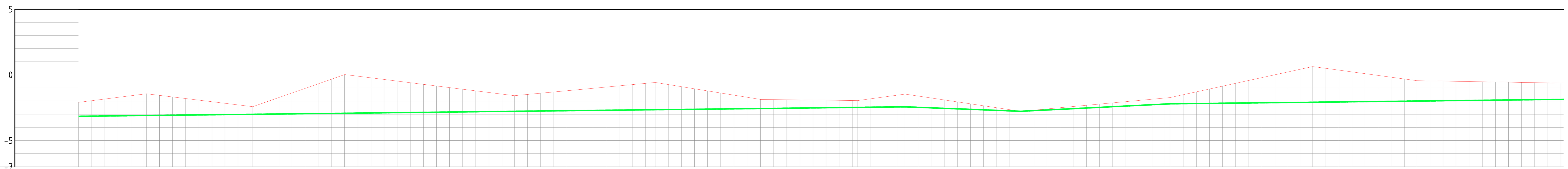

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	-3.13	-1.84
	-3.12	-1.71
	-3.10	-1.59
P.46	-3.09	-1.46
	-3.08	-1.56
	-3.07	-1.68
	-3.06	-1.80
	-3.05	-1.92
	-3.03	-2.04
	-3.02	-2.16
	-3.01	-2.28
P.47	-3.00	-2.41
	-2.99	-2.07
	-2.98	-1.72
	-2.97	-1.37
	-2.95	-1.03
	-2.94	-0.68
	-2.93	-0.33
P.48	-2.92	0.02
	-2.91	-0.09
	-2.90	-0.22
	-2.89	-0.34
	-2.87	-0.47
	-2.86	-0.59
	-2.85	-0.72
	-2.84	-0.84
	-2.83	-0.96
	-2.82	-1.09
	-2.80	-1.21
	-2.79	-1.34
	-2.78	-1.46
P.49		
	-2.76	-1.49
	-2.75	-1.39
	-2.74	-1.30
	-2.73	-1.20
	-2.71	-1.11
	-2.70	-1.02
	-2.69	-0.92
	-2.68	-0.83
	-2.67	-0.73
	-2.66	-0.64
P.50		
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	-2.63	-0.89
	-2.62	-1.05
	-2.61	-1.22
	-2.59	-1.38
	-2.58	-1.54
	-2.57	-1.70
P.51	-2.56	-1.86
	-2.55	-1.88
	-2.54	-1.89
	-2.52	-1.90
	-2.51	-1.91
	-2.50	-1.92
	-2.49	-1.93
P.52A	-2.47	-1.95
	-2.46	-1.81
	-2.45	-1.68
P.52	-2.44	-1.54
	-2.47	-1.61
	-2.51	-1.76
	-2.55	-1.90
	-2.58	-2.05
	-2.62	-2.20
	-2.66	-2.35
	-2.70	-2.50
	-2.74	-2.64
P.53		
	-2.72	-2.68
	-2.67	-2.59
	-2.62	-2.49
	-2.57	-2.40
	-2.52	-2.31
	-2.47	-2.22
	-2.42	-2.12
	-2.37	-2.03
	-2.32	-1.94
	-2.27	-1.85
P.54	-2.22	-1.76
	-2.19	-1.50
	-2.18	-1.29
	-2.17	-1.07
	-2.16	-0.85
	-2.14	-0.64
	-2.13	-0.42
	-2.12	-0.20
	-2.11	0.01
	-2.10	0.23
	-2.09	0.45
P.55		
	-2.07	0.50
	-2.06	0.37
	-2.05	0.23
	-2.03	0.10
	-2.02	-0.04
	-2.01	-0.17
	-2.00	-0.31
P.56		
	-1.98	-0.46
	-1.97	-0.47
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	-1.93	-0.52
	-1.92	-0.54
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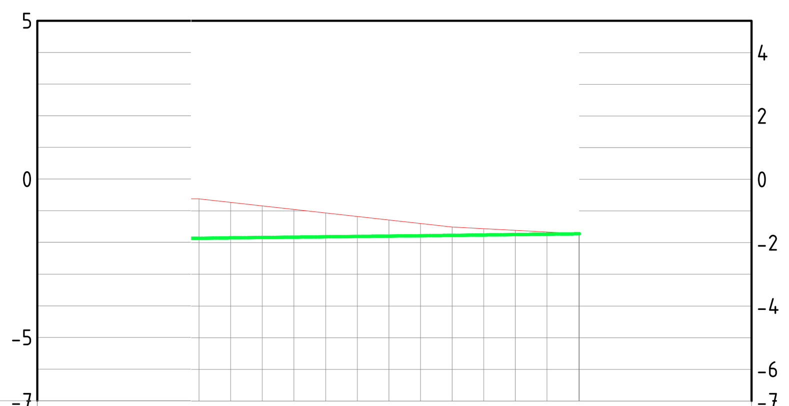

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	-1.84	-0.84
	-1.83	-0.95
	-1.81	-1.07
	-1.80	-1.18
	-1.79	-1.29
	-1.78	-1.40
P.58		
	-1.76	-1.56
	-1.75	-1.61
	-1.73	-1.67
P.59A	-1.72	-1.72

KEY MAP

SCALE 1:40000

LEGEND

EXISTING GROUND

DREDGING

0 20 40 60 80 100m

SCALE 1:2000

PROJECT MASTERPLAN WELANG RIVER

DREDGING WELANG RIVER
LONG SECTION

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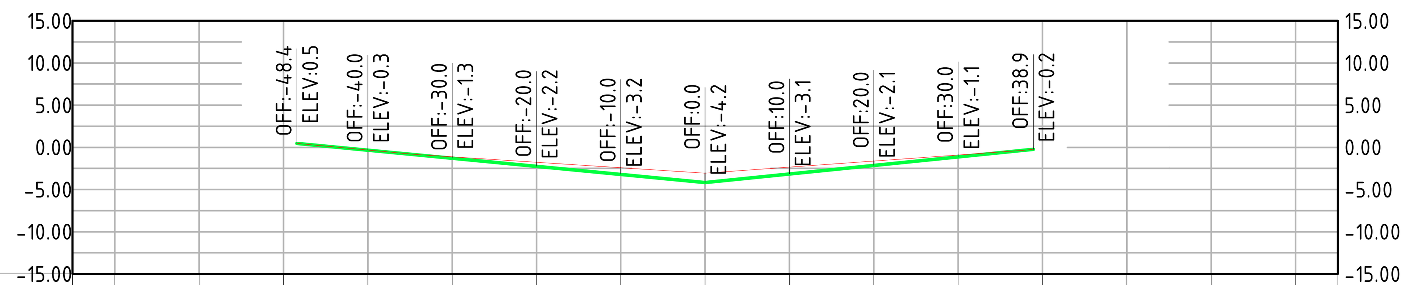

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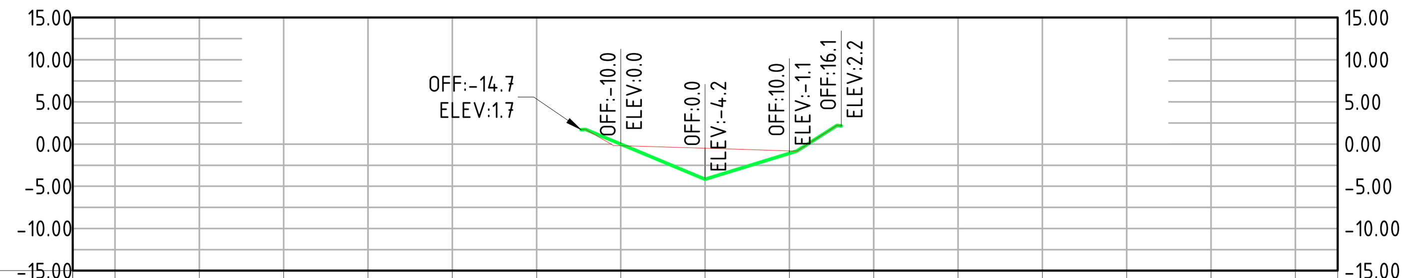

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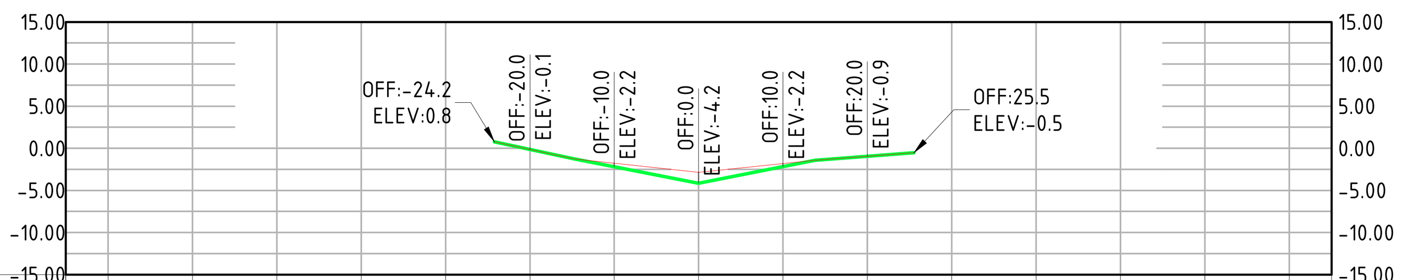

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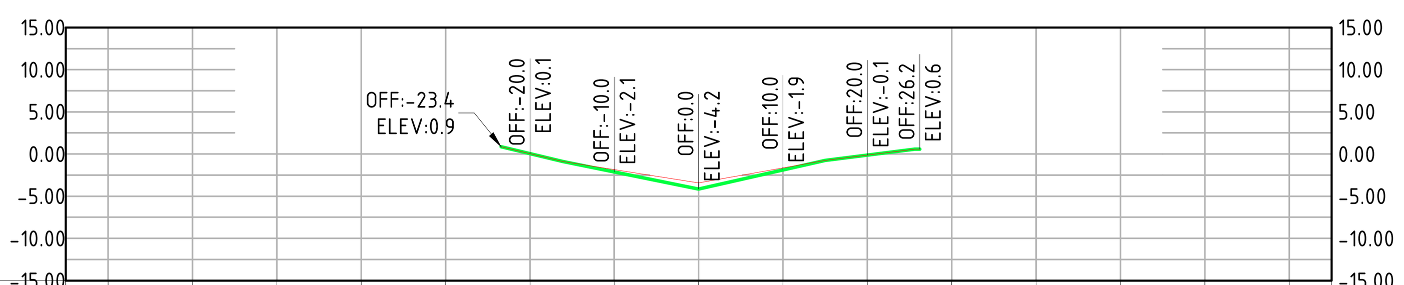

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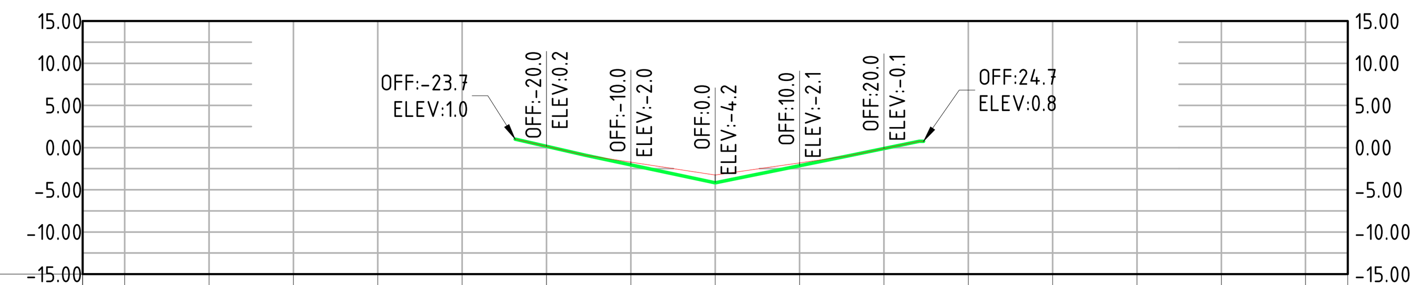

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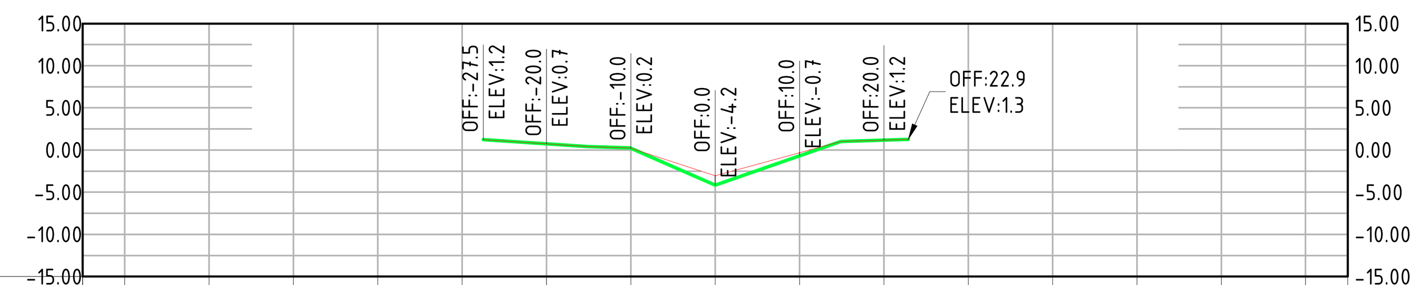

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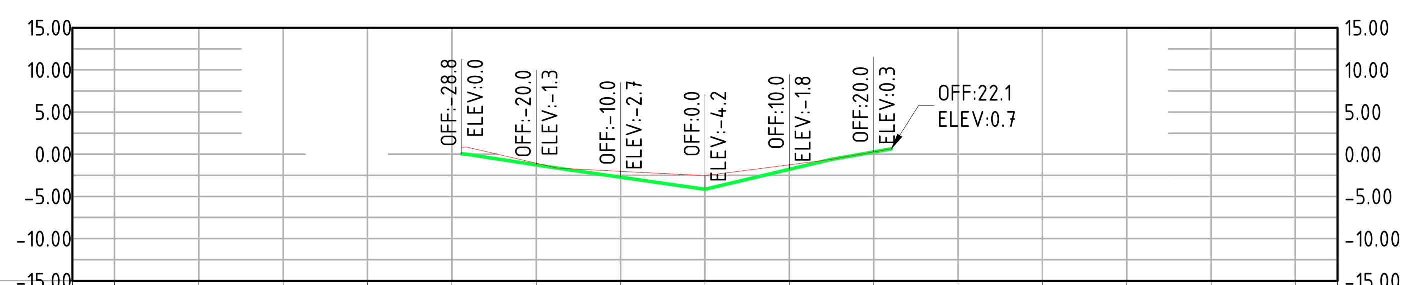

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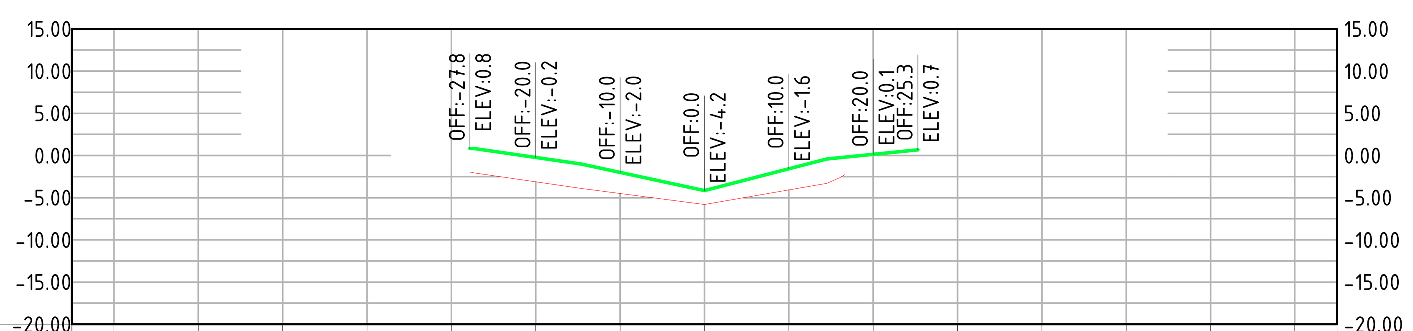

CS-P.7

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KEY MAP

SCALE 1:40000

LEGEND

EXISTING GROUND

DREDGING

0 5 10 15 20 25m

SCALE 1:500

PROJECT MASTERPLAN WELANG RIVER

DREDGING WELANG RIVER
CROSS SECTION

Witteveen+Bos

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Size A1

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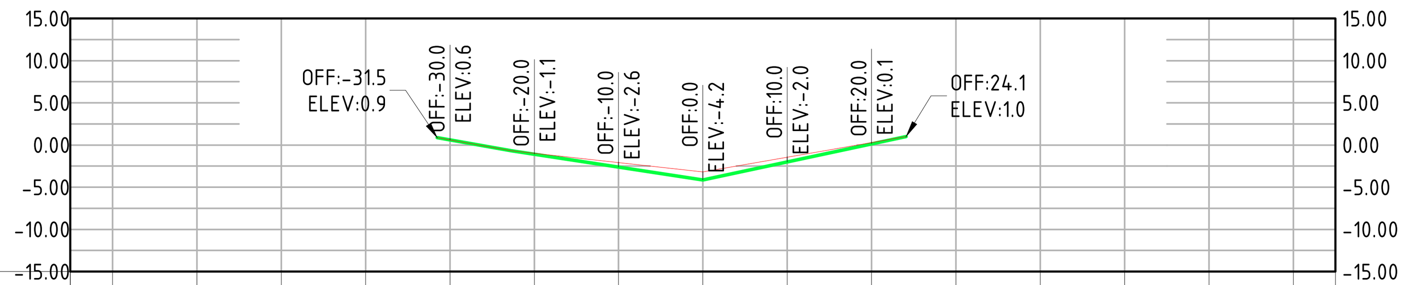

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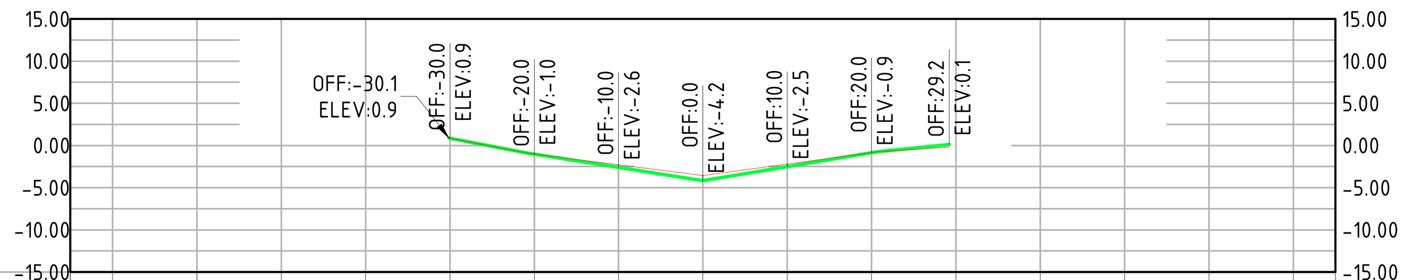

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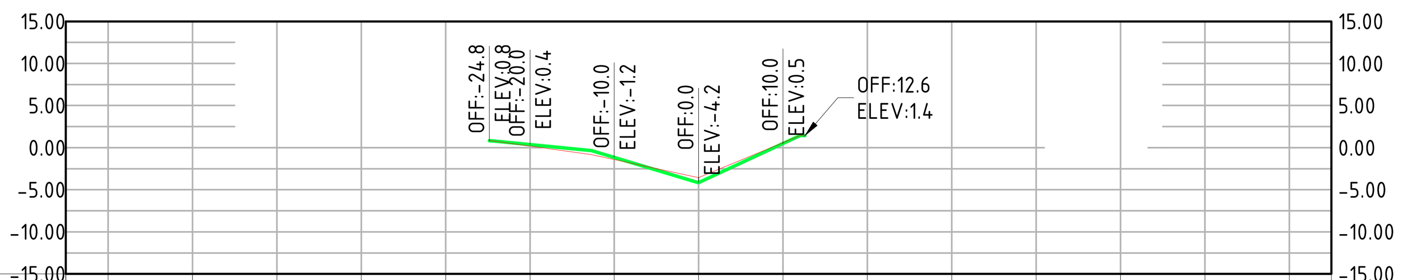
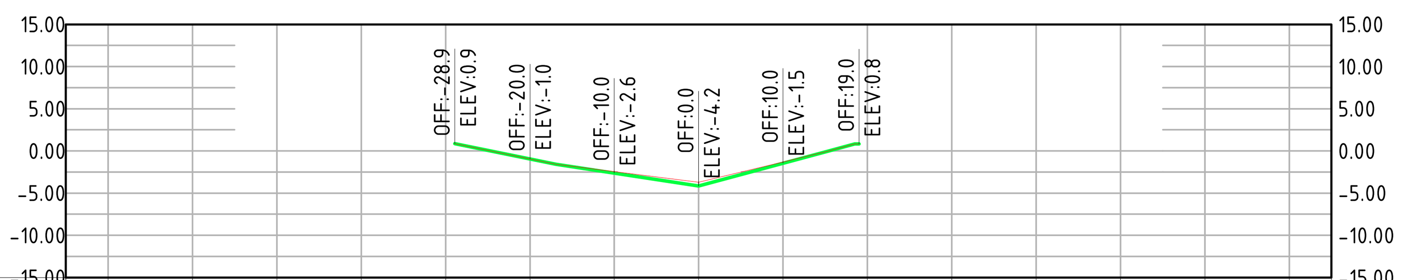
EG LEVEL	0.9	-1.0	-2.3	-3.6	-2.2	-0.8

CS-P.9



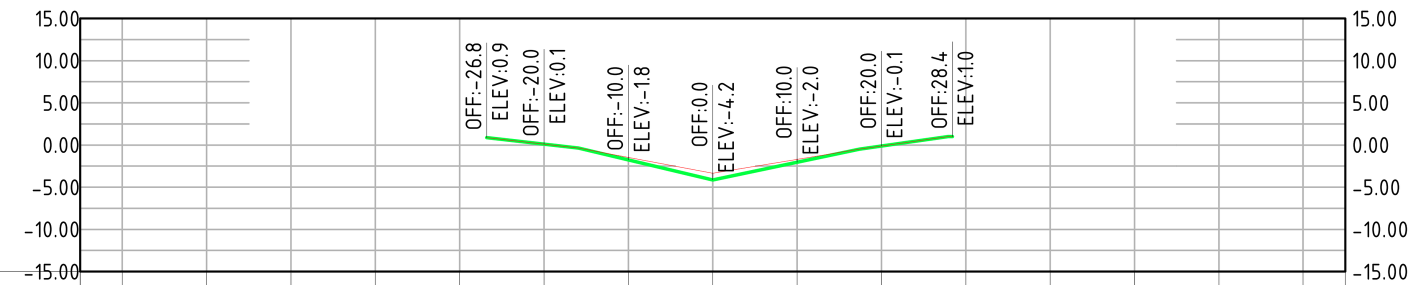
DESIGN LEVEL	0.4	-1.2	-4.2	0.5
EG LEVEL	0.2	-1.4	-3.5	0.6

CS-P.10



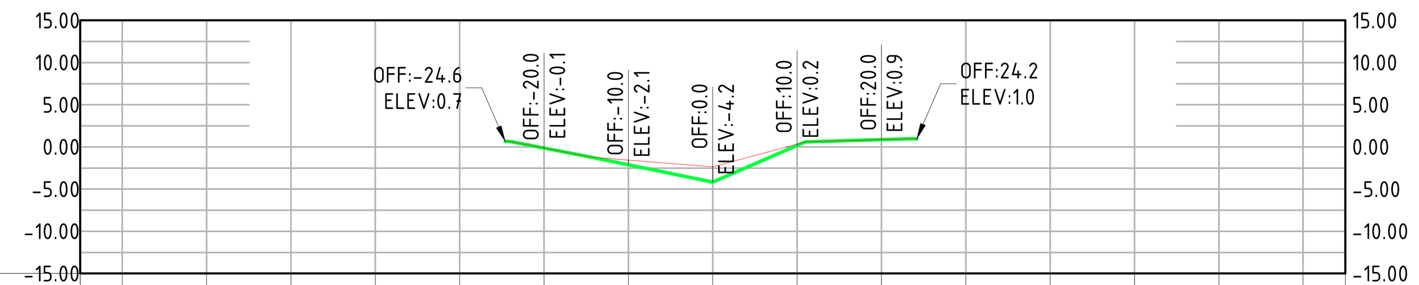
DESIGN LEVEL	-1.0	-2.6	-4.2	-1.5
EG LEVEL	-1.0	-2.5	-3.7	-1.3

CS-P.11



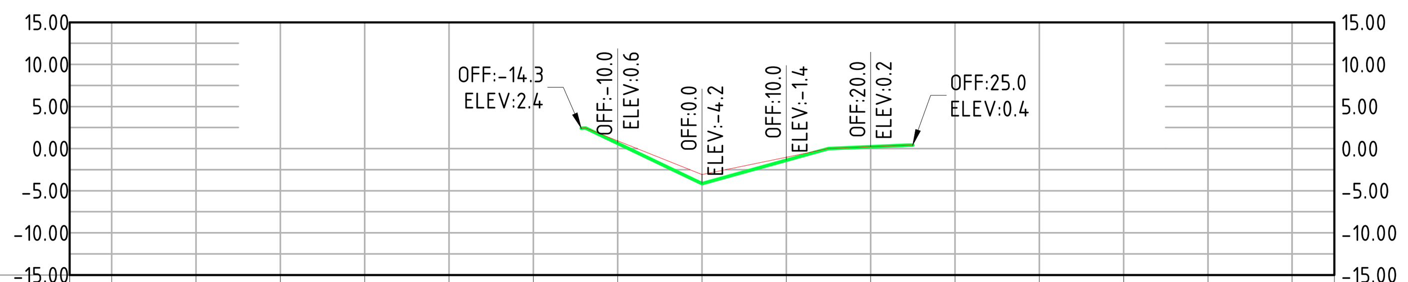
DESIGN LEVEL	0.1	-1.8	-4.2	-2.0	-0.1
EG LEVEL	0.1	-1.5	-3.3	-1.7	-0.1

CS-P.12



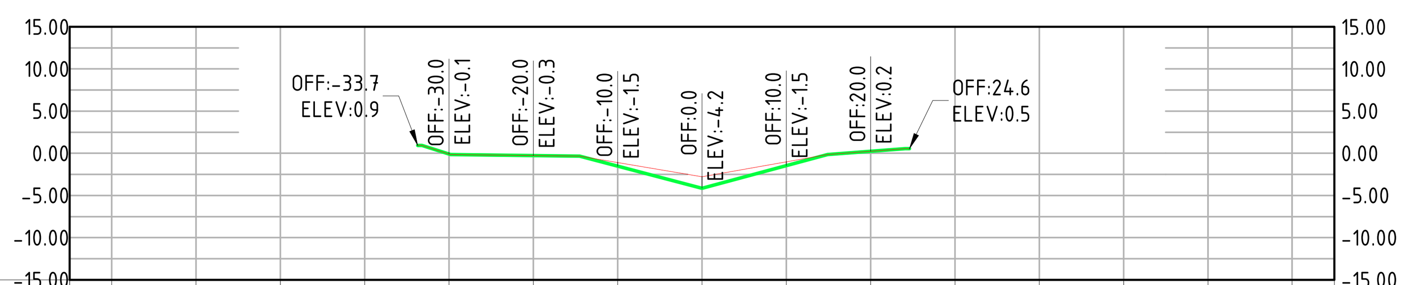
DESIGN LEVEL	-0.1	-2.1	-4.2	0.2	0.9
EG LEVEL	-0.1	-1.6	-2.3	0.3	0.9

CS-P.13



DESIGN LEVEL	0.6	-4.2	-1.4	0.2
EG LEVEL	0.9	-3.1	-1.0	0.2

CS-P.14



DESIGN LEVEL	-0.1	-0.3	-1.5	-4.2	-1.5	0.2
EG LEVEL	-0.1	-0.3	-1.1	-2.8	-1.0	0.2

CS-P.15

KEY MAP
SCALE 1:40000

LEGEND

EXISTING GROUND
DREDGING

0 5 10 15 20 25m
SCALE 1:500

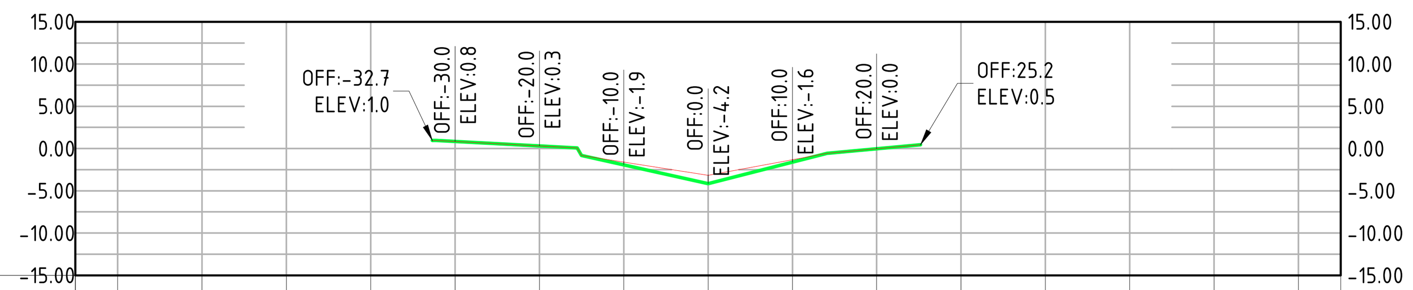
PROJECT MASTERPLAN WELANG RIVER

DREDGING WELANG RIVER
CROSS SECTION

Witteveen+Bos
Park View Plaza 6th floor
Jl. Taman Kemang No. 27
Kemang - Jakarta Selatan 12730 Phone: +62 21 719 1282
P.O. Box 1687 JKS 12016, Indonesia Telefax: +62 21 719 1283

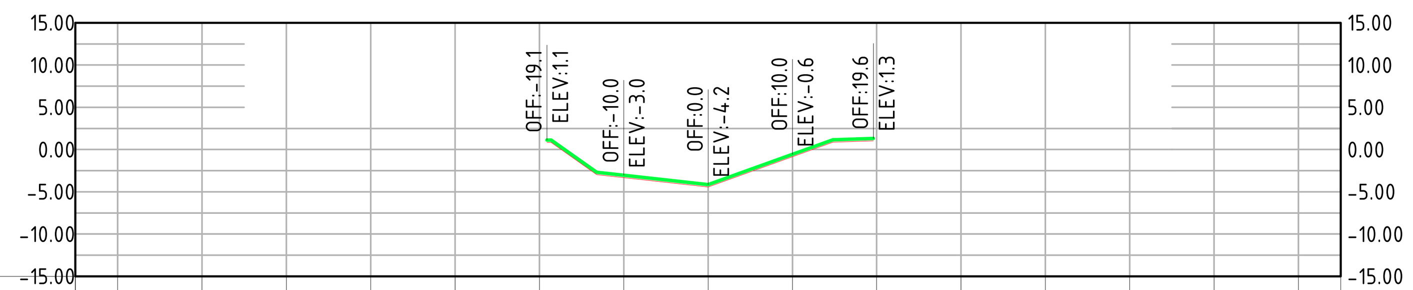
Drawn	Aland hasbi
Checked	Weny Sihombing
Authorized	
Date	
Scale	1:750
	122683.1101
Size	A1

Plot date: 9 Desember 2021



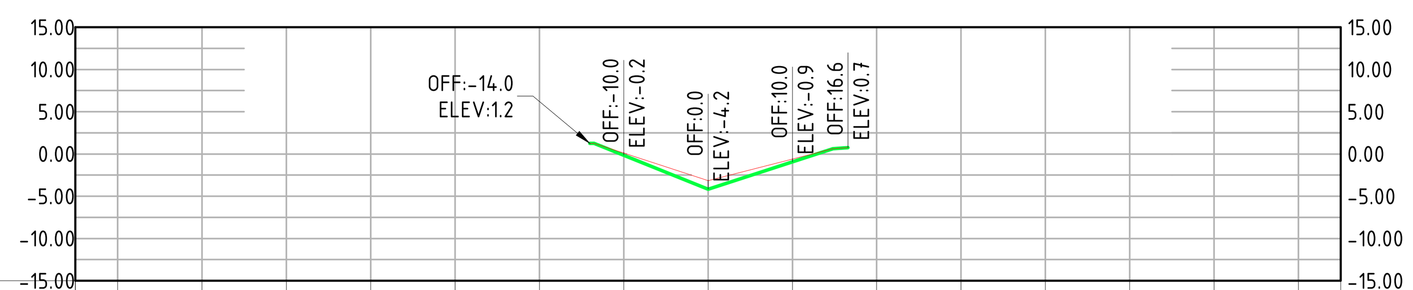
DESIGN LEVEL	0.8	0.3	-1.9	-4.2	-1.6	0.0
EG LEVEL	0.8	0.3	-1.6	-3.2	-1.3	0.0

CS-P.16



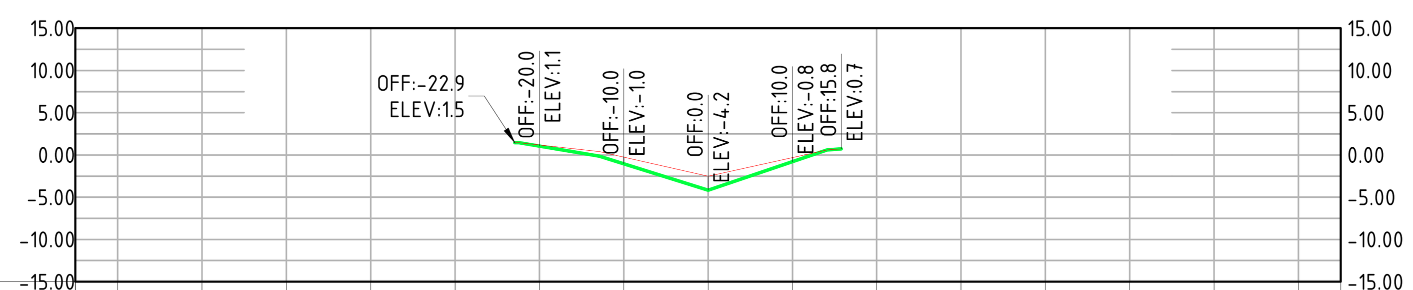
DESIGN LEVEL	-3.0	-4.2	-0.6
EG LEVEL	-3.3	-4.4	-0.9

CS-P.17



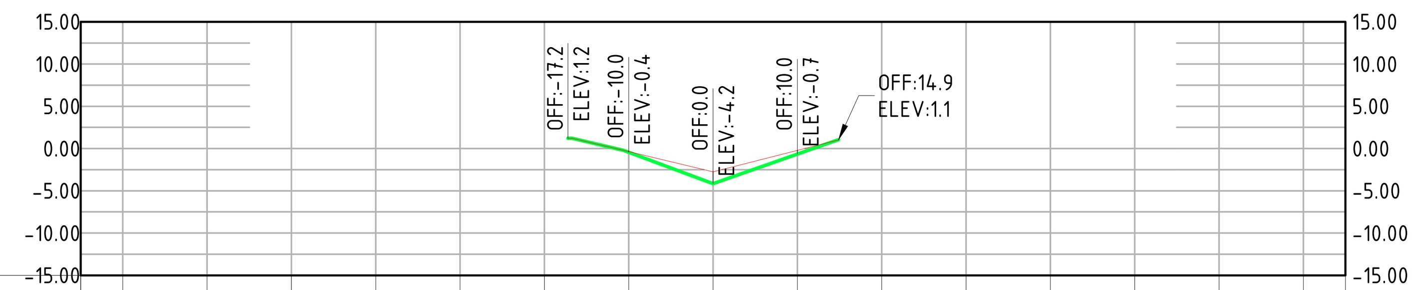
DESIGN LEVEL	-0.2	-4.2	-0.9
EG LEVEL	0.1	-3.1	-0.6

CS-P.18



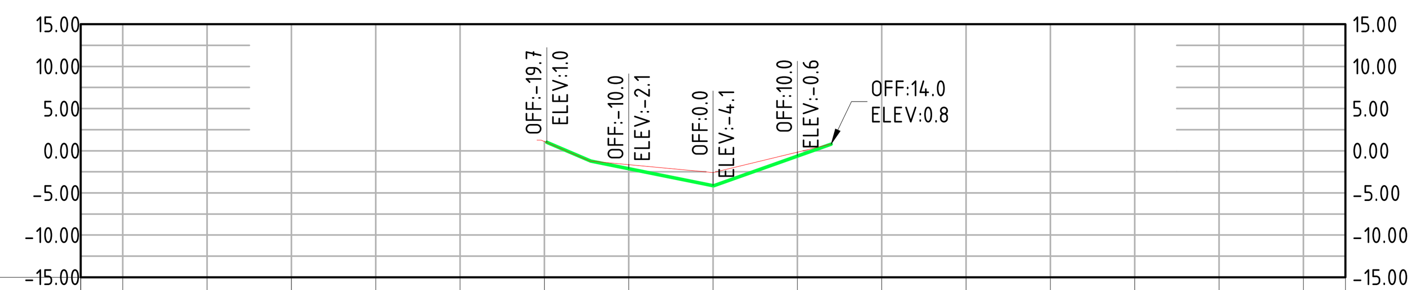
DESIGN LEVEL	1.1	-1.0	-4.2	-0.8
EG LEVEL	1.2	-0.3	-2.5	-0.3

CS-P.19



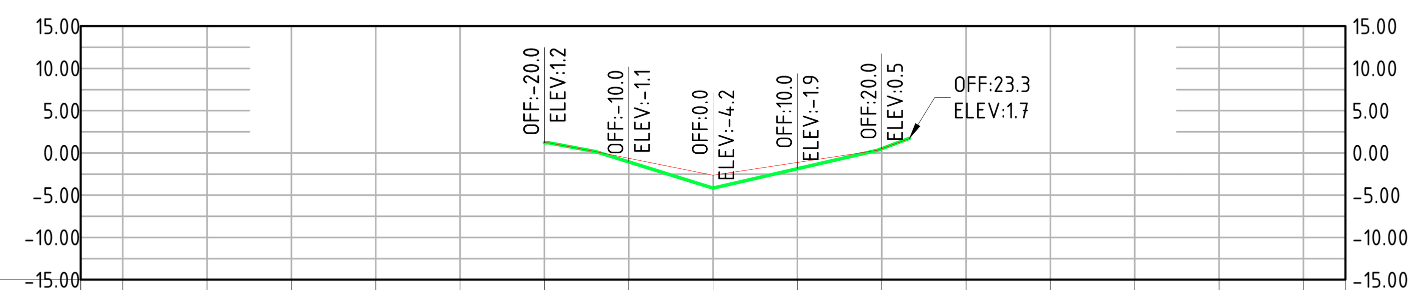
DESIGN LEVEL	-0.4	-4.2	-0.7
EG LEVEL	-0.4	-2.8	-0.2

CS-P.20



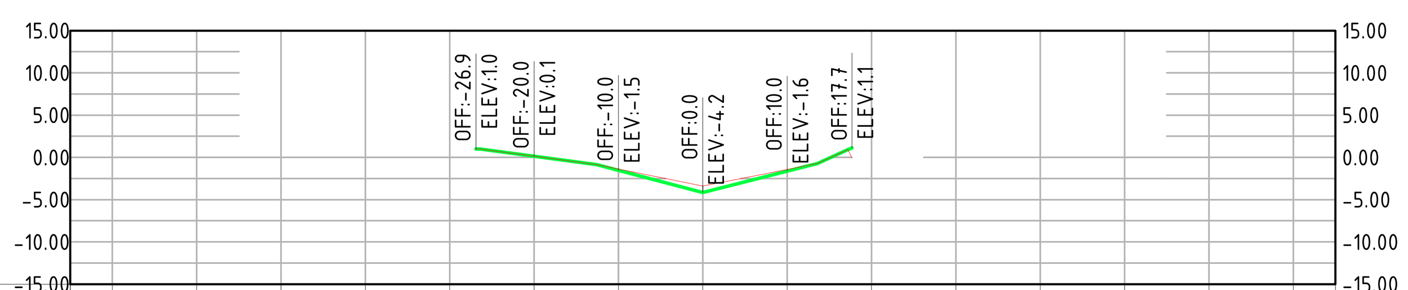
DESIGN LEVEL		-2.1	-4.1	-0.6
EG LEVEL	1.1	-1.7	-2.6	-0.2

CS-P.21



DESIGN LEVEL	1.2	-1.1	-4.2	-1.9	0.5
EG LEVEL	1.2	-0.6	-2.6	-1.1	0.5

CS-P.22



DESIGN LEVEL	0.1	-1.5	-4.2	-1.6
EG LEVEL	0.1	-1.4	-3.4	-1.4

CS-P.23

KEY MAP
SCALE 1:40000

LEGEND

EXISTING GROUND
DREDGING

0 5 10 15 20 25m
SCALE 1:500

PROJECT MASTERPLAN WELANG RIVER

DREDGING WELANG RIVER
CROSS SECTION

G
F
E
D
C
B
A
Revisions

Witteveen + Bos

Park View Plaza 6th floor
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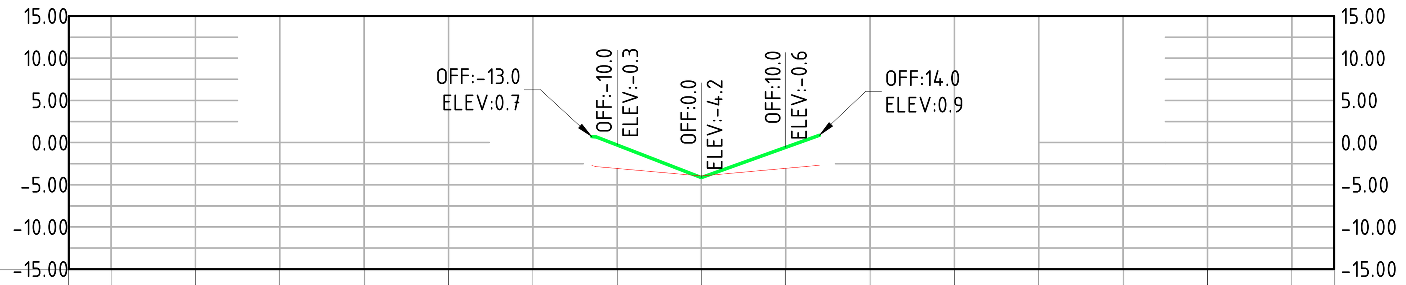
Drawn	Aland hasbi	Scale	1:750
Checked	Weny Sihombing		122683.1102
Authorized			
Date		Size	A1

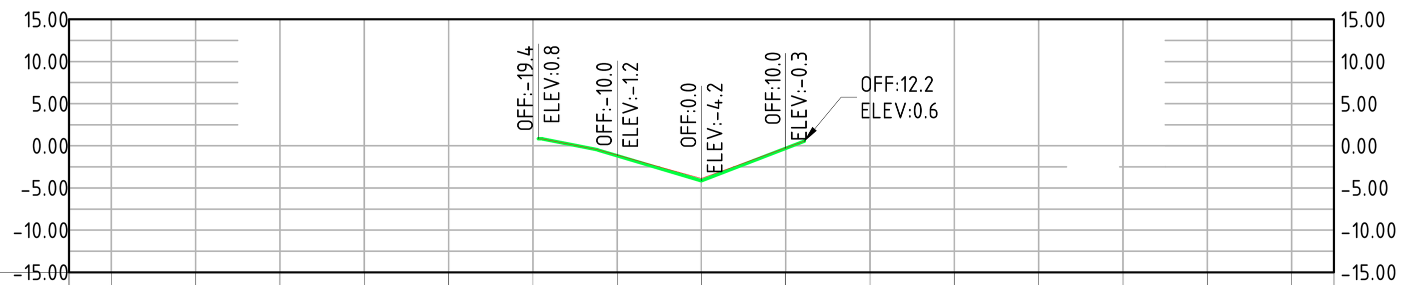
Plot date: 9 Desember 2021

CAD DRW: P:\122683\123845\WIP\Models\100 Civil 3D\01 Data\New folder\CS-Cross section Dredging Welang-Model.dwg



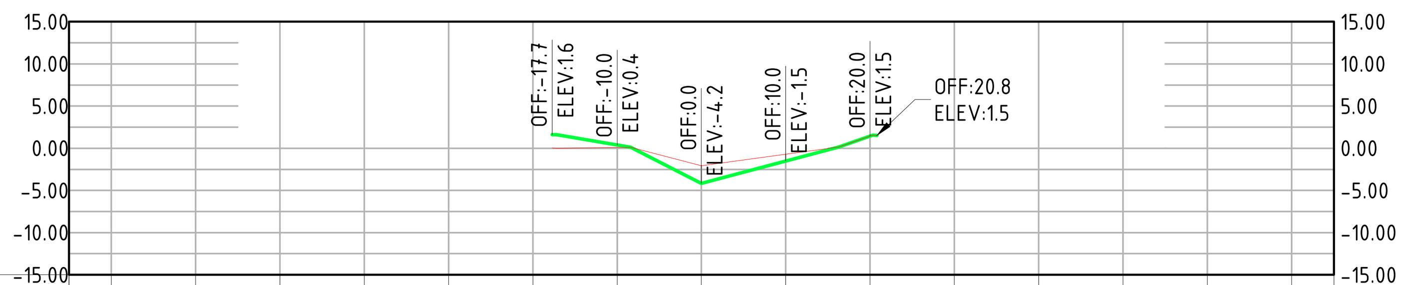
DESIGN LEVEL	-0.3	-4.2	-0.6
EG LEVEL	-3.1	-4.0	-3.1

CS-P.24



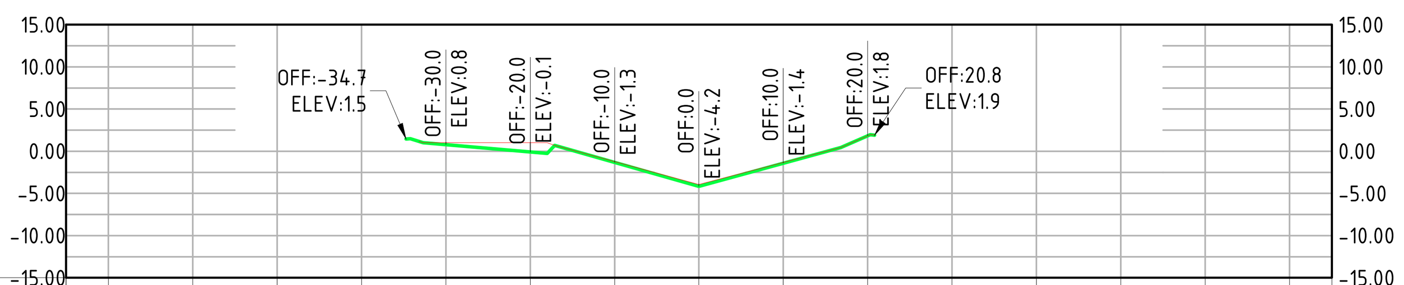
DESIGN LEVEL	-1.2	-4.2	-0.3
EG LEVEL	-1.1	-3.9	-0.2

CS-P.25



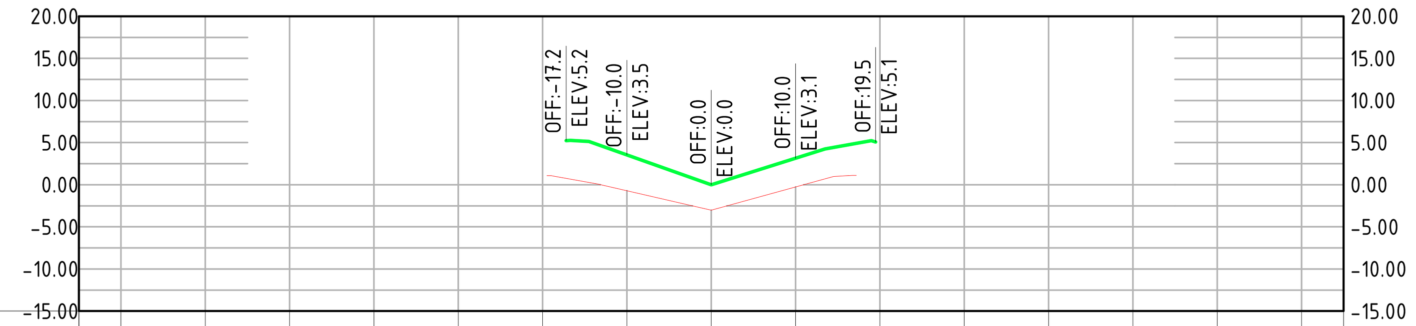
DESIGN LEVEL	0.4	-4.2	-1.5	1.5
EG LEVEL	0.1	-2.1	-0.7	1.5

CS-P.26



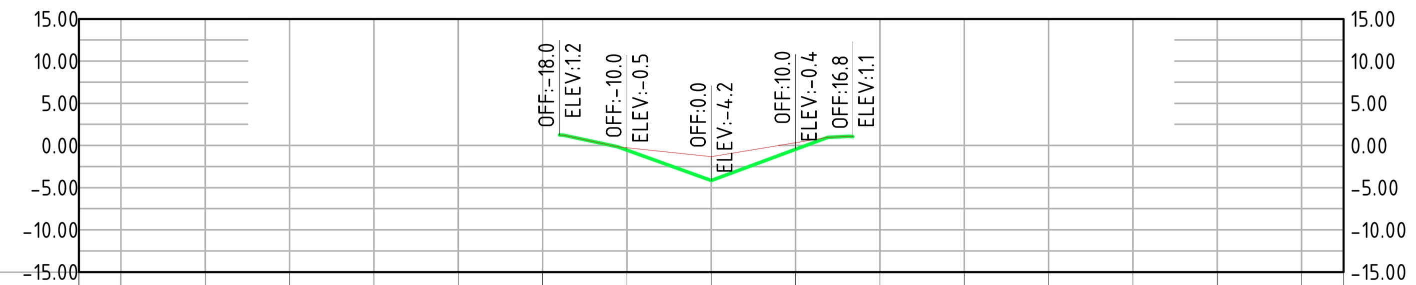
DESIGN LEVEL	0.8	-0.1	-1.3	-4.2	-1.4	1.8
EG LEVEL	1.0	1.0	-1.2	-3.9	-1.3	1.8

CS-P.27



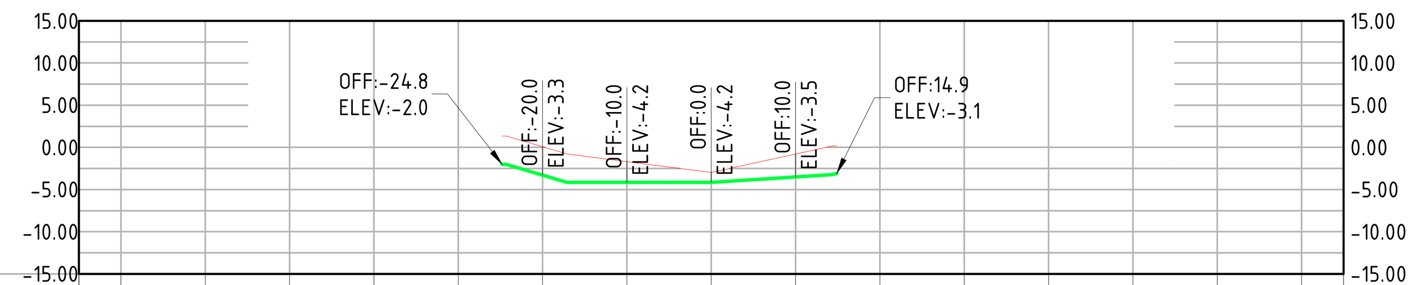
DESIGN LEVEL	3.5	0.0	3.1
EG LEVEL	-0.7	-3.0	-0.3

CS-P.28



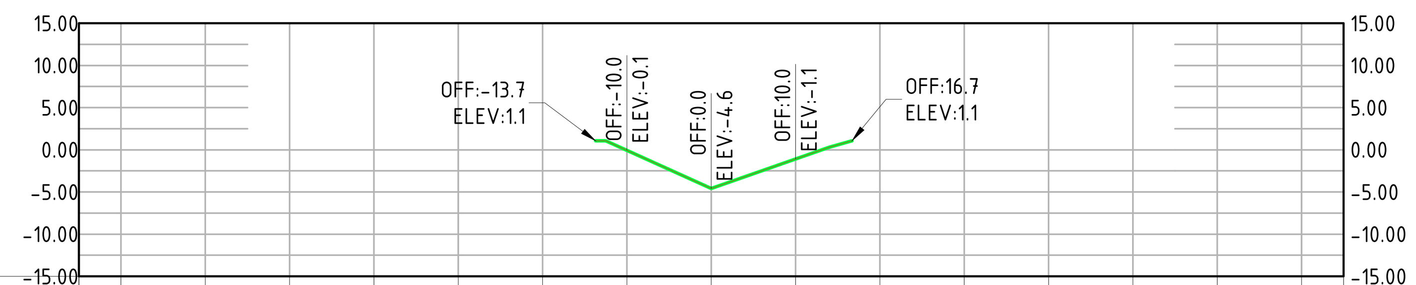
DESIGN LEVEL	-0.5	-4.2	-0.4
EG LEVEL	-0.3	-1.3	0.3

CS-P.29



DESIGN LEVEL	-3.3	-4.2	-4.2	-3.5
EG LEVEL	0.1	-1.7	-3.0	-0.8

CS-P.30



DESIGN LEVEL	-0.1	-4.6	-1.1
EG LEVEL	-0.1	-4.6	-1.1

CS-P.31

KEY MAP
SCALE 1:40000

LEGEND

EXISTING GROUND
DREDGING

0 5 10 15 20 25m
SCALE 1:500

PROJECT MASTERPLAN WELANG RIVER

DREDGING WELANG RIVER
CROSS SECTION

Witteveen+Bos
Park View Plaza 6th floor
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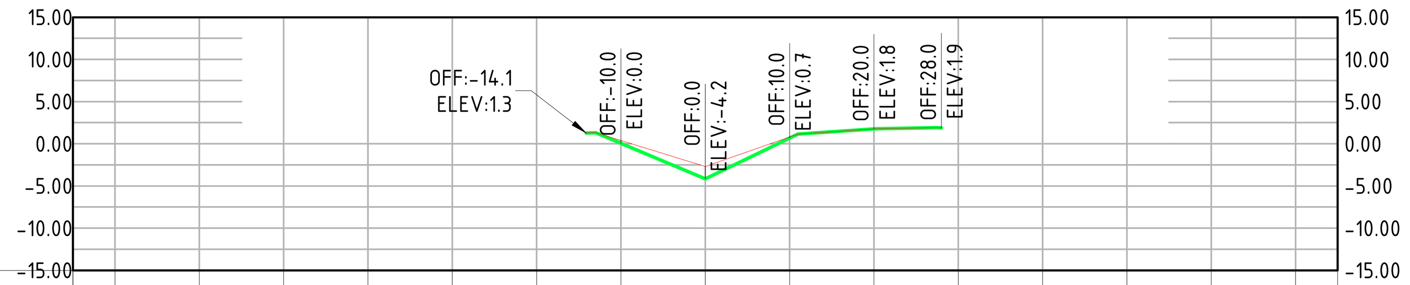
Kemang - Jakarta Selatan 12730 Phone: +62 21 719 1282
P.O. Box 1687 JKS 12016, Indonesia Telefax: +62 21 719 1283

Drawn: Aland hasbi
Checked: Weny Sihombing
Authorized
Date

Revisions: G, F, E, D, C, B, A

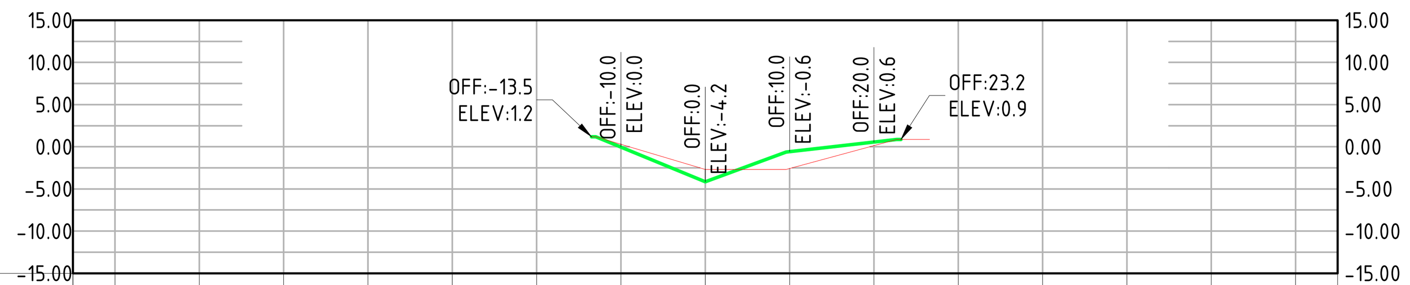
Scale: 1:750
122683.1103
Size: A1

Plot date: 9 Desember 2021



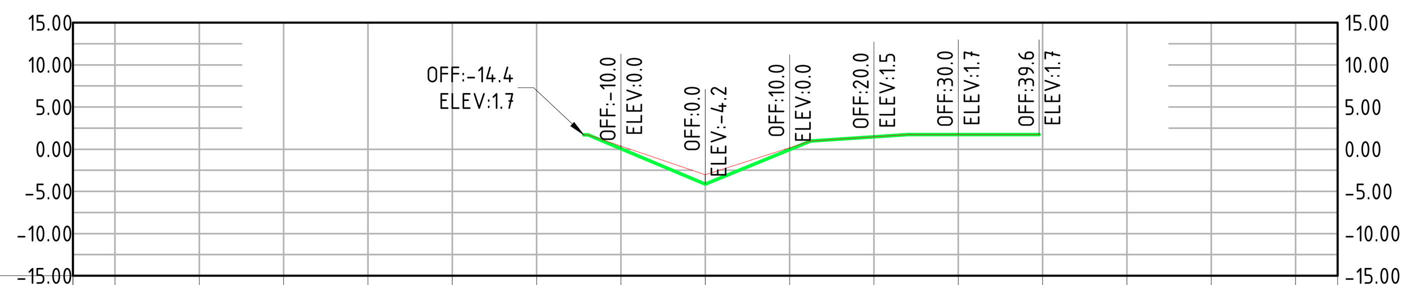
DESIGN LEVEL	0.0	-4.2	0.7	1.8
EG LEVEL	0.4	-2.7	0.8	1.8

CS-P.32



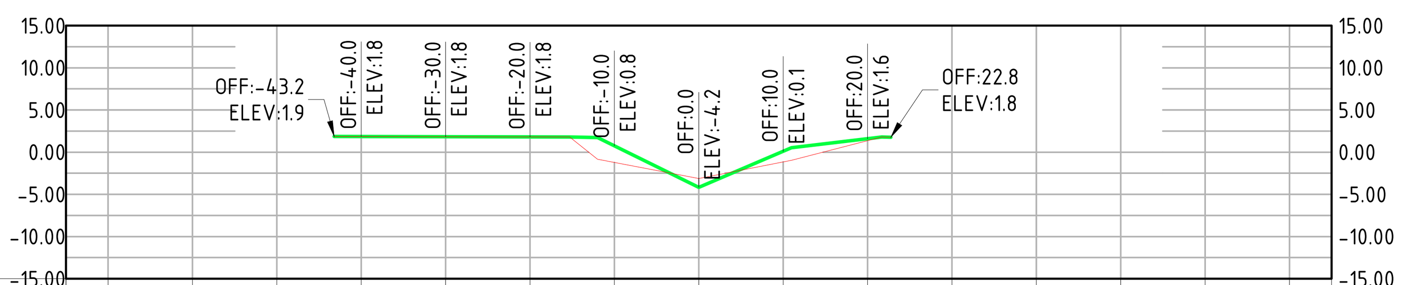
DESIGN LEVEL	0.0	-4.2	-0.6	0.6
EG LEVEL	0.3	-2.7	-2.6	0.1

CS-P.33



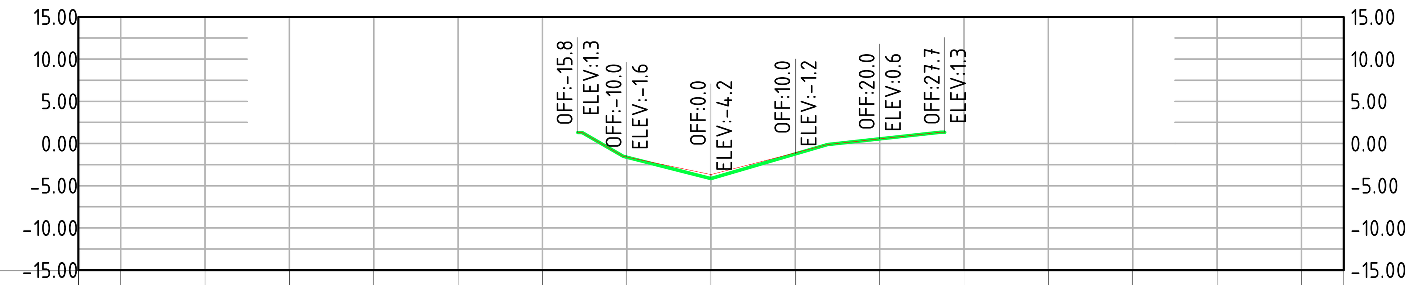
DESIGN LEVEL	0.0	-4.2	0.0	1.5	1.7
EG LEVEL	0.4	-3.0	0.2	1.5	1.7

CS-P.34



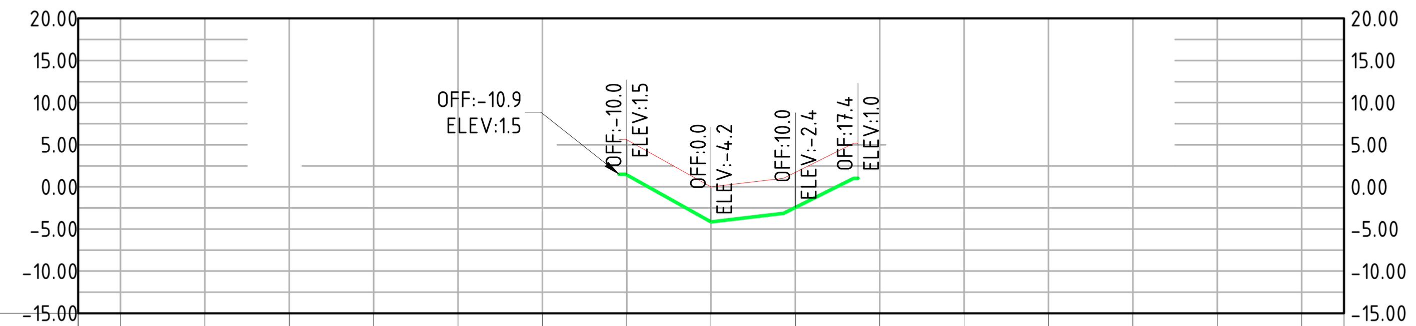
DESIGN LEVEL	1.8	1.8	1.8	0.8	-4.2	0.1	1.6
EG LEVEL	1.8	1.8	1.8	-1.2	-3.1	-1.1	1.3

CS-P.35



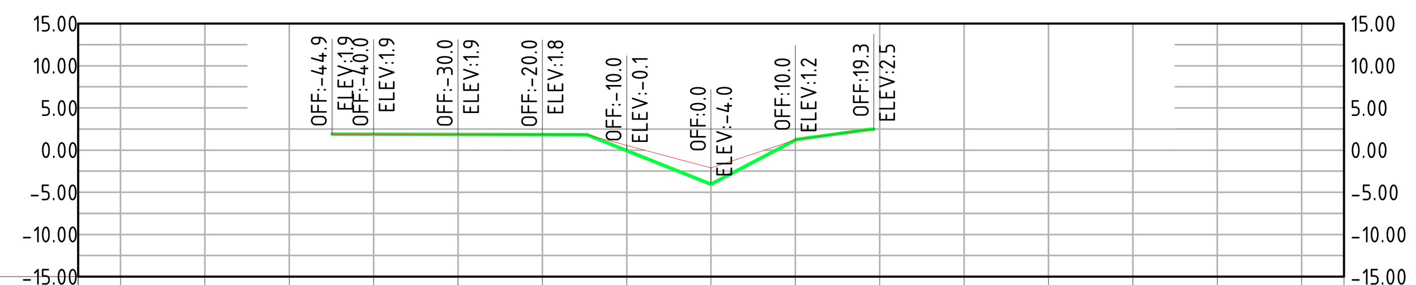
DESIGN LEVEL	-1.6	-4.2	-1.2	0.6
EG LEVEL	-1.6	-3.7	-1.1	0.6

CS-P.36



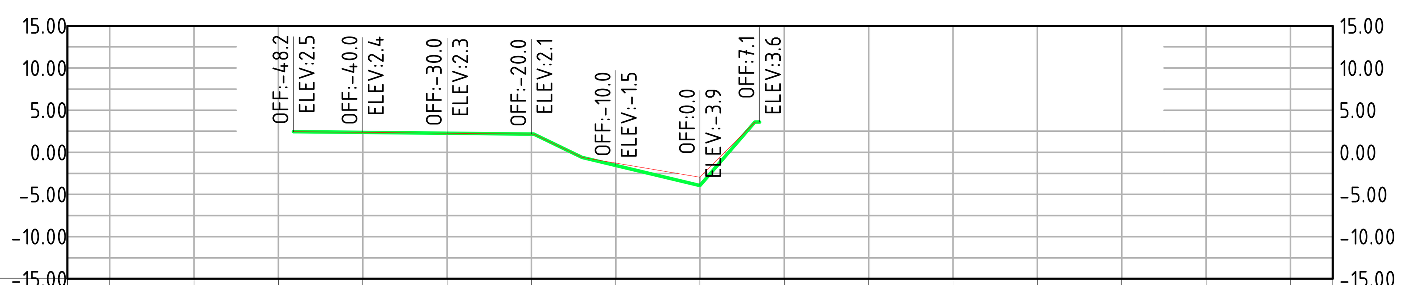
DESIGN LEVEL	1.5	-4.2	-2.4
EG LEVEL	5.6	0.0	1.7

CS-P.37



DESIGN LEVEL	1.9	1.9	1.8	-0.1	-4.0	1.2
EG LEVEL	1.9	1.9	1.8	0.6	-2.1	1.2

CS-P.38



DESIGN LEVEL	2.4	2.3	2.1	-1.5	-3.9
EG LEVEL	2.4	2.3	2.1	-1.3	-2.9

CS-P.39

KEY MAP

SCALE 1:40000

LEGEND

EXISTING GROUND

DREDGING

0 5 10 15 20 25m

SCALE 1:500

PROJECT MASTERPLAN WELANG RIVER

DREDGING WELANG RIVER

CROSS SECTION

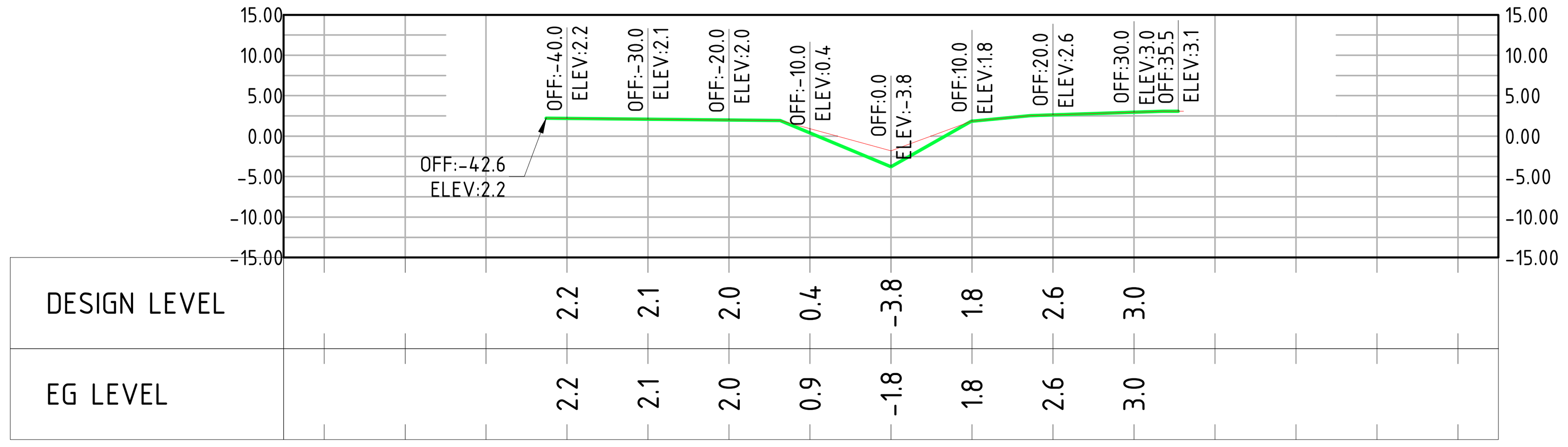
Witteveen + Bos

Park View Plaza 6th floor
Jl. Taman Kemang No. 27
Kemang - Jakarta Selatan 12730 Phone: +62 21 719 1282
P.O. Box 1687 JKS 12016, Indonesia Telefax: +62 21 719 1283

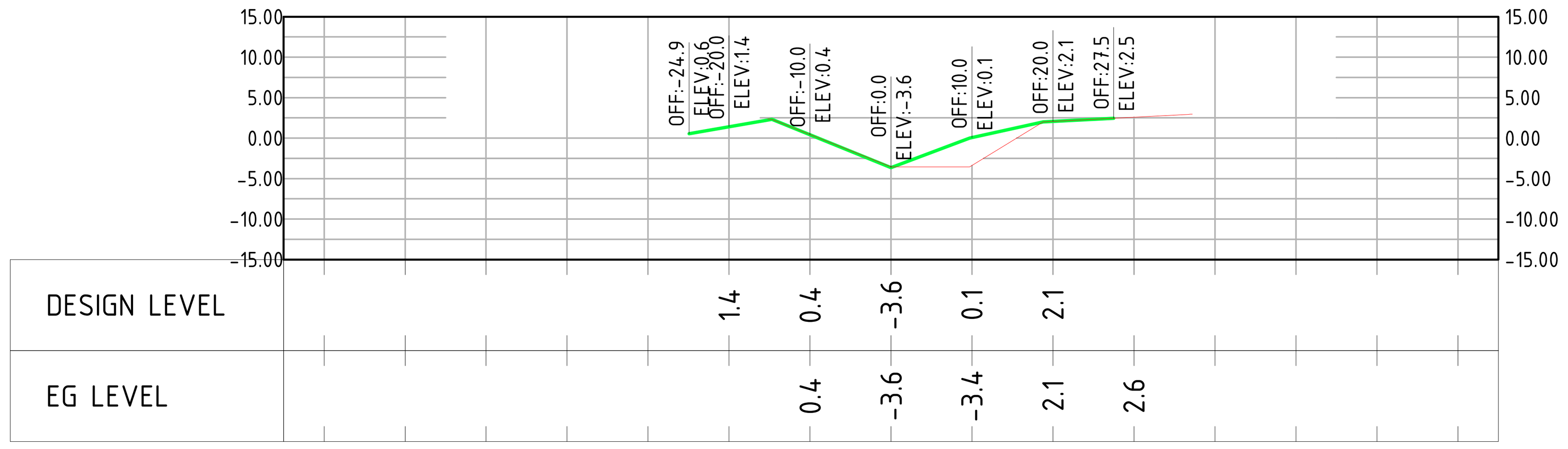
Drawn	Aland hasbi
Checked	Weny Sihombing
Authorized	
Date	
Scale	1:750
	122683.1104
Size	A1

Revisions: G, F, E, D, C, B, A

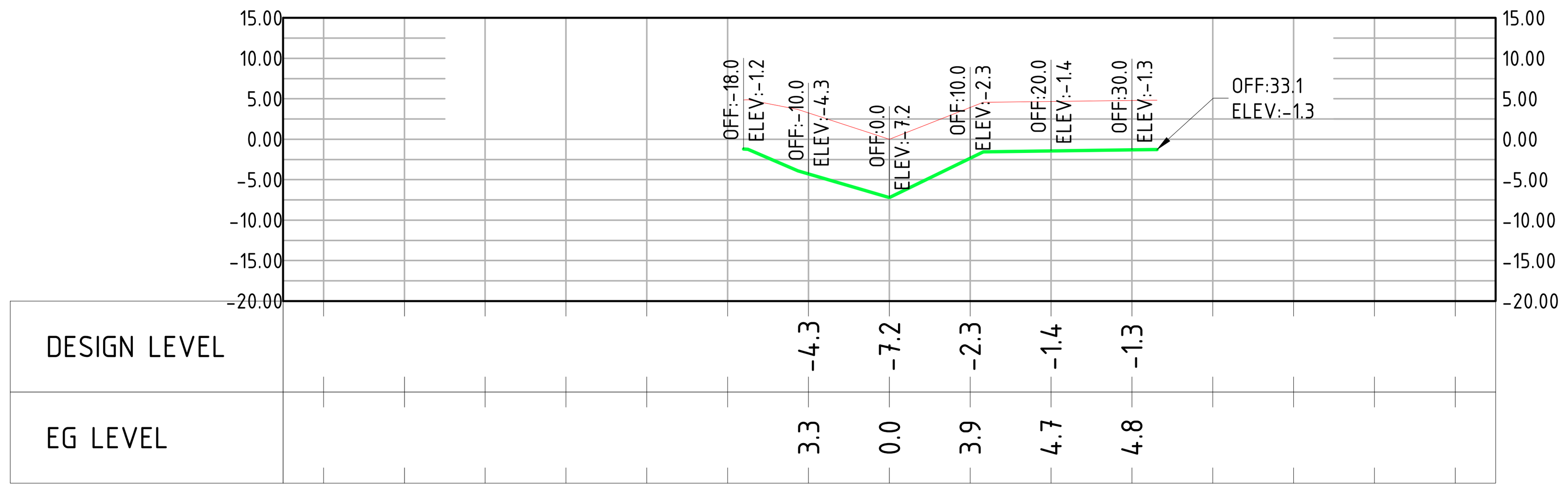
Plot date: 9 Desember 2021



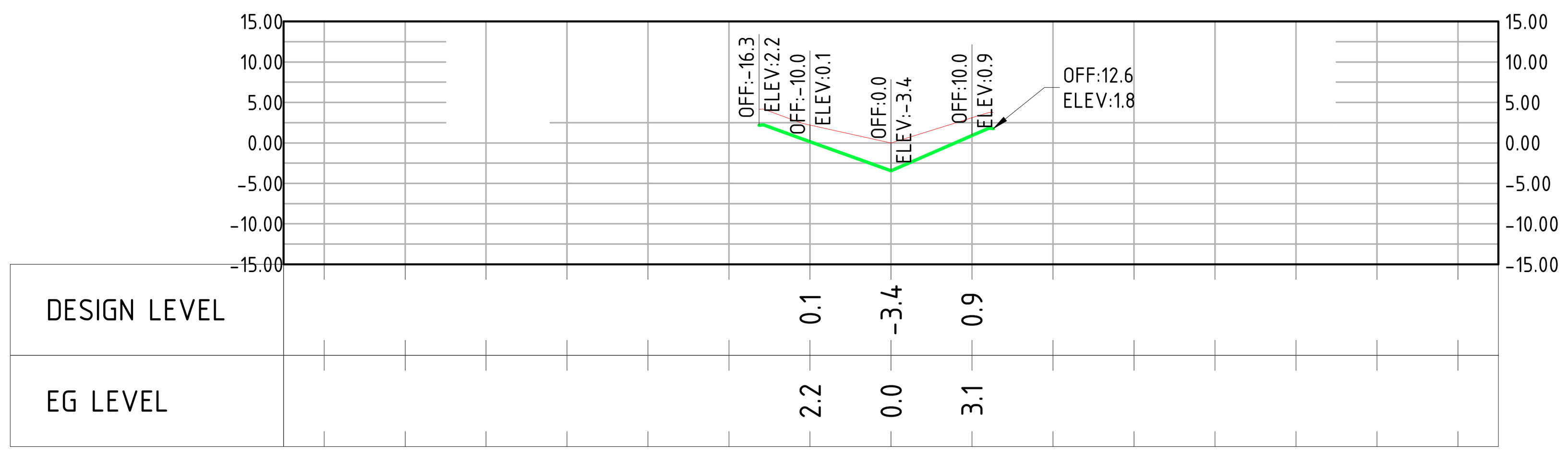
CS-P.40



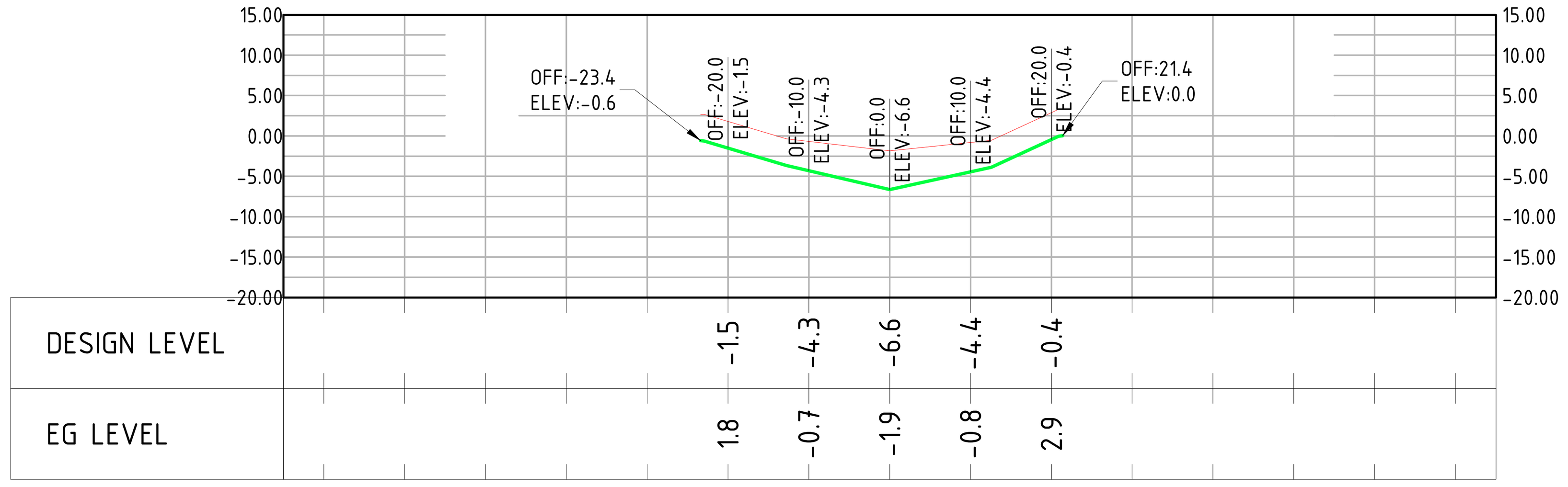
CS-P.41



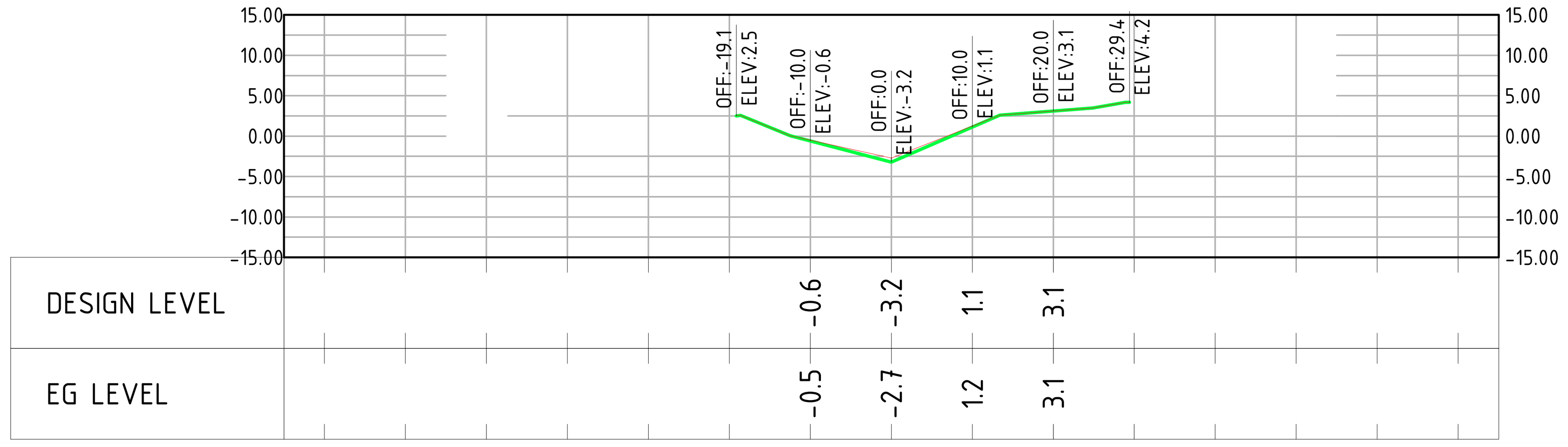
CS-P.42



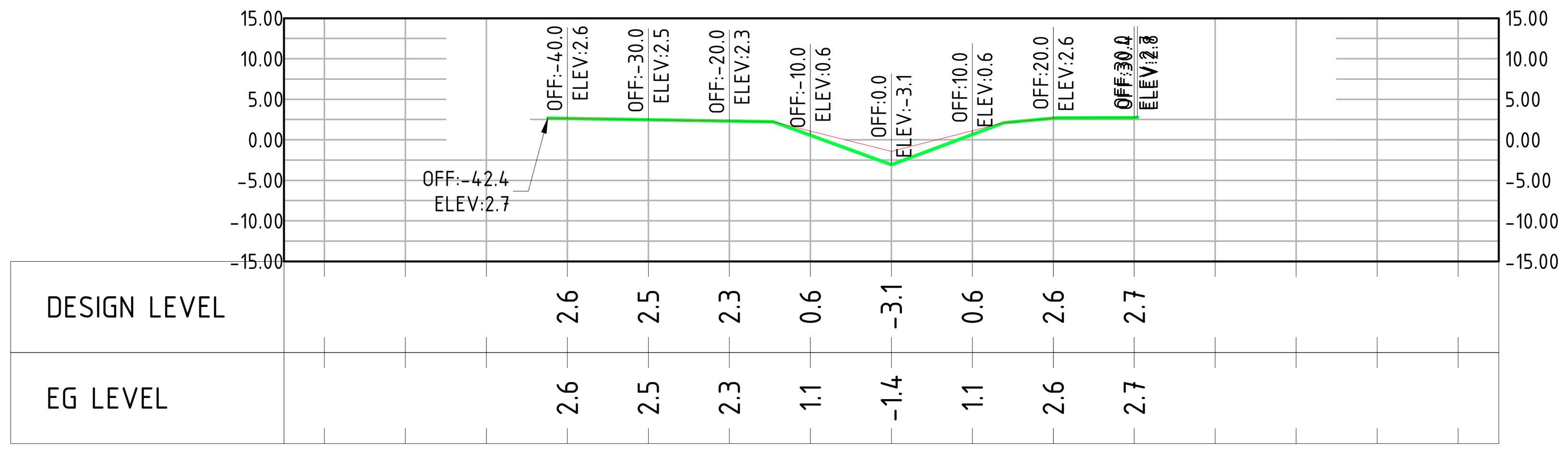
CS-P.43



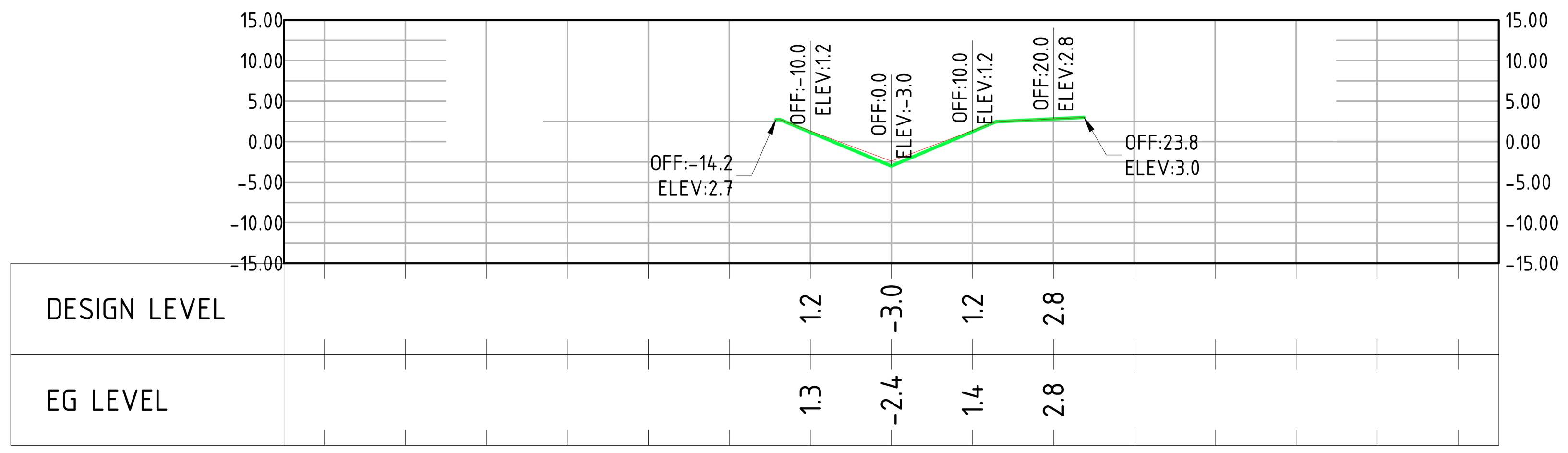
CS-P.44



CS-P.45



CS-P.46



CS-P.47

KEY MAP
SCALE 1:40000

LEGEND

EXISTING GROUND
DREDGING

0 5 10 15 20 25m
SCALE 1:500

PROJECT MASTERPLAN WELANG RIVER

DREDGING WELANG RIVER
CROSS SECTION

Drawn	Aland hasbi
Checked	Weny Sihombing
Authorized	
Date	
Scale	1:750
	122683.1105
Size	A1

Witteveen + Bos
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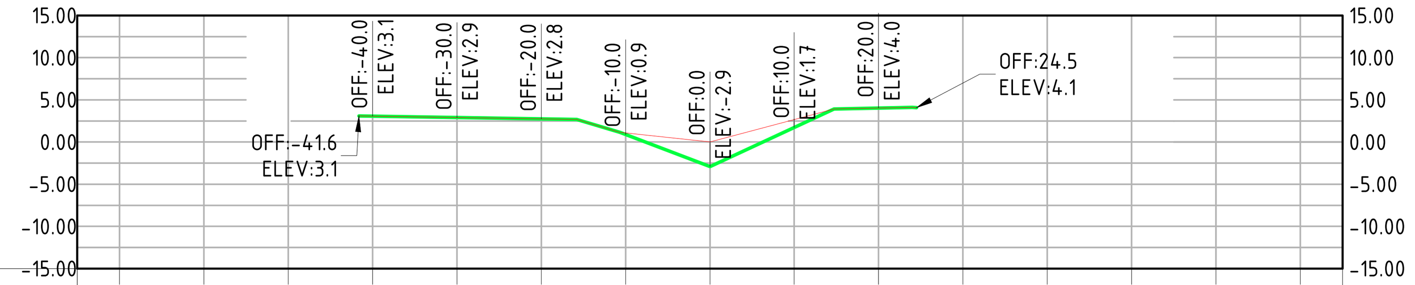
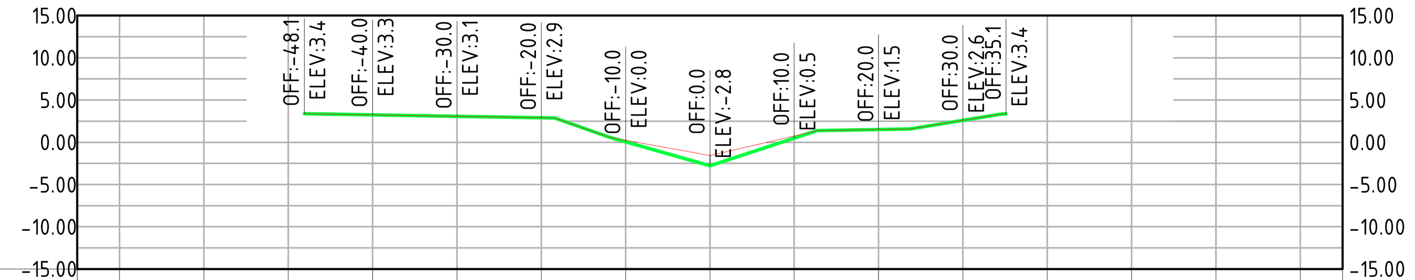
P.O. Box 1687 JKS 12016, Indonesia Telefax: +62 21 719 1283

Plot date: 9 Desember 2021



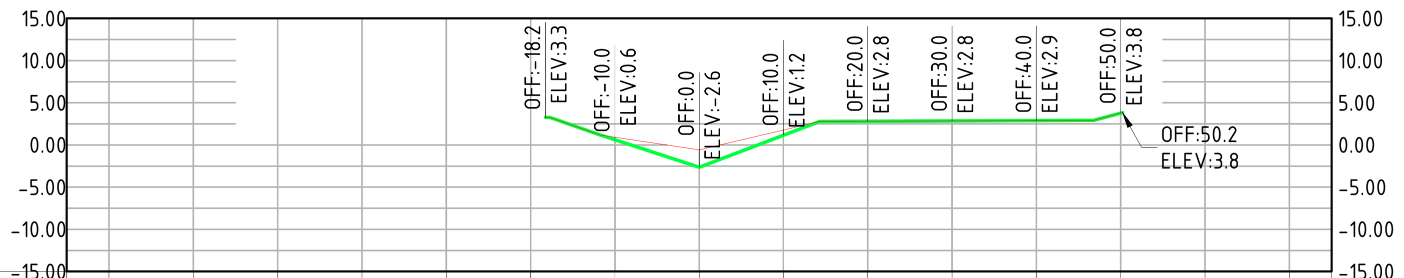
DESIGN LEVEL	3.1	2.9	2.8	0.9	-2.9	1.7	4.0
EG LEVEL	3.1	2.9	2.8	1.1	0.0	2.7	4.0

CS-P.48



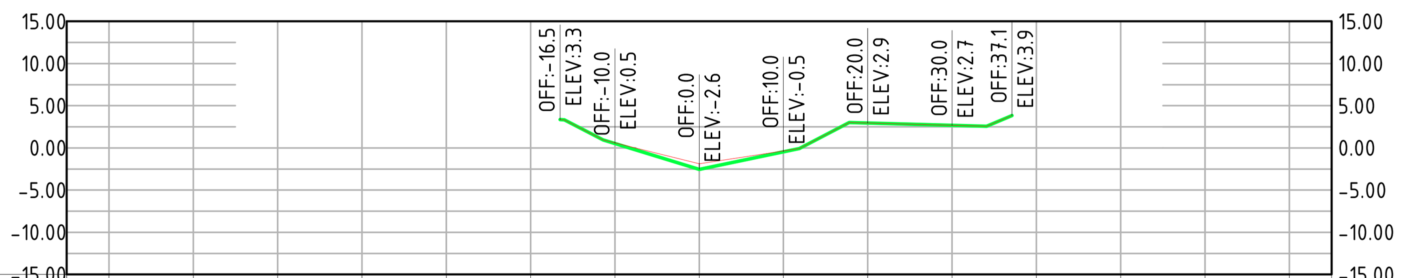
DESIGN LEVEL	3.3	3.1	2.9	0.0	-2.8	0.5	1.5	2.6
EG LEVEL	3.3	3.1	2.9	0.2	-1.6	0.8	1.5	2.6

CS-P.49



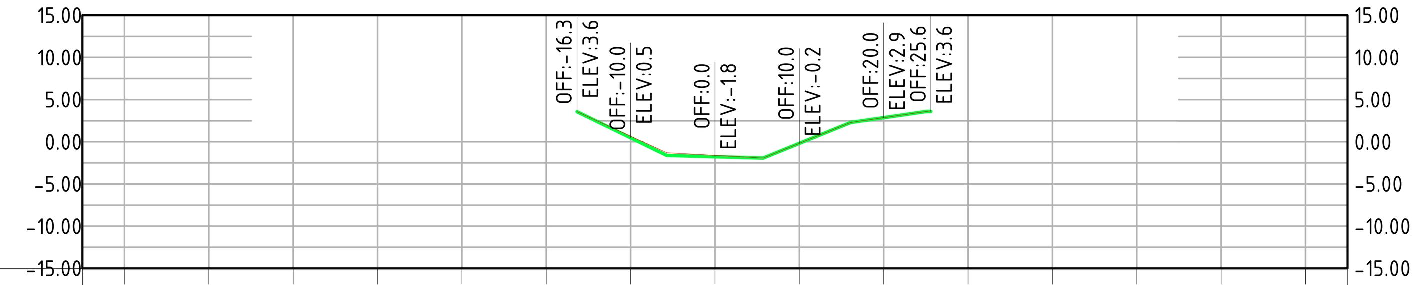
DESIGN LEVEL	0.6	-2.6	1.2	2.8	2.8	2.9	3.8
EG LEVEL	0.9	-0.6	1.8	2.8	2.8	2.9	3.8

CS-P.50



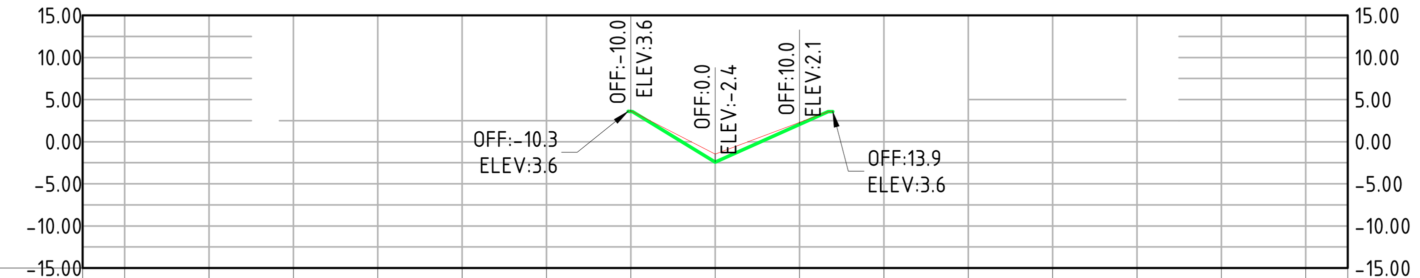
DESIGN LEVEL	0.5	-2.6	-0.5	2.9	2.7
EG LEVEL	0.6	-1.9	-0.3	2.9	2.7

CS-P.51



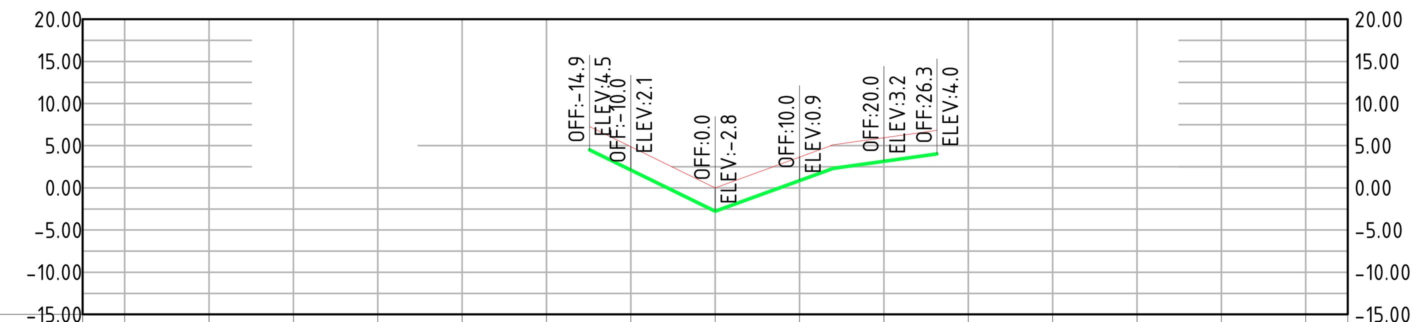
DESIGN LEVEL	0.5	-1.8	-0.2	2.9
EG LEVEL	0.7	-1.6	-0.2	2.9

CS-P.52A



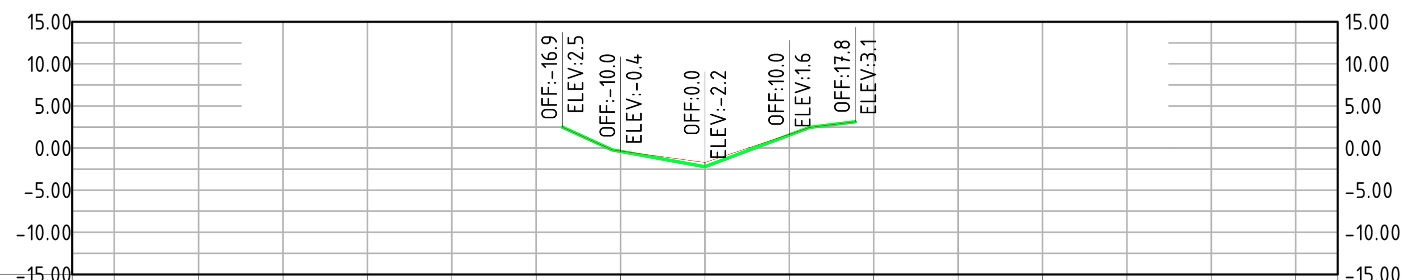
DESIGN LEVEL	3.6	-2.4	2.1
EG LEVEL	3.6	-1.5	2.3

CS-P.52



DESIGN LEVEL	2.1	-2.8	0.9	3.2
EG LEVEL	4.9	0.0	3.6	5.9

CS-P.53



DESIGN LEVEL	-0.4	-2.2	1.6
EG LEVEL	-0.4	-1.7	1.6

CS-P.54

KEY MAP
SCALE 1:40000

LEGEND

EXISTING GROUND
DREDGING

0 5 10 15 20 25m
SCALE 1:500

PROJECT MASTERPLAN WELANG RIVER

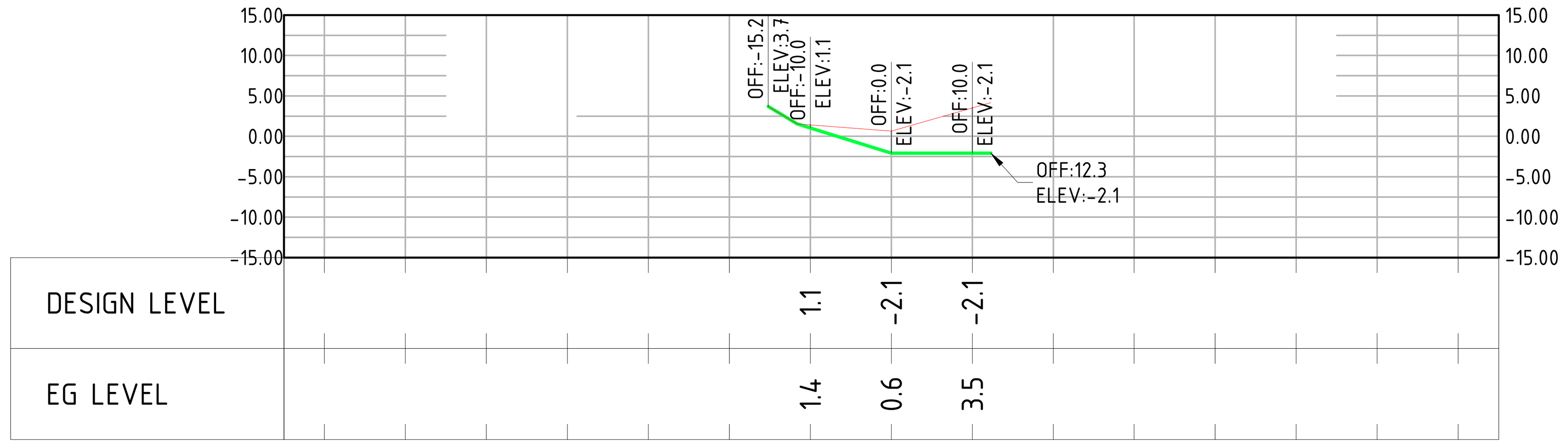
DREDGING WELANG RIVER
CROSS SECTION

Witteveen+Bos
Park View Plaza 6th floor
Jl. Taman Kemang No. 27
Kemang - Jakarta Selatan 12730 Phone: +62 21 719 1282
P.O. Box 1687 JKS 12016, Indonesia Telefax: +62 21 719 1283

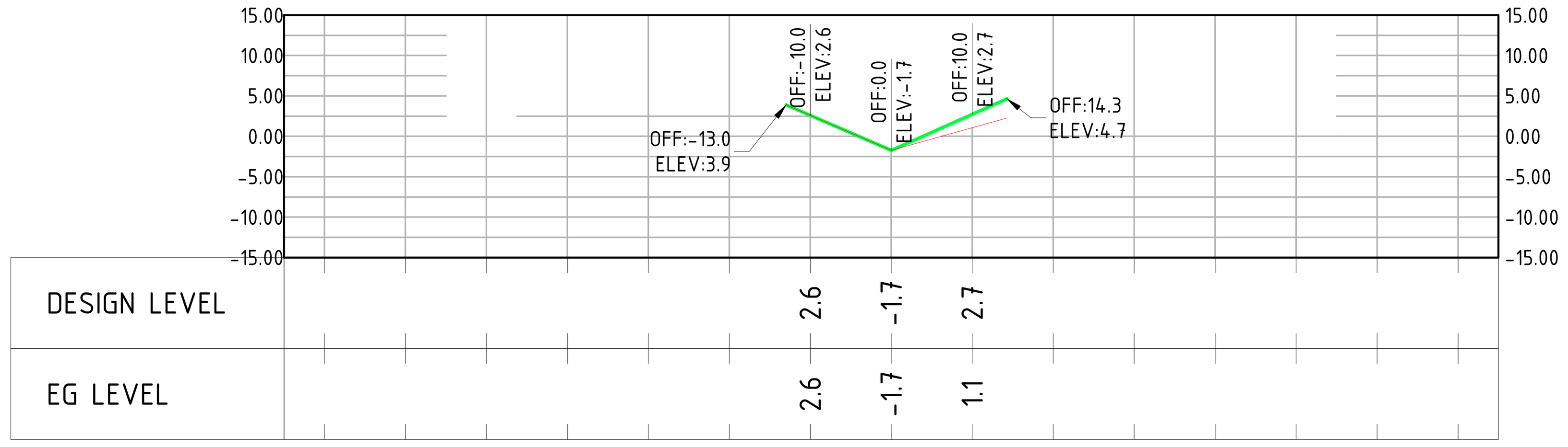
Drawn	Aland hasbi	Scale	1:750
Checked	Weny Sihombing		122683.1106
Authorized			
Date		Size	A1

Revisions: G F E D C B A

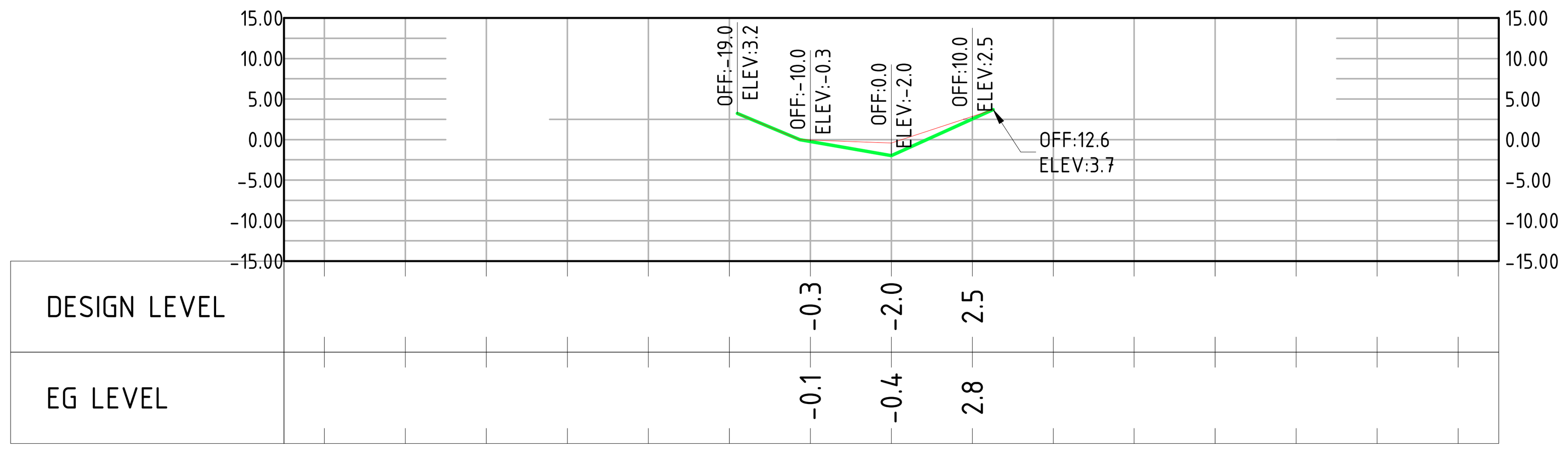
Plot date: 9 Desember 2021



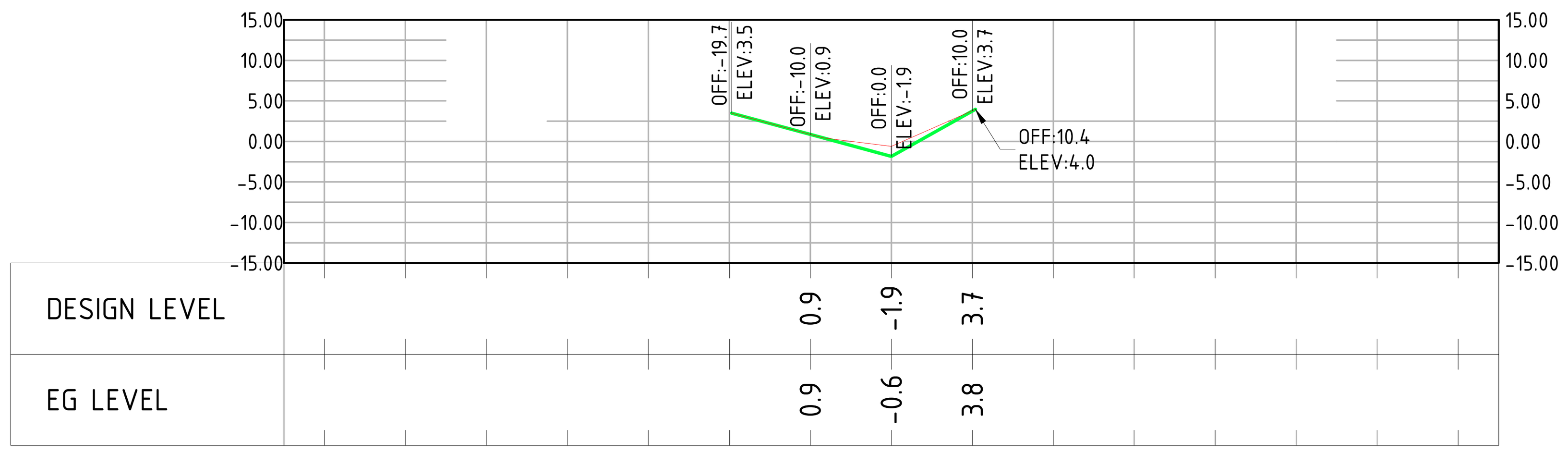
CS-P.55



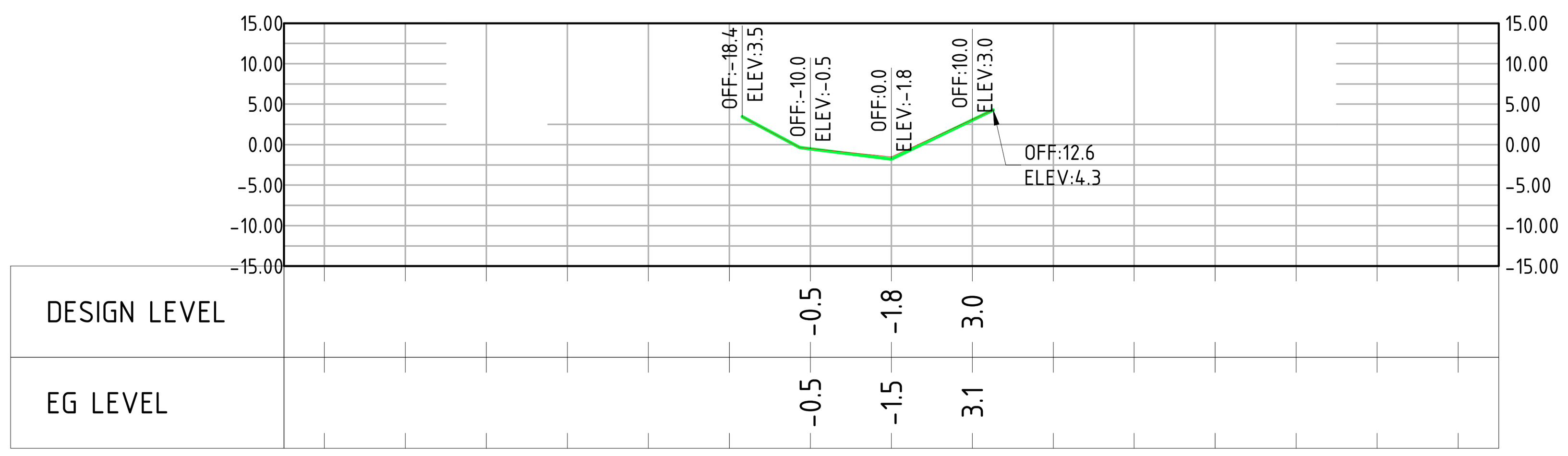
CS-P.59A



CS-P.56



CS-P.57



CS-P.58

KEY MAP
SCALE 1:40000

LEGEND

EXISTING GROUND
DREDGING

0 5 10 15 20 25m
SCALE 1:500

PROJECT MASTERPLAN WELANG RIVER

DREDGING WELANG RIVER
CROSS SECTION

Witteveen+Bos
Park View Plaza 6th floor
Jl. Taman Kemang No. 27
Kemang - Jakarta Selatan 12730 Phone: +62 21 719 1282
P.O. Box 1687 JKS 12016, Indonesia Telefax: +62 21 719 1283

Drawn	Aland hasbi	Scale	1:750
Checked	Weny Sihombing		122683.1107
Authorized			
Date		Size	A1

G F E D C B A Revisions

Plot date: 9 Desember 2021

NodeID	Zmin [m]	Area differences [m2]	Distance from the southernmost point [m]	Distance between nodes [m]	Volume dredged [m3]
P_P.59A	-1.7	0.0	34,690.46	40.34	-
P_P.58	-1.8	2.9	34,730.80	79.98	231.99
P_P.57	-1.9	10.9	34,810.78	112.51	1,222.41
P_P.56	-2.0	16.7	34,923.29	79.53	1,330.07
P_P.55	-2.1	27.3	35,002.82	109.20	2,979.48
P_P.54	-2.2	3.9	35,112.02	114.42	447.57
P_P.53	-2.8	0.0	35,226.44	88.54	-
P_P.52	-2.4	7.8	35,314.98	36.18	283.25
P_P.52A	-2.5	3.0	35,351.16	74.21	220.23
P_P.51	-2.6	8.0	35,425.37	80.95	650.69
P_P.50	-2.6	23.1	35,506.32	107.81	2,492.64
P_P.49	-2.8	13.4	35,614.13	129.67	1,740.96
P_P.48	-2.9	31.2	35,743.80	70.46	2,197.87
P_P.47	-3.0	5.8	35,814.26	81.20	471.62
P_P.46	-3.1	16.2	35,895.46	101.77	1,646.68
P_P.45	-3.2	6.0	35,997.23	99.11	599.30
P_P.44	-3.3	18.6	36,096.34	105.19	1,956.17
P_P.43	-3.4	16.2	36,201.53	140.31	2,269.70
P_P.42	-3.6	11.8	36,341.84	40.40	476.49
P_P.41	-3.6	0.8	36,382.24	130.15	101.16
P_P.40	-3.8	17.6	36,512.39	119.91	2,113.04
P_P.39	-3.9	8.6	36,632.30	103.47	892.53
P_P.38	-4.0	13.8	36,735.77	98.77	1,360.00
P_P.37	-4.2	0.0	36,834.54	97.95	-
P_P.36	-4.2	4.9	36,932.49	65.96	324.28
P_P.35	-4.2	11.7	36,998.45	146.48	1,720.96
P_P.34	-4.2	12.7	37,144.93	101.09	1,286.08
P_P.33	-4.2	13.4	37,246.02	100.21	1,346.85
P_P.32	-4.2	10.7	37,346.23	115.50	1,237.74
P_P.31	-4.6	0.0	37,461.73	87.65	-
P_P.30	-4.2	16.7	37,549.38	91.62	1,528.25
P_P.29	-4.2	33.3	37,641.00	119.24	3,967.83
P_P.28	-4.2	15.3	37,760.24	104.63	1,604.94
P_P.27	-4.2	3.7	37,864.87	93.09	345.55
P_P.26	-4.2	25.9	37,957.96	94.83	2,453.56
P_P.25	-4.2	3.1	38,052.79	106.08	328.73
P_P.24	-4.2	2.2	38,158.87	81.48	177.46
P_P.23	-4.2	10.2	38,240.35	110.76	1,124.49
P_P.22	-4.2	25.3	38,351.11	96.25	2,436.78
P_P.21	-4.2	22.5	38,447.36	102.73	2,311.50
P_P.20	-4.2	15.7	38,550.09	106.89	1,677.71
P_P.19	-4.2	20.2	38,656.98	106.22	2,140.89
P_P.18	-4.2	13.7	38,763.20	80.18	1,095.42
P_P.17	-4.4	0.0	38,843.38	122.49	-
P_P.16	-4.2	14.3	38,965.87	87.47	1,249.78
P_P.15	-4.2	18.4	39,053.34	91.06	1,676.69
P_P.14	-4.2	14.3	39,144.40	101.37	1,453.43
P_P.13	-4.2	21.2	39,245.77	97.37	2,067.38
P_P.12	-4.2	13.7	39,343.14	107.51	1,474.99
P_P.11	-4.2	7.2	39,450.65	99.95	716.44
P_P.10	-4.2	7.6	39,550.60	96.30	735.58
P_P.9	-4.2	12.3	39,646.90	100.93	1,237.73
P_P.8	-4.2	22.6	39,747.83	94.61	2,134.17
P_P.7	-4.2	18.3	39,842.44	100.33	1,832.05
P_P.6	-4.2	26.3	39,942.77	115.81	3,044.95
P_P.5	-4.2	12.2	40,058.58	91.02	1,107.31
P_P.4	-4.2	14.0	40,149.60	100.95	1,409.66
P_P.3	-4.2	11.6	40,250.55	107.30	1,243.04
P_P,2	-4.2	18.6	40,357.85	98.60	1,829.38
P_P.1	-4.2	26.2	40,456.45	92.22	2,411.72
P_P.0	-4.2	39.6	40,591.93	43.25	1,712.82
				Total volume dredged [m3]	80,130.00

PROJECT MASTERPLAN WELANG RIVER

DREDGING WELANG RIVER
VOLUME DREDGED

G
F
E
D
C
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A
Revisions

Witteveen + Bos
Park View Plaza 6th floor
Jl. Taman Kemang No. 27
Kemang - Jakarta Selatan 12730 Phone: +62 21 719 1282
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Drawn	Aland hasbi	Scale	N.T.S
Checked	Weny Sihombing		122683.1108
Authorized			
Date		Size	A1

CAD DRW: P:\1238\123845\WIP\Models\08) Civil 3D\01) Data\New folder\NEW ls-Cross section Dredging Welang-Model.dwg

Plot date: 9 Desember 2021

KEY MAP
SCALE 1:40000

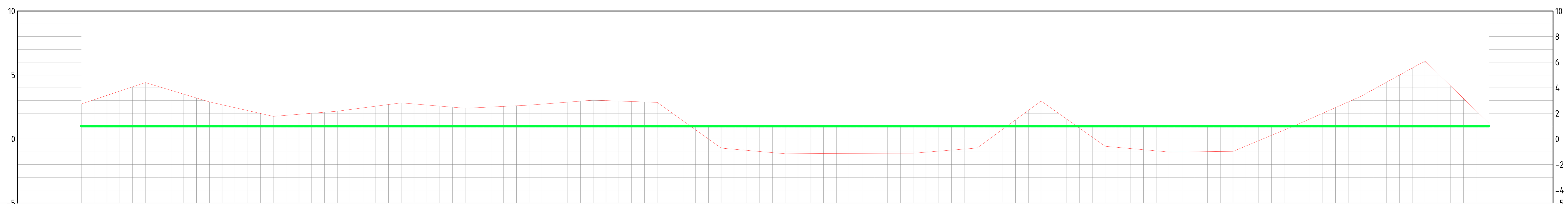
LEGEND

- CENTER LINE
- CONTOUR MAJOR
- CONTOUR MINOR
- DREDGING SIDE
- GRADING CUT
- PRODILE DREDGING
- PROFILE TOPO EG
- RESERVED AREA 10 M FROM BY PASS SIDE

NOTES

AREA NAME	AREA (M^2)
BY PASS	55000
RESERVED AREA LEFT	11000
RESERVED AREA RIGHT	11000

CL-BY PASS PROFILE



CHAINAGE	-0+050.00	0+050.00	0+100.00	0+150.00	0+200.00	0+250.00	0+300.00	0+350.00	0+400.00	0+450.00	0+500.00	0+550.00
DESIGN ELEVATION		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
EXISTING ELEVATION		4.40	2.90	1.76	2.17	2.82	2.40	2.65	3.03	2.85	-0.71	-1.15

CHAINAGE	0+600.00	0+650.00	0+700.00	0+750.00	0+800.00	0+850.00	0+900.00	0+950.00	1+000.00	1+050.00	1+100.00	1+150.00
DESIGN ELEVATION	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		
EXISTING ELEVATION	-1.13	-1.11	-0.71	2.97	-0.57	-1.02	-0.97	1.12	3.34	6.10		

0 20 40 60 80 100m
SCALE 1:2000

PROJECT MASTERPLAN WELANG RIVER

BY PASS WELANG RIVER
LAYOUT AND CENTER LINE LONG SECTION

G
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Revisions

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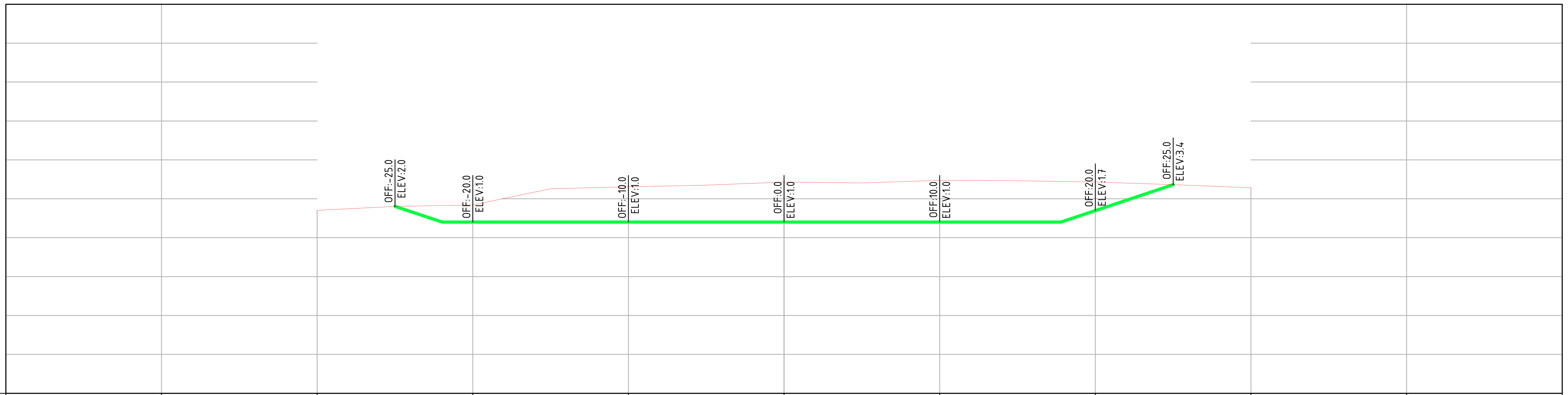
Drawn	Aland hasbi	Scale	1:2000
Checked	Wenny Sihombing		122683.1000
Authorized			
Date		Size	A1

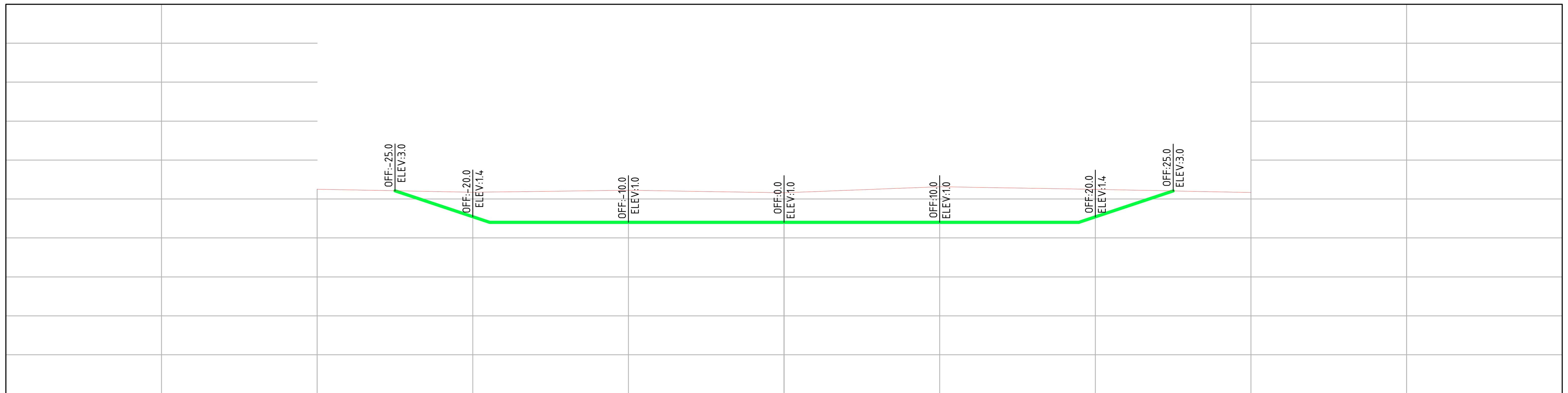
CAD DRW: P:\1238\123845\WIP\Models\08) Civil 3D\04) Alignment & Profile View\18112021 BY PASS WELANG.dwg

Plot date: 24 November 2021



DESIGN LEVEL			1.0	1.0	1.0	1.0	1.7		
EG LEVEL		1.8	2.1	3.3	3.6	3.7	3.6	3.2	
OFFSET	-40.0	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0

CS-0+025.00



DESIGN LEVEL			1.4	1.0	1.0	1.0	1.4		
EG LEVEL		3.1	2.9	3.1	2.9	3.3	3.1		
OFFSET	-40.0	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0

CS-0+100.00

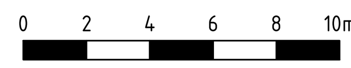
KEY MAP

SCALE 1:7000

LEGEND

EXISTING GROUND

DREDGING



SCALE 1:200

PROJECT MASTERPLAN WELANG RIVER

BY PASS WELANG RIVER

CROSS SECTION : CH 0+025 & CH 0+100

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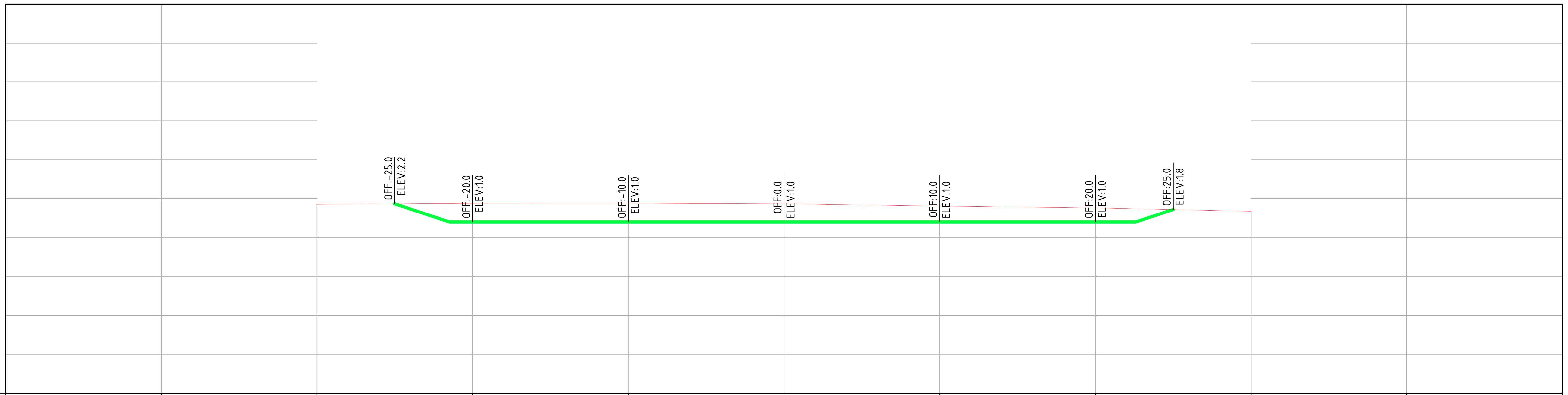
Revisions

Witteveen + Bos

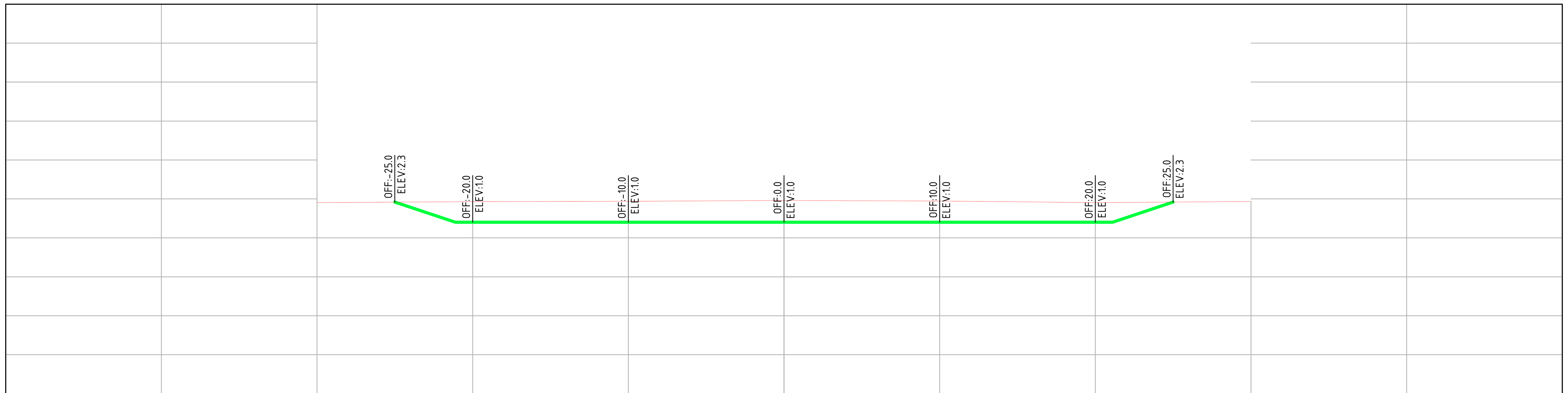
Park View Plaza 6th floor
Jl. Taman Kemang No. 27
Kemang - Jakarta Selatan 12730 Phone: +62 21 719 1282
P.O. Box 1687 JKS 12016, Indonesia Telefax: +62 21 719 1283

Drawn	Aland hasbi	Scale	1:200
Checked	Weny Sihombing		122683.1100
Authorized			
Date		Size	A1



DESIGN LEVEL			1.0	1.0	1.0	1.0	1.0		
EG LEVEL		2.1	2.2	2.2	2.2	2.0	1.9	1.7	
OFFSET	-40.0	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0

CS-0+200.00



DESIGN LEVEL			1.0	1.0	1.0	1.0	1.0		
EG LEVEL			2.3	2.3	2.4	2.4	2.3	2.3	
OFFSET	-40.0	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0

CS-0+300.00

KEY MAP
SCALE 1:7000

LEGEND

EXISTING GROUND
DREDGING

0 2 4 6 8 10m
SCALE 1:200

PROJECT MASTERPLAN WELANG RIVER

BY PASS WELANG RIVER
CROSS SECTION : CH 0+200 & CH 0+300

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Revisions

Witteveen + Bos

Park View Plaza 6th floor
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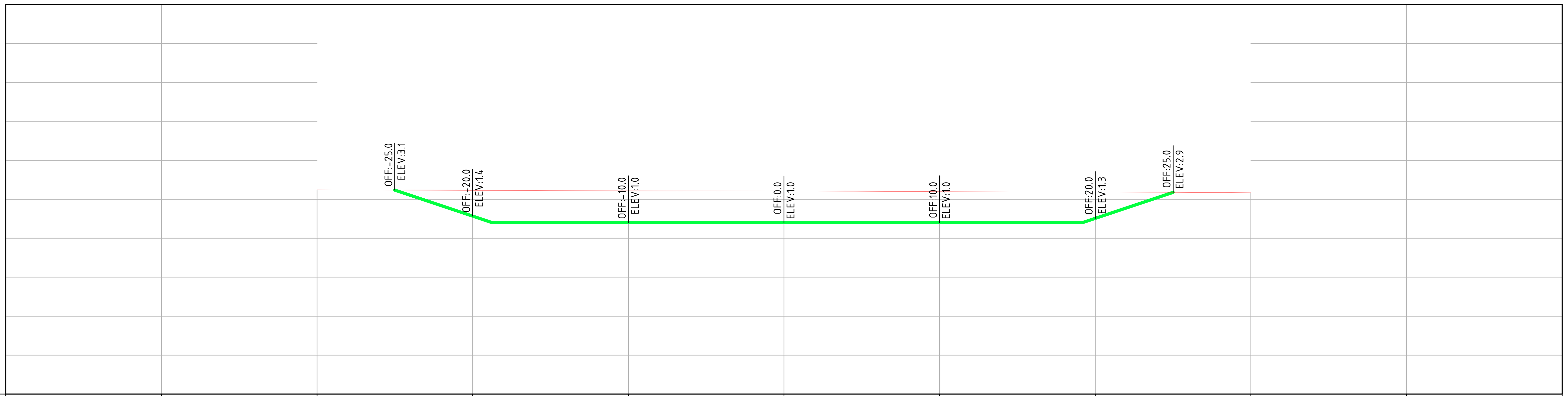
Kemang - Jakarta Selatan 12730 Phone: +62 21 719 1282
P.O. Box 1687 JKS 12016, Indonesia Telefax: +62 21 719 1283

Drawn	Aland hasbi	Scale	1:200
Checked	Weny Sihombing		122683.1101
Authorized			
Date		Size	A1

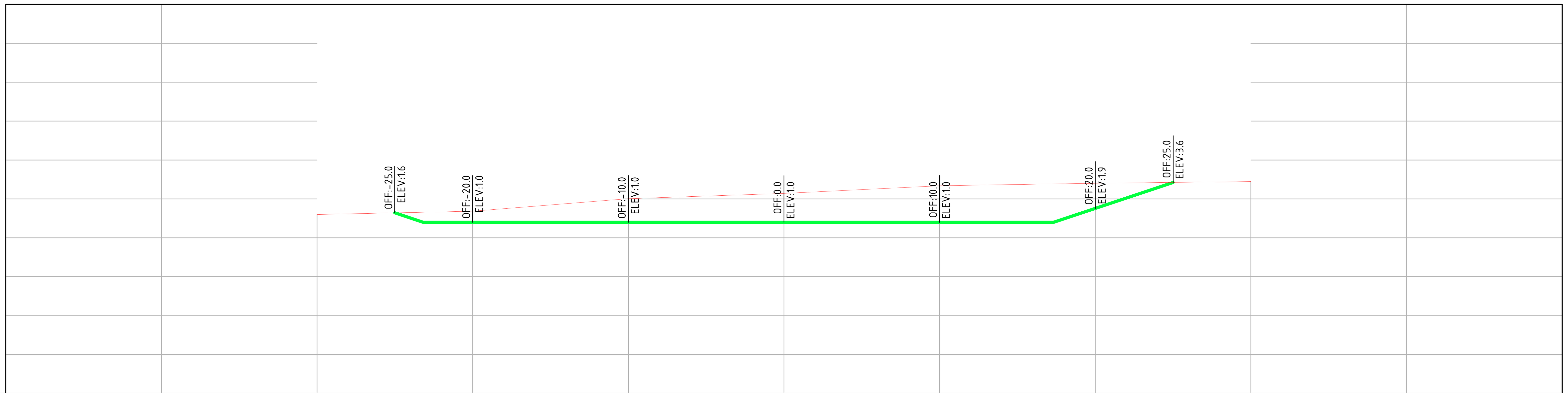
CAD DRW: P:\1238\123845\WIP\Models\08) Civil 3D\04) Alignment & Profile View\18112021 BY PASS WELANG.dwg

Plot date: 18 November 2021



DESIGN LEVEL			1.4	1.0	1.0	1.0	1.3		
EG LEVEL		3.1	3.1	3.0	3.0	3.0	3.0	2.9	
OFFSET	-40.0	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0

CS-0+400.00



DESIGN LEVEL			1.0	1.0	1.0	1.0	1.9		
EG LEVEL		1.5	1.7	2.5	2.9	3.3	3.5	3.6	
OFFSET	-40.0	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0

CS-0+450.00

KEY MAP
SCALE 1:7000

LEGEND

EXISTING GROUND
DREDGING

0 2 4 6 8 10m
SCALE 1:200

PROJECT MASTERPLAN WELANG RIVER

BY PASS WELANG RIVER
CROSS SECTION : CH 0+400 & CH 0+450

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Revisions

Witteveen + Bos

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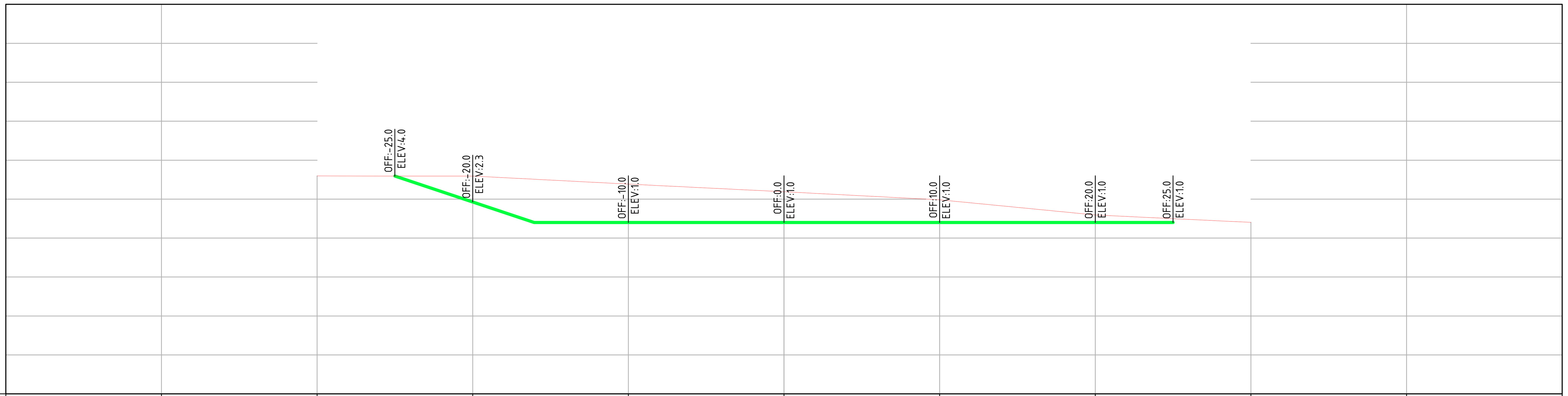
P.O. Box 1687 JKS 12016, Indonesia Telefax: +62 21 719 1283

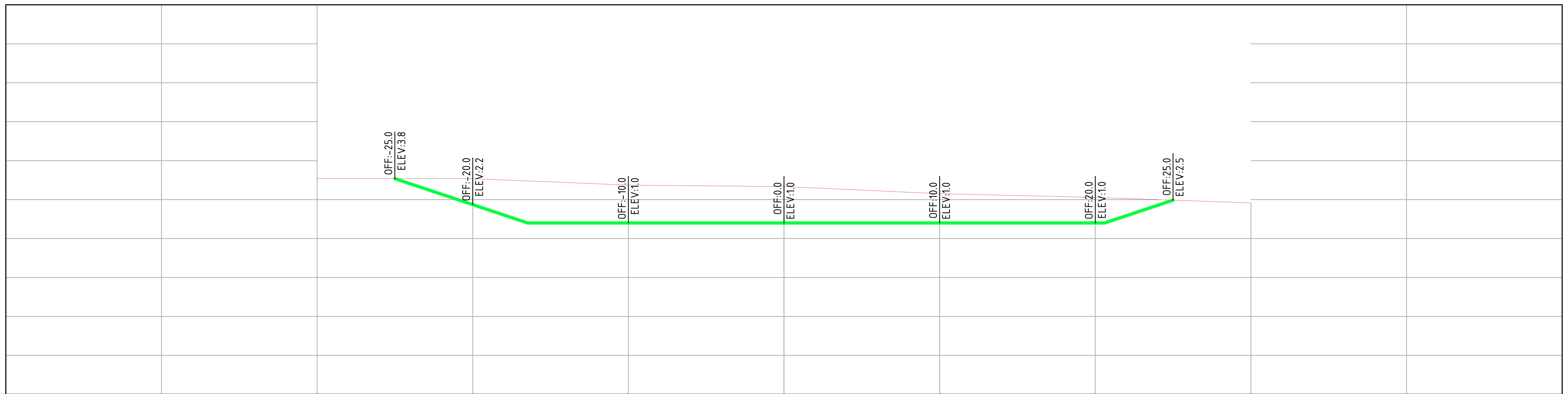
Drawn	Aland hasbi	Scale	1:200
Checked	Weny Sihombing		122683.1102
Authorized			
Date		Size	A1

Plot date: 18 November 2021



DESIGN LEVEL			2.3	1.0	1.0	1.0	1.0		
EG LEVEL		4.0	4.0	3.5	3.0	2.5	1.5	1.0	
OFFSET	-40.0	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0

CS-0+750.00



DESIGN LEVEL			2.2	1.0	1.0	1.0	1.0		
EG LEVEL			3.8	3.4	3.3	2.9	2.6	2.3	
OFFSET	-40.0	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0

CS-1+000.00

KEY MAP

SCALE 1:7000

LEGEND

EXISTING GROUND

DREDGING

0 2 4 6 8 10m

SCALE 1:200

PROJECT MASTERPLAN WELANG RIVER

BY PASS WELANG RIVER

CROSS SECTION : CH 0+750 & CH 1+000

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Revisions

Witteveen + Bos

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Drawn	Aland hasbi	Scale	1:200
Checked	Weny Sihombing		122683.1103
Authorized			
Date		Size	A1

Plot date: 18 November 2021

CAD DRW: P:\1238\123845\WIP\Models\08) Civil 3D\04) Alignment & Profile View\18112021 BY PASS WELANG.dwg

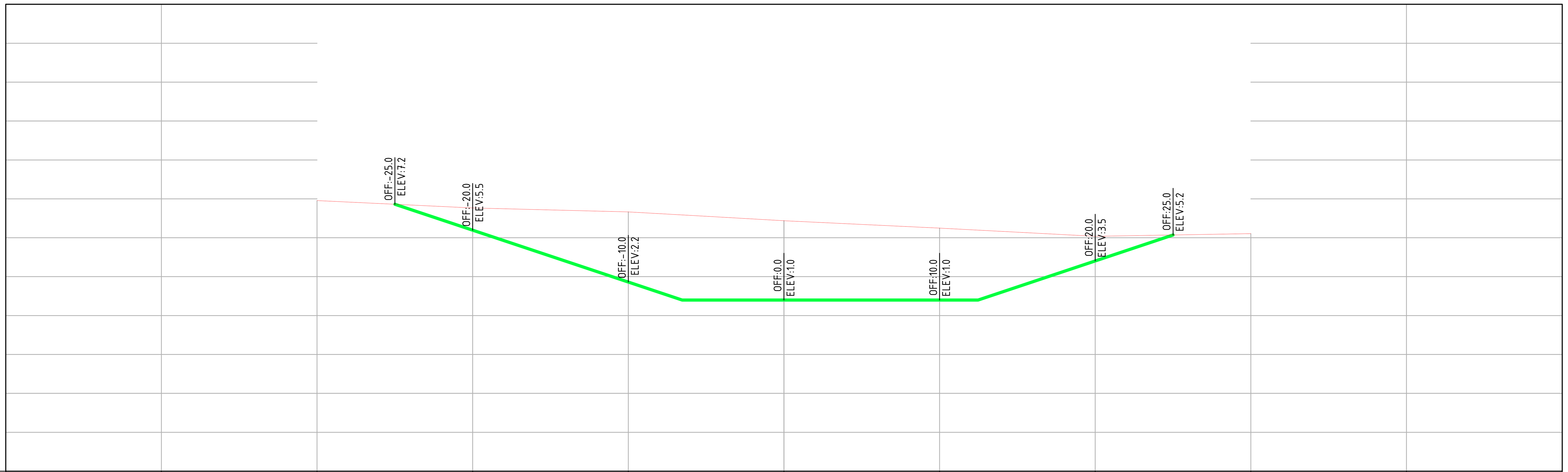
KEY MAP

SCALE 1:7000

LEGEND

EXISTING GROUND

DREDGING



DESIGN LEVEL			5.5	2.2	1.0	1.0	3.5		
EG LEVEL		7.4	6.9	6.7	6.1	5.6	5.1	5.3	
OFFSET	-40.0	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0

CS-1+050.00

0 2 4 6 8 10m

SCALE 1:200

PROJECT MASTERPLAN WELANG RIVER

BY PASS WELANG RIVER

CROSS SECTION : CH 1+050

Witteveen + Bos

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P.O. Box 1687 JKS 12016, Indonesia Telefax: +62 21 719 1283

Drawn	Aland hasbi	Scale	1:200
Checked	Weny Sihombing		122683.1104
Authorized			
Date		Size	A1

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Revisions

CAD DRW: P:\1238\123845\WIP\Models\08) Civil 3D\04) Alignment & Profile View\18112021 BY PASS WELANG.dwg

Plot date: 18 November 2021

Cut/Fill Report

Generated: 2021-11-18 14:30:29
By user: HASA2
Drawing: P:\1238\123845\WIP\Models\08) Civil 3D\04) Alignment & Profile View\P:\1238\123845\WIP\Models\08) Civil 3D\04) Alignment & Profile View\18112021 BY PASS WELANG.dwg

Volume Summary							
Name	**Type**	**Cut Factor**	**Fill Factor**	**2d Area** (sq.m)	**Cut** (Cu. M.)	**Fill** (Cu. M.)	**Net** (Cu. M.)
VOL-DREDGING	full	1.000	0.000	33212.99	52643.85	0.00*	52643.85*

Totals				
	2d Area (sq.m)	**Cut** (Cu. M.)	**Fill** (Cu. M.)	**Net** (Cu. M.)
Total	33212.99	52643.85	0.00*	52643.85*

* Value adjusted by cut or fill factor other than 1.0

III

APPENDIX: RE-USE OPTIONS (NETICS)

MEMO

Witteveen + Bos
t.a.v. Michel Zuijderwijk
Leeuwenbrug 8
7411 TJ Deventer
The Netherlands

Document ID	:	NP.2020.274.9.1
Pages	:	13
Written by	:	I. Boon
Approved by	:	E.A. Volbeda
Date	:	6 December 2021
Version	:	1.3 (DEF)
Project description	:	**SEDIMENT REUSE OPTIONS WELANG RIVER**

1. INTRODUCTION

Welang River is located in the East Java Province, Indonesia's second-most-populous province. The downstream part is prone to floods due to limited discharge capability. This is caused by significant erosion upstream (leading to sedimentation downstream), and sedimentation due to mineral aggregate mining for brick production[1]. Additionally, the river suffers from a decrease in water availability, and pollution. Compounding these factors result in the need to take action. Two measures are proposed for the downstream part of the Welang River: dredging the entire downstream river, and adding a bypass/high water channel. Both measures involve dredging / sediment removal. This imposes a challenge on finding a new destination for the dredged or excavated sediments, especially in a densely populated area. Conventionally, this material is considered to be waste. NETICS however has developed methods to convert these waste sediments into valuable construction material, allowing for 100% reuse, and was asked to consult on this project. This memo is a brief analysis of the matter. Two reuse options are considered: geotextile tubes and brick production. The aim of this memo is to investigate the reuse possibilities of sediment bricks and embankments made out of geotextile tubes filled with the dredged material. An estimation will be given for the amount of houses that can be built, and the total length of embankments that can be restored. This will be accompanied by information regarding the financial aspects of reusing dredged sediments from the downstream section of the Welang River.

Figure 1 Project location (satellite image Google)

[1] Europese aanbesteding volgens de openbare procedure voor het opstellen van een masterplan voor de Welang rivier in Indonesië, 18 August 2020, IUC 202005107

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2. PROJECT INFORMATION

The Welang River restoration project spans from point A to point B (Figure 2), a distance of 5,260 metres. A bypass between the river and sea is planned for location C.

Figure 2 Project details (satellite image Google)

The expected dredging volume is 80,000 m^3, excavation volume for the bypass is 52,500 m^3, resulting in a total volume of sediment to be removed of 132,500 m^3. A significant portion of this is concentrated at the southern part.

Cone penetration tests were performed along the river to gain insight into its stratigraphy (Figure 3). The upper layers are of importance for this project, since those are the ones that will be dredged/excavated. They mainly consist of silty clay.

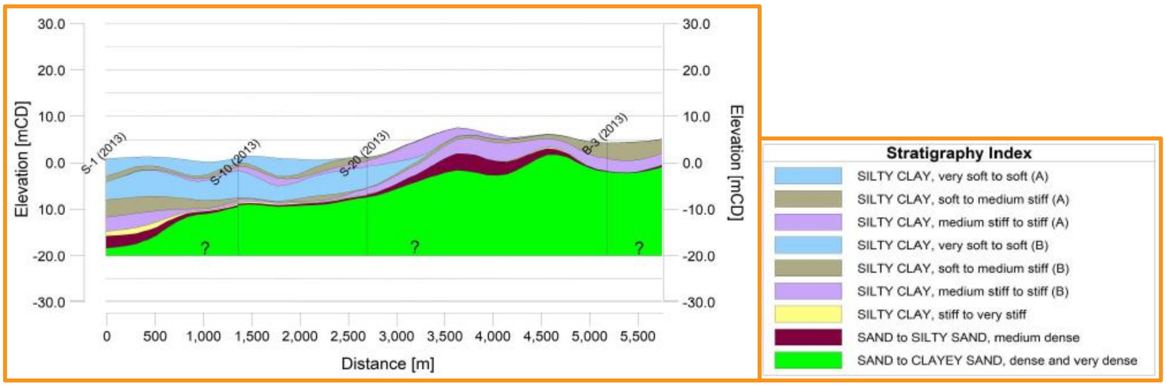

Figure 3 Welang River stratigraphy

This high percentage of fines correlates with a downstream section of a river. Using the description of 'silty clay' in conjunction with the USDA soil triangle (Figure 4) would indicate a distribution of about 45% clay – 45% silt – 5% sand.

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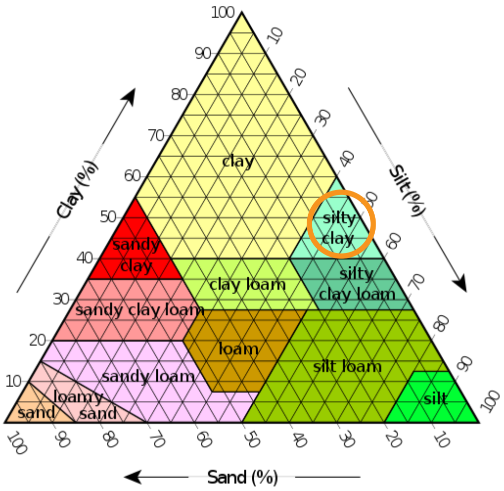

Figure 4 USDA Soil triangle

The intention for this project is to locally reuse the dredged sediment. The business case for such an application heavily depends on logistics. It is highly beneficial if the reuse options are close to the dredging location. This is especially the case for brick production. Right now this is done by locals in the flood plains (i.e. directly adjacent to the river).

Figure 5 Brick Making (source: W+B site visit 6/7 Sept)

Satellite images show that the downstream section of the river is sparsely populated, population density data corroborates this fact. The southern part of this river section is still adjacent to the nearby city of Pasuruan. This should minimise transport distance for the workers for the brick production, and for the bricks themselves.

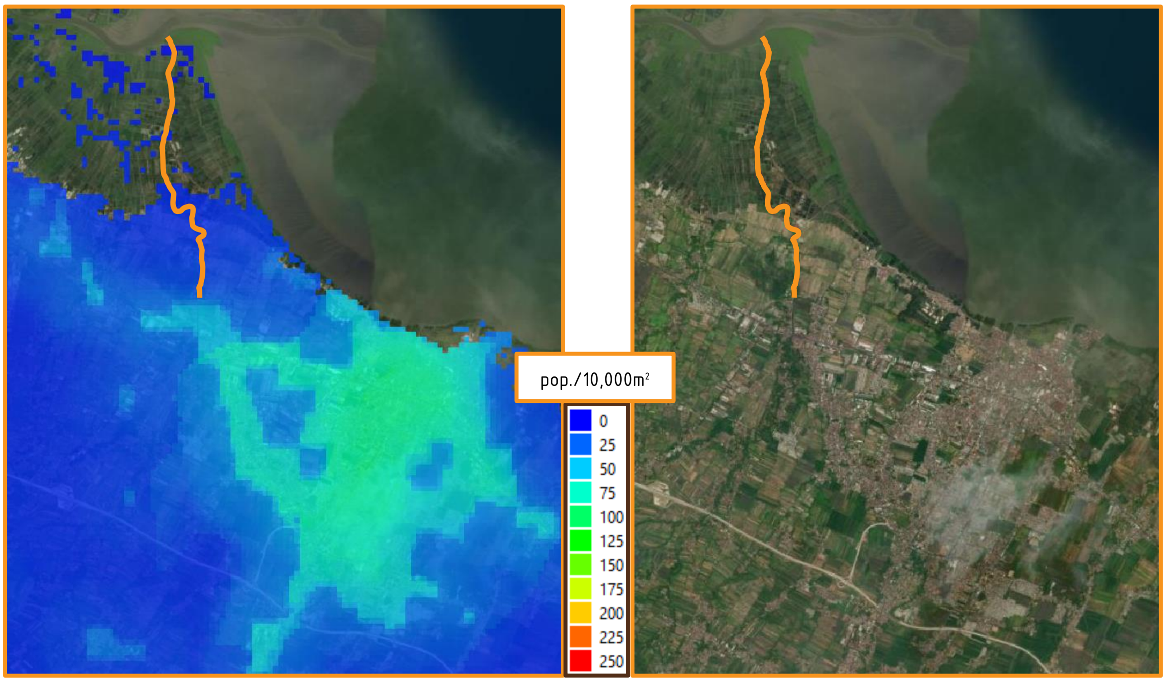

Figure 6 Population density 2015 (satellite image Bing, dataset UN)

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The geotextile tubes will be used to reinforce the embankments which will increase their safety and reduce erosion rate. Such projects are already being executed, for instance the revetment is being improved at Welang and Sumber Penang (Figure 7). Projects like these are ideal for geotextile tubes filled with dredged sediment. Such projects are expected to be more prevalent upstream of the project location, since that's where their impact will reach a greater amount of people, making it easier to reach enough support to get these projects underway.

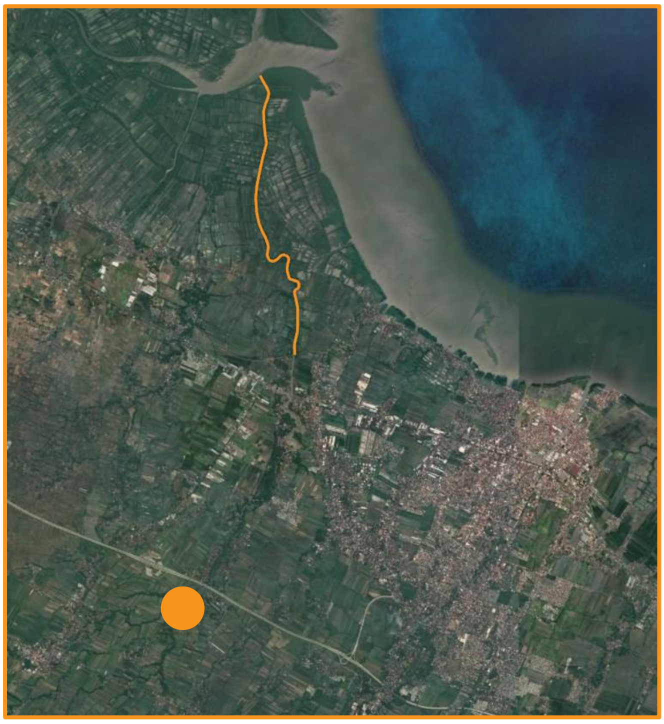

Figure 7 Location revetment Welang and Sumber Penang (satellite image Google)

3. BRICK PRODUCTION

Brick making from river sediment is common in the flood plains of Welang River. Often unregulated, it can lead to unwanted situations where mining takes place near embankments. Donating dredged sediment from the Welang River project can help mitigate this problem. Additionally, this prevents the need for the sediment to be transported to a disposal location, reducing cost.

A challenge with brick production from dredged sediment is to reduce the high water content. This is either done with a time (and land) investment through sun/air-drying, or by investing in machinery such as a belt press to speed up this process with a smaller land footprint. A belt press requires a significant investment, and is often used for large scale and long term industrial processes. It is therefore not deemed feasible to apply a belt press for this project. While a large portion of the project involves dredging sediment with a high water content, the creation of the bypass involves sediment/soil that is much drier in comparison. These works are also located closer towards populated areas. These factors, along with the fact that a more regulated brick production could reduce overall erosion/sedimentation, indicate a great opportunity for brick production.

The total volume to create the river bypass is 52,500 m^3. Assuming a standard brick size of 295 mm x 140 mm x 90 mm, with a total volume per brick is 0.003717 m^3, would result in about 14 million bricks. Assuming that on average a single two-storey house requires 10,000 bricks, **block making with the bypass sediment can provide enough construction material for 1400 homes**.

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Not only can the bricks be used to construct houses, other potential applications include (but are not limited to) revetments and retaining walls. A compressed and stabilised brick is able to withstand significant currents without showing signs of erosions, and is therefore perfectly suited for use in revetments (Figure 8).

Figure 8 Revetment from compressed stabilised sediment under construction

The one drawback, however, is that the density and compressive strength of these bricks is lower compared to conventional rock armour revetments. The rock for this material must have a minimum density of 2600 kg/m^3, and a compressive strength of at least 100 MPa. Bricks from compressed stabilised sediment tend to have a density of around 1800 kg/m^3, and a compressive strength of about 30 MPa. This does not rule out their applicability for revetments. It is just that their lower density must be accounted for when performing the necessary hydraulic engineering computations. Assuming a configuration where the area of 295 mm x 90 mm is in contact with the water interface, there will be roughly 38 bricks in 1 m^2 of revetment. Reusing all 14 million bricks for this application would result in **368,421 m^2** of revetment.

Using compressed stabilised sediment for a retaining wall is slightly more challenging. If the material is used in an actual load bearing type way, then the retaining wall must be constructed in the form of a gravity wall. The individual bricks have no means of withstanding tensile forces, so they must all be connected to form one cohesive mass. This method is not feasible compared to other methods. Bricks can still be used in retaining walls, but in the form of a facing for a reinforced soil retaining wall (. Soil on its own is also unable to withstand significant tensile forces, but reinforced soil with layered geogrids is able to do this. To prevent soil from eroding a facing is applied (which can also serve an aesthetic purpose). Using the bricks in the same orientation as for the revetment would mean that **368,421 m^2** of facing for reinforced soil can be constructed with compressed stabilised sediment bricks.

Figure 9 Reinforced soil retaining wall with brick facing (Belgard Commercial)

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To ensure that the blocks have a sufficient strength to allow construction of a durable, long-lasting house, they are often compressed using machinery. For a project this size there are two options: a hand press ($1,500.00) capable of producing 30 blocks/hour and is operated by 2 people, or a mobile production plant ($150,000.00) capable of producing 360 blocks/hour and is operated by 10 people. For reference, a typical brick production plant in Indonesia has an output of 700-1400 bricks per day[2].

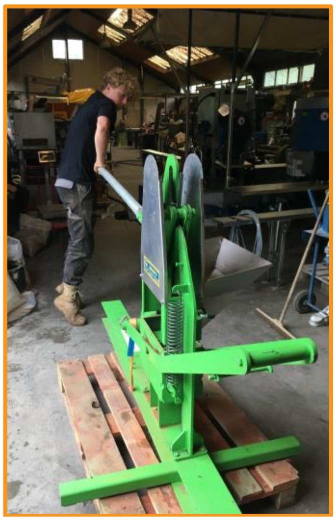

Figure 10 Hand press (l) and mobile unit (r) (Oskam V/F)

While the hand press (when operating in a larger array) is capable of a reasonable output, it is not suitable to process the full 52,500 m³ in a rational amount of time. For now it is assumed that the full 52,500 m³ will be processed through mobile units.

The total amount of soil must still be processed in a reasonable amount of time, this means that it is expected that multiple mobile units are needed. With a weekly operation time of about 35 hours, 4 of these units are capable of converting the soil into strong blocks in less than 5.5 years (Figure 11). **The block making operation will create official jobs for 40 people!**

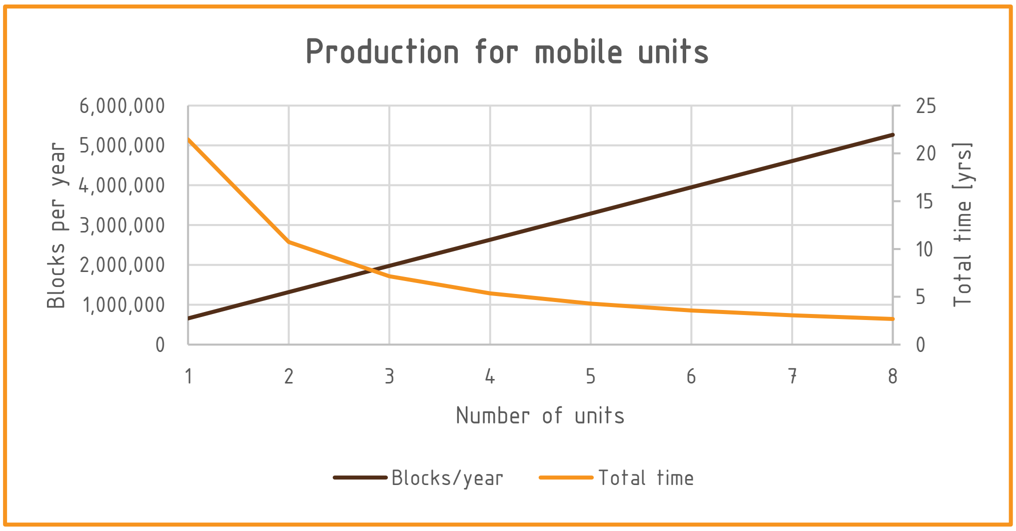

Figure 11 Annual production mobile units

[2] Nichols, J. The economics and methods of brick manufacture: a comparison of USA to SE Asian practices, 2009.

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These types of units are mobile, allowing them to easily be transported to locations close to where the soil is being excavated. This eliminates expensive transportation costs of the soil. With 4 mobile units, the costs added per brick to acquire these machines is $0.042 (assuming these machines are written off in their entirety on this project).

Not only are the blocks compressed to yield a high strength, they are also stabilised with a binder. Depending on the sediment characteristics the most optimal (combination of) binder(s) can be selected with the NETICS recipe model. For the Welang river the sediment at the bottom of the river contains a large percentage of fines. Whereas the soil excavated for the bypass contains a more diverse material with different sediment sizes, thus better for block production. The sediment characteristics are determined based on the stratigraphy shown in Figure 3, where it is shown that the silty clay layers are present due to sedimentation, and that the sandy layers are the original bed. In general, 7%-10% of binder could be used (percentage by weight). Assuming a density of 1,700 kg/m^3, this would require 170 kg of binder per m^3 of soil. A combination of binders such as lime ($170.00/tonne) or cement ($80.00/tonne) could be used. If all of the soil gets stabilised, the binders would add a cost per brick of $0.050.

The use of cement or lime are not the only methods to stabilise soils to create compressed stabilised earth bricks. There are sometimes more affordable binders available when they are sourced locally, cutting transportation costs. These can also be from waste streams, cutting cost even more. An abundant waste stream available in Indonesia is rice husk ash. When rice husks are incinerated at certain temperatures the organic compounds are eliminated while the silica maintains amorphous (instead of crystallised at higher temperatures). It requires lime to be activated, but then it also helps to enhance the effect of lime. When combined with certain soils, this combination of binders will increase their compressive strength.

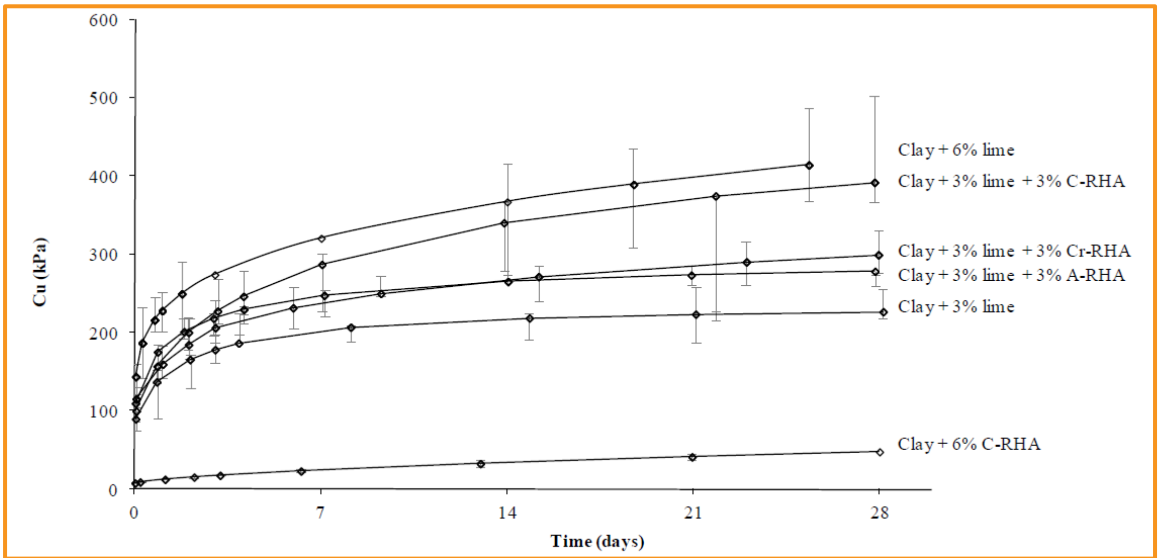

Figure 12 Strength development lime and rice husk ash[3]

While the block making units and binders are main expenditures, this is not yet the whole picture. One must also include labour, electrical, packaging, transport, and maintenance. Table 1 gives some estimations for these matters based on experience in South-East Asia.

[3] Pham, V. Utilisation of Rice husk ash in GeoTechnology – Applicability and effect of the burning conditions. 2012.

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Description	Price per block [$/pcs]	
Mobile units	0.042	CAPEX
Binders	0.050	OPEX
Labour	0,017	
Electrical	Negligible	
Packaging	0.0084	
Transport	0.0126	
Maintenance	0.0084	

Table 1 Expenditures

This would give a price per brick of about $0.14. On average, bricks on the Indonesian market will cost about $0.20-$0.35. Reusing locally available waste streams eliminates the need to purchase raw material, and allows significant cost savings on transport. **Reusing the 52,500 m^3 of soil from the bypass, 1400 homes can be made for a 50% lower construction price.**

After the capital dredging is completed the annual maintenance dredging of the river will commence. Projections indicate an annual yield of 2,000 m^3 of sediment at a concentrated transect at the southern part of the downstream section (Figure 13, orange section).

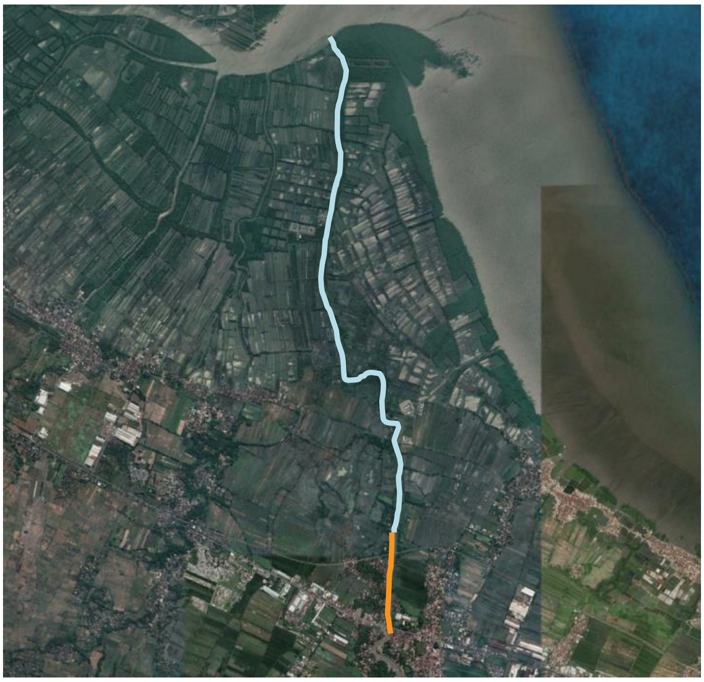

Figure 13 Location maintenance dredging (satellite image Google)

The intention is to use this sediment for brick production. The limited length of roughly 1,000 m allows the sediment to be transported to a single processing location with relative ease. The challenge, however, is that this dredged material will have a significantly higher water content. To use this material for brick production this water must be removed. This can be done through either natural drying processes, or mechanically with a belt filter press. Both options will be briefly examined here. The main assumptions here are that after drying the brick production cost will be the same as before (the added cost will be the drying process), that the maintenance dredging will occur once a year, and that there will be a duration of 10 years (this can be extended if needed).

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Natural drying

With the maintenance dredging happening once a year, there will be a sudden influx of 2,000 m^3 of sediment. The storage/drying basin must be large enough to facilitate this initial volume. During the rest of the year the top layer of the basin will be allowed to dry and will be periodically scraped off to use for brick production. This will occur with regular intervals throughout the year, until the basin is empty. Assuming a basin depth of 1 metre[4], the required area is 2,000 m^2 (this area can be reduced by investing in drainage equipment that stimulates the drying process). This means that a significant portion of land must be required for this method. Figure 14 gives an indication of the average land price of Indonesia. It is assumed that the land price for Bogor-Depok is similar to that of the project location.

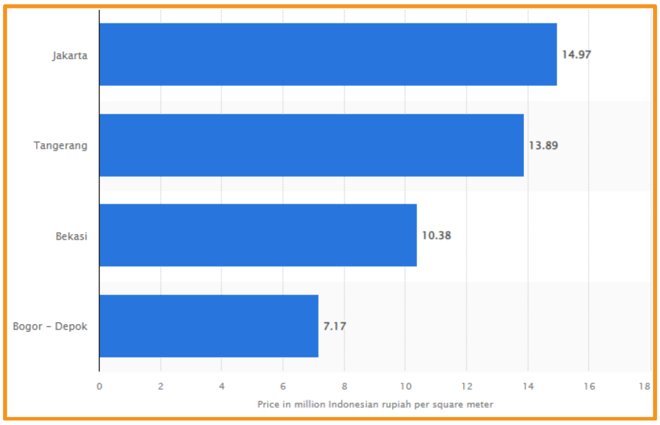

Figure 14 Average land price Indonesia[5]

An average land price of $500.74/$m^2$ will be used. This means that the total capital expenditure to procure the land is $1,001,480.00. After the 10 years has finished, the land can be sold. It is generally assumed that the land will quickly appreciate in value, allowing for a recovery on the investment. Nominal property prices in Indonesia, however, tend to have a small appreciation rate[6]. A nominal year-over-year rate of 1.59% is assumed (Surabaya area). Comparing this to a regular appreciation rate of for instance 6% on an investment, this means that the potential missed revenue on the investment can be interpreted as the added cost to dewater the sediment through natural drying. In this case, accounting for compound interest, the missed revenue is $620,892.77. The 2,000 m^3 of in-situ sediment allow for roughly **5,400,000 bricks** to be produced on an annual basis (roughly **54 homes** or **142,105 m^2 revetment/retaining wall facing**). Over 10 years this is **54,000,000 bricks**, or **540 homes** (or **1,421,052 m^2 revetment/retaining wall facing**). The added cost per brick is then **$0.12**, meaning that the total price would be **$0.26** per brick.

Mechanical drying

Mechanical drying of sediment is done with a belt filter press. These are often used in the mining industry to dewater tailings. Procurement of such a machine can require up to (adjusted for inflation) **$190,000.00**[7]. Additionally, there are operating expenses in the form of operation and maintenance (**$130.00/DTS**), and polymer conditioning (**$20.00/DTS**).

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[4] Natuurlijke verwerkingstechnieken voor baggerspecie, stimuleren van rijping van baggerspecie, Bodemrichtlijn

[5] Average land price of landed residential homes in Greater Jakarta, Indonesia as of the 1st half of 2021, by region, Statista

[6] Indonesia's house prices remain more or less steady, amidst the pandemic, Lalaine C. Delmendo, 22 February 2021, Global Property Guide

[7] Biosolids Technology Fact Sheet – Belt Filter Press, September 2000, United States Environmental Protection Agency.

Annual operating expenses will total roughly **$60,000.00**. Over the course of 10 years this would result in **$600,000.00**. Combined with the procurement of the machine itself, this would result in a total investment of **$790,000.00**. The added cost per brick is **$0.15**, resulting in a total price of **$0.29** per brick.

4. GEOTEXTILE TUBES

If all of the soil from creating the bypass gets reused to create building blocks, this leaves 80,000 m^3 of dredged sediment to be reused in geotextile tubes to strengthen river banks.

When considering filling geotextile tubes with dredged sediment, one must carefully consider the dredging method. There are two main options: mechanical and hydraulic. Mechanical dredging extracts the sediment by adding as little water as possible. This means that it cannot be easily transported via pipelines, and must instead be transported with barges to the geotextile tube filling location. Once arrived, it gets pumped into the geotextile tubes with a soil pump. After filling, the geotextile tubes won't need much dewatering.

Hydraulic dredging on the other hand adds a significant amount of water when extracting the sediment. This enables transport via pipelines, where ranges can be increased by adding boosters. Adding water to the sediment means this will need to be removed once it is in the geotextile tube. This is no problem when the sediment consists of coarse material that quickly settles and has a high permeability. The Welang River sediment however consists mainly of fines. This requires additional handling in the form of adding coagulants and flocculants. In short, these will cause the smaller particles to form large flocs causing rapid settling and dewatering.

When comparing both methods, one must take into account all transport factors. For mechanical dredging this involves the dredging itself, transport by hopper barges (including unloading), and the soil pump. For hydraulic dredging this involves dredging hydraulically, transport by pipelines (including boosters), and adding flocculants with a dosing unit. Figure 15 shows a comparison between the two methods. For shorter transport lengths, hydraulic dredging is more affordable due to its high output. However, transporting it over long distances will add a lot of extra costs in the form of boosters. The costs are divided by their transport lengths.

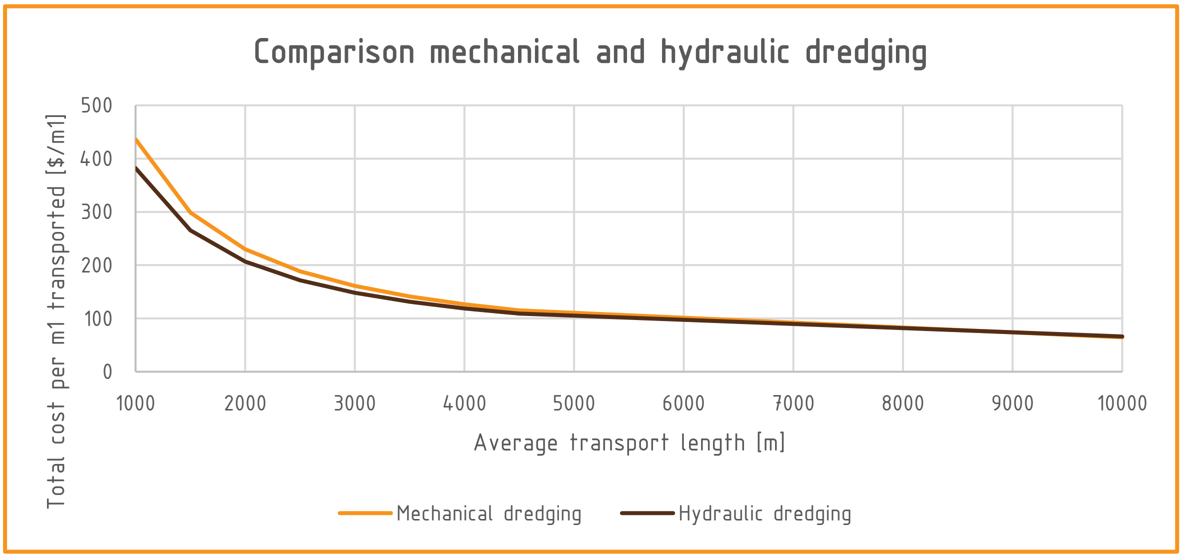

Figure 15 Comparison between mechanical and hydraulic dredging

The cost of a geotextile tube is largely based on the price of the base material, manufacturing is a much smaller portion of this. When designing a construction with geotextile tubes one must

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consider their circumference; standard circumference are 12m, 18.6m, 27.4m and 36.6m. A larger tube will allow a higher fill height, but will also increase its width. This means that the total potential length of the defence structure decreases when working with a finite volume. Figure 16 shows the cross-sectional area for a few standard size geotextile tubes at different fill levels.

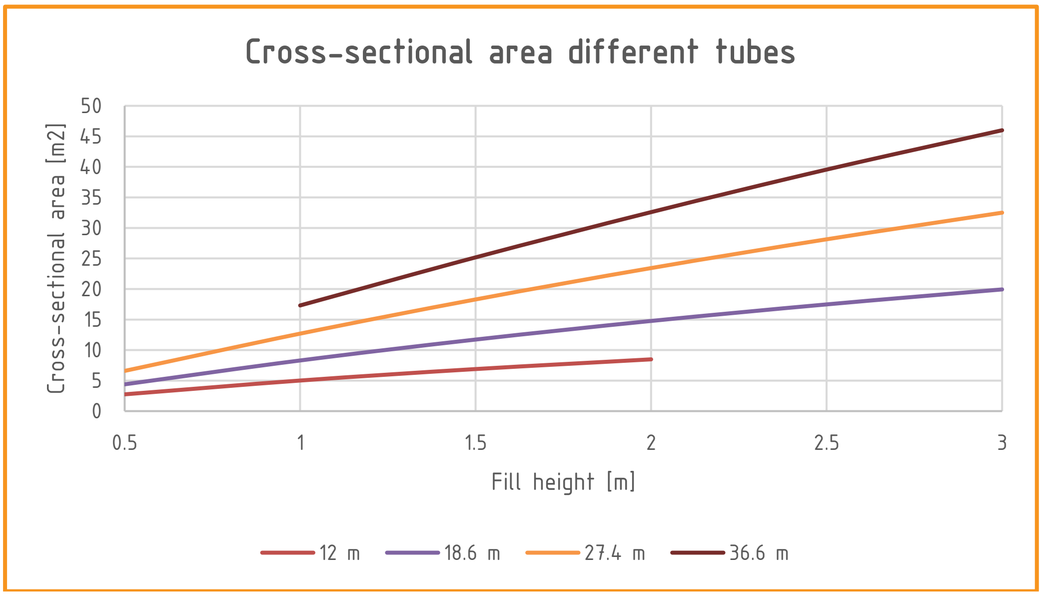

Figure 16 Cross-sectional area for different tube circumferences at different fill heights

Because we are dealing with a total dredge volume of 80,000 m³ we can compute the maximum length of embankment that can be restored with geotextile tubes filled with dredged sediments. Figure 17 depicts this for the different tube circumferences. From this figure it can be concluded that **Geotextile tubes filled with dredged sediments can restore 5-30 kilometres of embankments in the Welang River.**

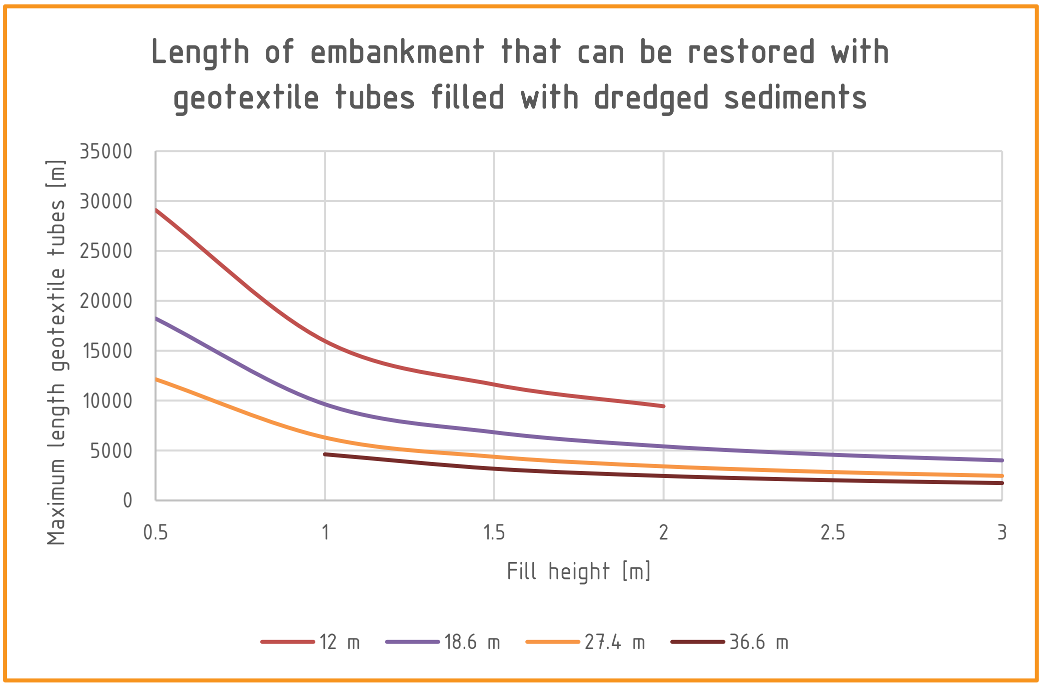

Figure 17 Maximum length of geotextile tube structures for different tube circumferences and fill heights

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Continuing on this path, potential embankment restoration locations along the Welang River are identified along with their lengths. Assuming the meandering river sections are undergoing erosion, these were mainly identified to have priority. Figure 18 shows these sections with severe erosion.

Figure 18 Possible restoration sections (satellite image Google)

Table 2 shows the different lengths of each section, along with their average distance from the dredging location. The total average transport distance weighted by section length is 4,935 m. The sum of the lengths of the sections is 5,611 m. **These 5611 metres of embankment can be restored with geotextile tubes with a circumference of 18.6 m and a fill height of 2m.**

Section	Length of the section [m]	Average distance from dredging location [m]
Section 1	1,360	1,400
Section 2	1,662	4,100
Section 3	802	5,500
Section 4	235	7,000
Section 5	339	7,300
Section 6	266	7,800
Section 7	381	8,300
Section 8	566	9,200
Total	**5611**	

Table 2 Potential restoration sections and their lengths

The costs for embankment restoration with geotextile tubes is calculated. For this calculation an average price for the geotextile of $6.30/m^2 is assumed. This will allow us to calculate a price per m^3 of dredged sediment for different tube sizes and filling heights. Figure 19 shows the prices per m^3 of dredged sediment based on a total volume of 80,000 m^3 of sediment that will be reused in geotextile tubes.

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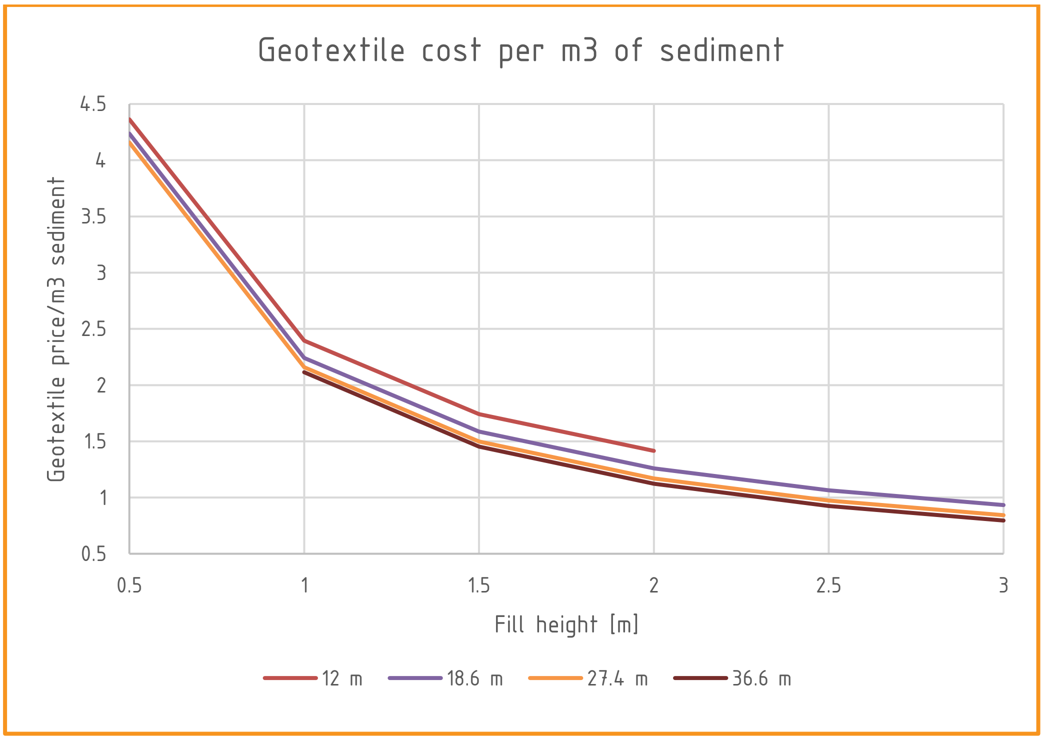

Figure 19 Geotextile cost per m³ of sediment

The geotextile tube with a circumference of 18.6 m and a filling height of 2 m was chosen to reuse the 80,000 m³ of dredged material and to restore 5,611 metres of river embankments. With this tubes, the investment will be roughly $100,000.00 to buy the tubes (CAPEX). The operational costs (OPEX) are, based on Figure 15, expected to be roughly $525,000.00. Resulting in a total cost of roughly $625,000.00 to restore 5,611 metres of river embankments. In other words, **restoring 5,611 metres of river embankment with 80,000 m³ of reused dredged material costs $110 per running metre.**

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