WATERWAY ASSET MANAGEMENT WITH HOLISTIC DREDGING AND SEDIMENT MANAGEMENT ON THE DANUBE

by

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ABSTRACT

Recent research on traffic development and transport economics in the Danube corridor revealed the importance of improved navigation conditions on the waterway Danube. The developed Waterway Asset Management System (WAMS) of viadonau allows a real-time calculation of fairway availability, planning of dredging measures, sediment management and budget estimations for various target conditions. The paper provides an overview of the WAMS with focus on dredging and sediment management in this software tool reproducing the entire dredging process, starting from an automated analysis of critical sections, planning of dredging measures per drag and drop, automated cost estimations based on economy-of-scale cost functions and an overview on the status of all measures. Prior to the developed solution estimations of dredging volumes had been based on single-beam surveys and the profile method or a more accurate "manual" assessment of multi-beam data in ArcGIS. With these new capabilities an analysis based on accurate multi-beam riverbed surveys is feasible accounting for deviations in billing of conducted dredging measures. Further functionalities include an analysis of dredging impact duration based on sedimentation and erosion rates, enabling an assessment of the efficiency of a dredging measure in comparison to other possible solutions (e.g. fairway alignment, construction of groynes). Thus, a much faster and efficient planning, implementation and controlling of dredging measures in order to achieve higher fairway availability has been realized. Based on the concept for a systematic sediment management the paper also gives insight into the key elements, findings and functionalities of an advanced sediment management taking into account both economic and ecologic factors. By facilitating an analysis of sedimentation and erosion rates on short sections for a fixed time frame as well as the development over time including dredging and dumping measures the developed WAMS provides an overview on all conducted dredging measures and related dumping sites for a given time frame as well as a total balance on all erosion and sedimentation volumes for any given time frame and river stretch (sediment balance). Instead of lengthy analyses and studies the Module Sediment Management allows viadonau to constantly assess and adapt their approaches by optimizing both the selection and the timing of appropriate measures. In summary, the developed functionalities enable an efficient balancing of both the interests of environmental protection and inland navigation at the same time. The comprehensive analysis and documentation system is constantly being updated based on previous results, thus becoming more accurate with every year.

KEYWORDS: Inland waterway Danube, dredging management, sedimentation and erosion, balancing and compensation

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1. INTRODUCTION

1.1 Investing in transport infrastructure and IWW (OECD – Countries)

Transport infrastructures as important assets of national economies develop in very long cycles due to their service lives and costs whereas transport of goods (and passengers) are closely related to economic development. The connection of investments in transport infrastructure and economic development is well documented. Like all production functions the benefits of additional spending are decreasing with high levels of income and already developed transport systems. Nevertheless, the spending for high level transport infrastructure increases almost linear with income amounting to roughly 1% of total GDP. The over-view on high level transport infrastructure investments in Figure 1 shows, that the majority of investments goes into road (~60%) and rail (~30%). The remaining share (~10%) is divided between Air-ports, harbor structures and inland waterways. Despite a number of EU backed initiatives to shift goods transport from road to rail and waterway in-creasing spending and market shares for these modes are not to be expected under current circumstances (Hoffmann 2018).

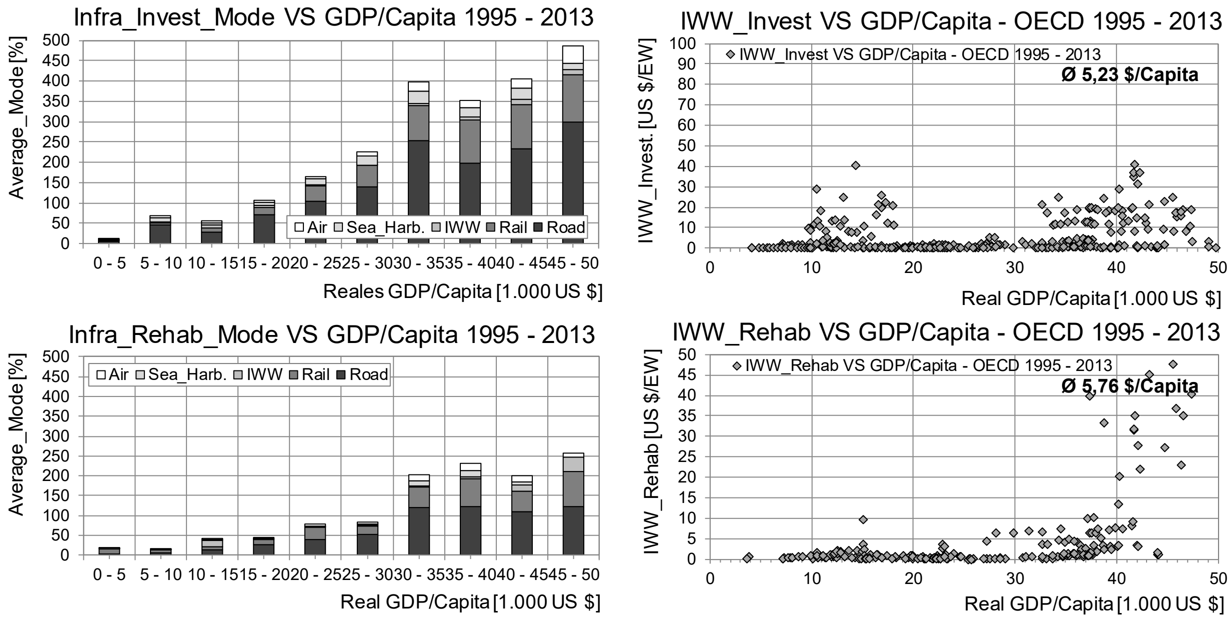
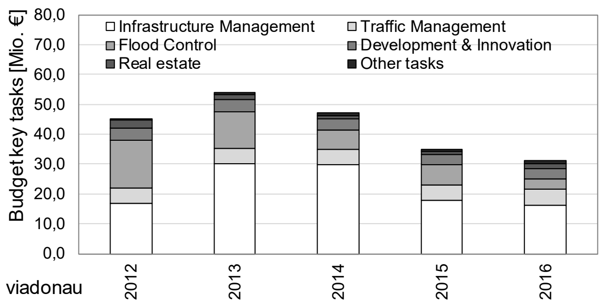


Figure 1: Total transport infrastructure investments and investments in inland waterways in OECD – Countries per capita VS Real GDP/Capita 1995-2013

1.2 Investing in IWW (Austria)

Managing the waterway Danube in Austria falls in the responsibility of the Austrian Waterway Company viadonau. The main tasks of viadonau are transport infrastructure and traffic management, flood control, real estate and other tasks (e.g. maintaining towpaths). In addition, viadonau spends a sufficient part of the budget for development and innovation (viadonau 2016, 2017). The budgeting shown in Figure 2 is variable depending on necessary additional expenditures (e.g. flood control, dredging 2012/13/14).



viadonau KEY FACTS:

- **maintains 350 km of waterways**
- **ensures the maintenance of 500 km of towpaths**
- **manages 200 km of flood protection dams**
- **maintains 800 km of river banks**
- **manages about 600 properties**
- **handles about 100,000 vessels passing through Danube locks per year**
- **operates the DoRIS (Donau River Information Services)**
- **260 employees in headquarter, locks and service centers**

Figure 2: Investments in IWW in Austria and key facts on the waterway company viadonau

2. Overview Waterway Asset Management System WAMS

2.1 WAMS – Modules, availability concept and Levels of Service (LOS)

Effective waterway management with sufficient fairway width and depth throughout the year is crucial for an economically successful development of waterway goods transport. Therefore, viadonau decided in 2012 to move from existing empiric reactive approaches towards an analytic proactive life cycle costing approach with the development of a waterway asset management system WAMS (Hoffmann, M. et. al. 2014a,b, Haselbauer, K. 2016). At the core of the developed approach is the total availability concept based on all possible available combinations of fairway width and depth in days per year with the levels of service accounting for typical encounter situations at a minimum fairway depth of 2.5 m (Fig. 3).

The principal methodological approach and software WAMS 1.0 with Module 1: Database, core system and availability and Module 2: Dredging Management have been developed in cooperation with Vienna University of Technologies - Institute of Transportation from 2012 to 2015 with the software being operational since July 2015. In the second stage viadonau teamed up with the principal developers (Hoffmann, M. & Haberl, A.) in order to extend the system with Module 3: Sediment Management, Module 4: Structure Management and Module 5: Traffic Management (Fig. 4) from 2016 to 2018.

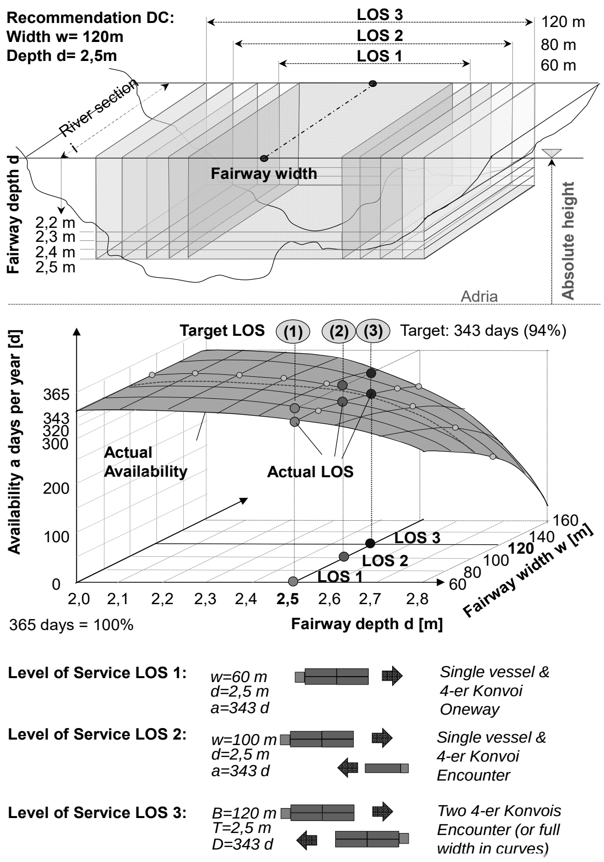


Figure 3: Fairway recommendations, total availability concept and Levels of Service

The focus of this paper is presenting an overview on principal considerations and methods together with developed functionalities and results from Module 3: Sediment Management in the WAMS software. The goal of Module 3 is to provide the waterway operator viadonau with all necessary information regarding sedimentation and erosion processes on the free-flowing sections of the Danube in Austria. In the following sections, the paper describes the basic approach in sediment management.

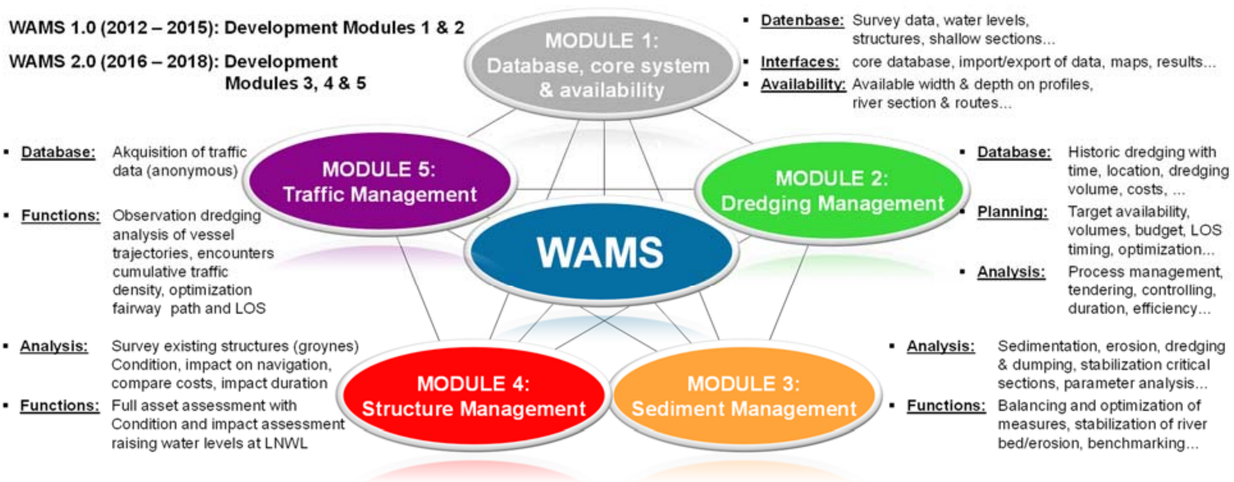


Figure 4: Overview developed modern modular Waterway Asset Management System WAMS of viadonau being operational since 2015

2.2 WAMS – Module 1: Database, core system and availability

Starting from a holistic asset management and total availability perspective, trying to achieve recommended fairway parameters under changing conditions with limited budget cannot yield efficient results. Instead, calculating all possible combinations of available fairway width and depth yields a concave falling availability surface with any target condition being just a point above or below this surface. Improving insufficient availability (e.g. fairway alignment, maintenance dredging, river engineering) starting with the most critical section will lead to increasing costs for additional availability. Drawing from previous research on transport costs it can be shown that increasing fairway depth at low water periods even at the expense of narrowing fairway width is cost efficient, as transport costs are mainly related to actual draughts loaded on a transport route. Optimizing for a given budget therefore yields the combination of width and depth with minimal transport costs (Hoffmann, M. et. al. 2014a,b).

For a calculation of fairway availability, it was necessary to manually assess all shallow sections based on data from riverbed surveys (single & multi beam) in combination with water levels calculated from gauging stations and actual fairway alignment. Apart from the massive amount of data from riverbed surveys alone any manual assessment would take too much time to be efficient, also preventing a transition from reactive maintenance to quantitative analysis and pro-active waterway asset management. Therefore, the development of the WAMS system started with Module 1, acting as a central SQL database and graphical interface for analysing riverbed surveys, gauging data, fairway alignment and marking. Based on this, Module 1 is capable of analysing surveys, water depths, sedimentation and erosion processes, providing the user with automated maps, charts and recommendations. Furthermore, Module 1 combines this information to calculate fairway availability for any given set of parameters as well as availability surfaces for every cross-sectional profile, shallow section or the entire Danube in Austria (350 km) for any given time frame. Additional capabilities are an early-warning system and priorities regarding critical developments (Fig. 5).

Apart from the principal capability of storing and analysing data the main requirement for developing Module 1 was streamlining the entire process of data acquisition, verification, analysis and output based on a user-friendly design, reducing processing time from two to three weeks to just a few days. In a next step, the released capacities were used to import available data from previous years providing information on systematic developments and correlations. Furthermore, riverbed survey intervals were shortened on most critical sections, allowing to provide inland navigation with most recent information on fairway availability as well as gaining further insight into the efficiency of conducted maintenance measures. Setting up a backup-system as well as consistent user permissions from limited view (guest), data input (user) and administrator ensures data safety and integrity in each step of the process. In summary, Module 1 acts as central database, platform and viewer for all other modules of the software.

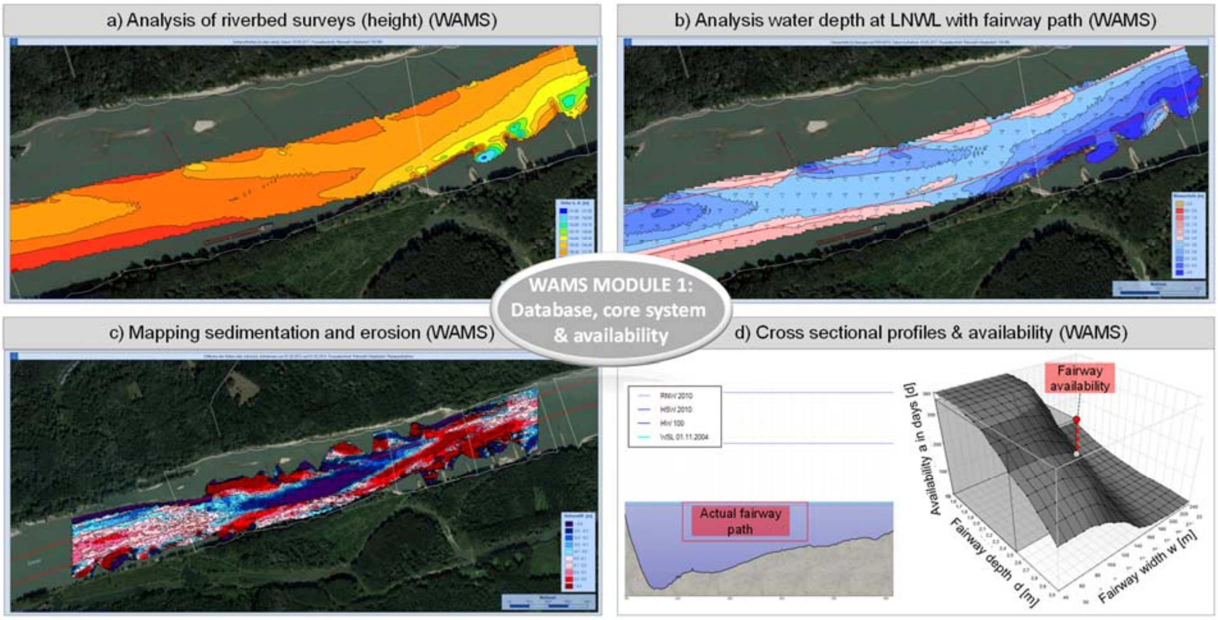


Figure 5: WAMS Module 1 with automatic analysis of a) Riverbed survey, b) Water depth, c) Sedimentation & erosion, d) Cross sectional profiles & availability calculation

2.3 WAMS – Module 2: Dredging Management

Prior to the implementation of WAMS Module 2, fairway maintenance dredging measures had been based on a manual assessment of shallow sections, a rough estimation based on the profile method of possible dredging volumes and a cost estimation derived from average unit costs of previous years. In a next step, selected and approved dredging measures were tendered with a riverbed survey before and after dredging for assessment and billing purposes (Fig. 6). This kind of "manual" dredging planning, which is based on experience, was time-consuming and not capable of providing systematic analysis on alternatives. Furthermore, dredging volume and cost estimations took time, were of limited accuracy and did not provide information on impact duration as a basis for life-cycle analysis and management.

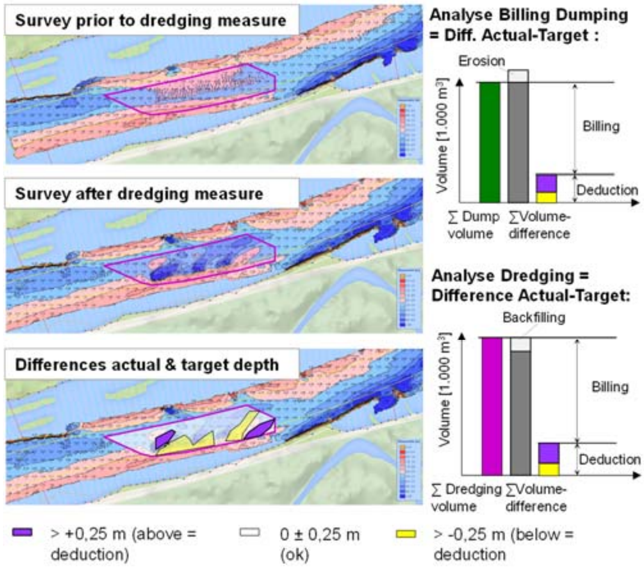


Figure 6: Calculation of dredging and dumping volumes controlling for deviations due to backfilling and differences to target depth

WAMS Module 2 reproduces the entire dredging process, starting from an automated analysis of critical sections, planning of dredging measures per drag and drop, automated cost estimations based on economy-of-scale cost functions and an overview on the status of all measures (Fig. 7). Prior to the development of the WAMS software, estimations of dredging volumes had been based on single-beam surveys and the profile method or a more accurate "manual" assessment of multi-beam data in ArcGIS. In Module 2 both methods are implemented for automatic analysis, revealing substantial deviations in comparison. However, as the analysis with multi-beam riverbed surveys is more accurate, it is now standard for deviation analysis in billing of conducted dredging measures. Further functionalities of this module include an analysis of dredging impact duration based on sedimentation and erosion rates, enabling an assessment of the efficiency of a dredging measure in comparison to other solutions (e.g. fairway alignment, construction of groynes). In summary, the development of Module 2 allows much faster and efficient planning, implementation and controlling of dredging to achieve higher fairway availability. The comprehensive analysis and documentation system is constantly being updated based on previous results, thus becoming more accurate with every year. Since 2015, Module 2 has been successfully used for planning of all dredging measures, providing a constant feedback for improvements.

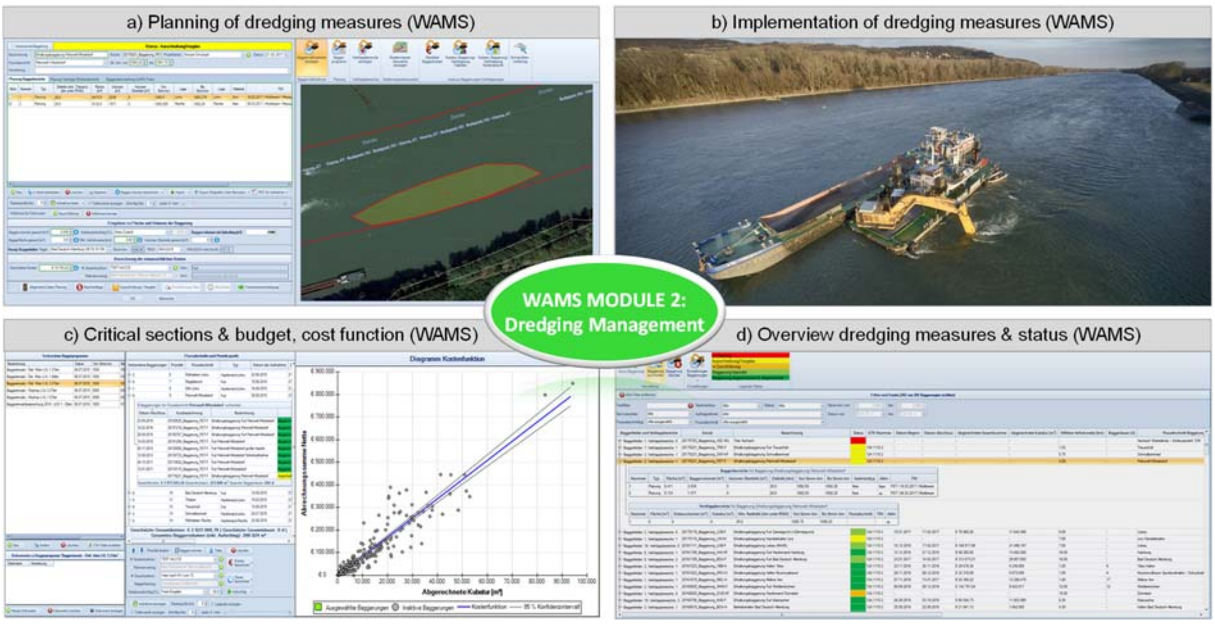


Figure 7: WAMS Module 2 with a) Planning of dredging, b) Implementation & controlling, c) Critical sections, costs and budgeting, d) Overview status and implementation of dredging

2.4 WAMS – Module 3: Sediment Management

The river Danube in Austria features a number of consecutive hydraulic power plants and two major free-flowing sections with a number of shallow sections from Melk to Krems and from Vienna to the Austrian-Slovakian border. Parts of these sections are characterized by river-engineering structures (groyne fields) with substantial impacts on river morphology. Due to substantial stretches of the river banks being fixed and a dynamic riverbed, there have been ongoing erosion tendencies between Vienna and Hainburg of roughly 1.0 m from 1950 to 2010 (Klasz, G. 2013, 2015). Furthermore, there are a number of scours showing a low thickness of stable riverbed layer which require regular monitoring with regard to critical erosion tendencies.

Thus, the goal for Module 3 was to develop and implement a concept for a systematic assessment of critical scours, assessing sedimentation and erosion rates in these areas. Furthermore, to provide analytic capabilities, an automatized overview has been implemented on all conducted dredging and dumping activities countering erosion together with a volume balance sheet covering historic and actual developments. The developed approach is based on dredging shallow sections and dumping dredged material in critical scours upstream, thus improving fairway availability while countering riverbed erosion at the same time. Another necessary analytical capability of Module 3 is a detailed analysis of shallow sections with an assessment of backfilling behaviour after dredging measures depending on water levels and discharge. The same goes for the analysis of dumping sites and critical scours, with this kind of analysis providing the basis to distinguish between “natural erosion” and impact of dredging with dumping upstream.

Based on the concept for a systematic sediment management (Klasz, G. 2015, Hoffmann M. et. al. 2016), Fig. 8 provides an overview on already implemented software features. Module 3 already facilitates an analysis of sedimentation and erosion rates on short sections for a fixed time frame as well as the development over time including dredging and dumping measures. Further capabilities are an overview on all conducted dredging measures and related dumping sites for a given time frame as well as a total balance on all erosion and sedimentation volumes for any given time frame and river stretch (sediment balance).

From a waterway asset management perspective, Module 3 provides viadonau with the capability of going beyond optimal fairway parameters for inland navigation, balancing necessary maintenance and the needs of environmental protection and stabilization of the riverbed. Instead of lengthy analyses and studies this module allows viadonau to constantly assess and adapt their approaches by optimizing both the selection and the timing of appropriate measures. In summary, Module 3 will help to efficiently balance the interests of environmental protection and inland navigation. Furthermore, the generated results will provide viadonau with the basis for future insights and improvements.

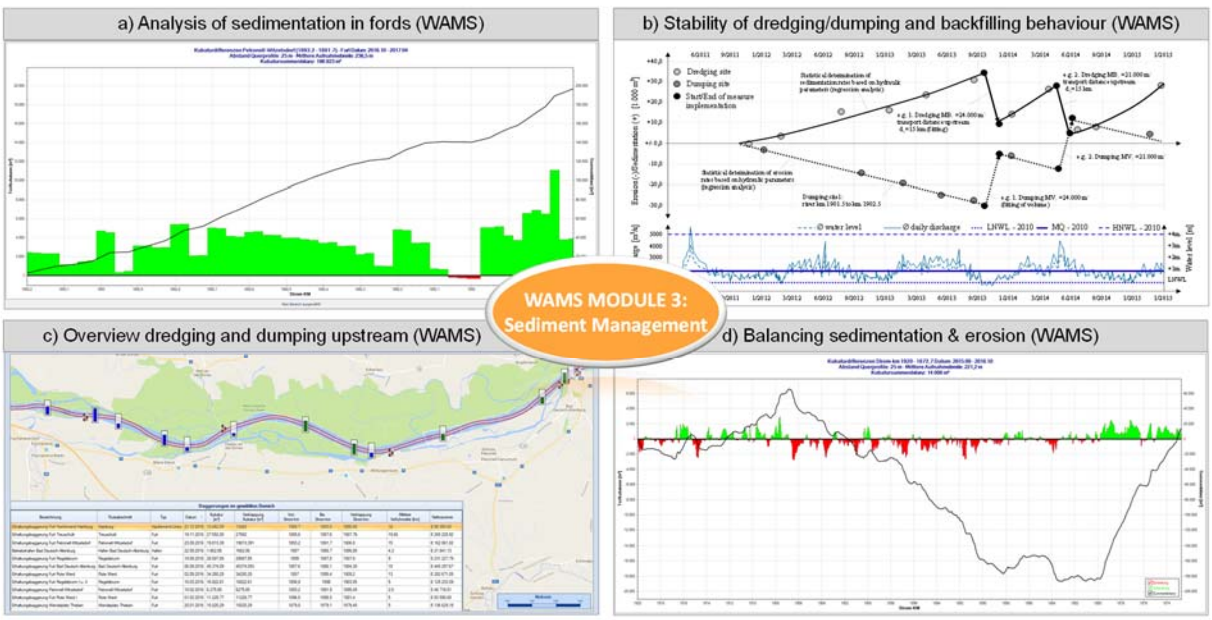


Figure 8: WAMS Module 3 with a) Sedimentation in fords, b) Stability of dredging/backfilling, c) Overview conducted dredging and dumping, d) Balancing sedimentation and erosion

2.5 WAMS – Module 4: Structures Management

On the free-flowing section of the Danube east of Vienna there are a large number of hydraulic-engineering structures (groynes, training walls) as well as some embankment and bottom protection measures which were mainly constructed at in the 20th century. In Austria groynes are constructed from loose boulders reducing cross sections and thus increasing water levels and as well as fairway depths at low navigational water levels (LNWL). In contrast, airway dredging the fairway path lowers the river bed increasing also increases fairway depths, but as well also slightly lowering lowers water levels (Fig. 9). Thus, dredging for greater fairway width becomes increasingly inefficient when compared to long- lasting groynes, especially if dredging exhibits a short impact duration due to high sedimentation rates (Krouzecky, N. 2015, Hoffmann, M. et. al. 2016).

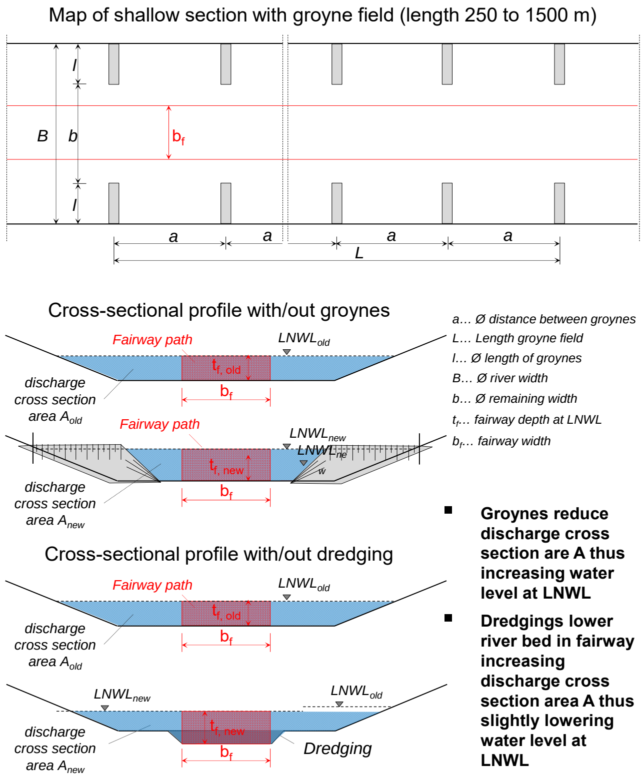


Figure 9: Impact of river engineering measures and dredging in the fairway path on available depth at low navigational water levels (LNWL)

The goal of in developing Module 4 therefore was therefore to develop provide a consistent approach regarding an implementation of waterway structures in the waterway asset management as a basis for decision making. The developed functionalities of the WAMS in this module include a survey of existing and/or defective waterway structures, volumetric analysis for assessing possible reconstruction costs as well as a functional assessment regarding fairway availability. Based on an overview and analysis of existing waterway structures and their functionality, it will be possible to decide whether dredging measures or lasting river engineering are cost efficient. Furthermore, this will allow to minimize necessary interventions, balancing the environmental needs with those of inland navigation. Furthermore, acting as a basis for planning and cost estimations in the reconstruction and adaption of existing or necessary additional waterway structures. In summary, Module 4 will enable viadonau to include hydraulic-engineering structures in the holistic asset management process of WAMS.

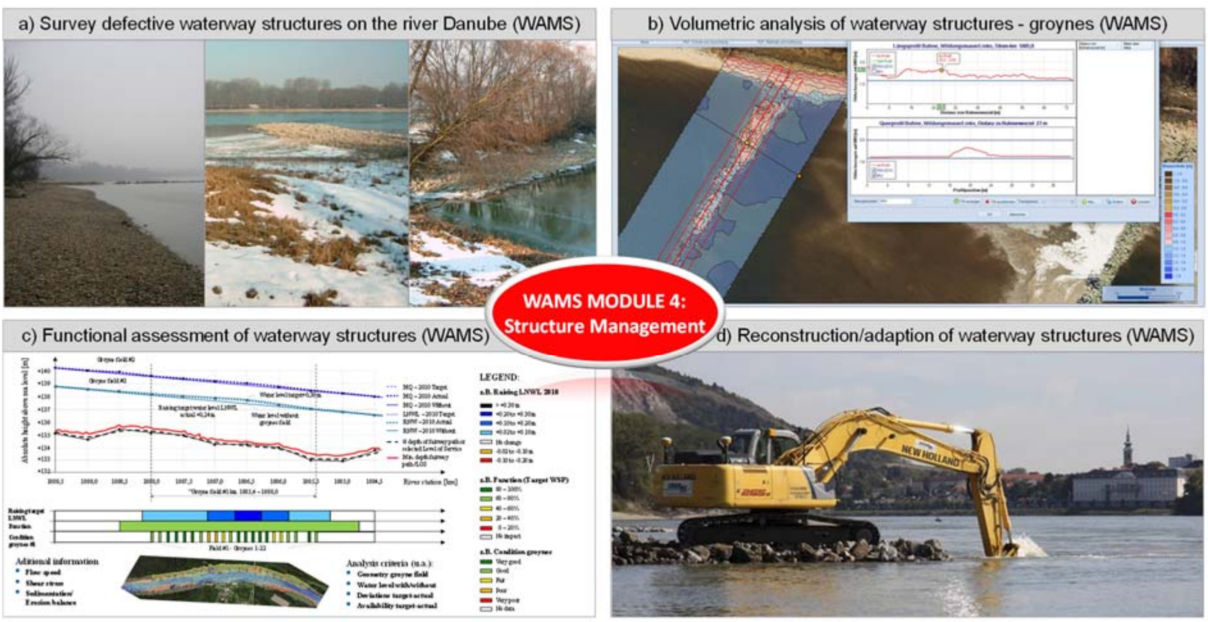


Figure 10: WAMS Module 4 with a) Survey defective structures, b) Volumetric analysis, c) Functional assessment of structures, d) Reconstruction and adaption of waterway structures

2.6 WAMS – Module 5: Traffic Management

As, previously mentioned, the fairway availability on a transport route is always limited at a certain time by the most critical shallow section, a non-functioning lock or other physical impediments. With two locks on every hydrological power station as well as an almost permanent availability of at least one lock with sufficient capacity for usual traffic volumes, the main issue is providing a sufficient fairway depth of at least a deep fairway channel. Thus, shallow sections form a serial system with changing availability over time, with the total availability being defined by the critical path for any given time frame. As necessary maintenance and especially river engineering measures take time, it is of crucial importance to determine critical developments prior to their occurrence based on comprehensive prediction functionalities. Other Another possibility is a fairway alignment which is much faster in implementation but is limited by river width, curvature and actual traffic flows. For an optimization of the efficiency of both waterway transport and efficiency of communication results it is also important to know actual of availability the current utilization of fairway availability based on a comprehensive analysis of traffic flows. The goal for the development of Module 5 was therefore to extend the WAMS with additional capabilities regarding actualization of fairway paths, markings and buoys as well as an integration of all important navigational structures on river shores. Further functionalities are tracking dredging vessels between dredging and dumping sites, integration and analysis of anonymized vessel trajectories for traffic and encounter analysis. However, the main goal was a quantitative assessment of traffic flows and distribution on cross- sectional profiles and maps with the possibility to align the fairway path, Levels of Service (LOS) and signalization & marking. In addition, conveying reliable availability information to skippers via signalization marking and different communication channels is equally important for enabling a high utilization rates (Haselbauer, K. 2015, Hoffmann, M. et. a. 2016).

The developed WAMS Module 5 is capable of tracking dredging vessels as they are obliged to provide this information for controlling purposes based on dredging contracts. In contrast, an automated import function for track information from passenger and goods transport uses an automated import function to anonymizes transponder data, leaving computing only vessel type, position and draught loaded. The developed algorithm for an analysis of traffic flows is based on the intersection of vessel trajectories with a defined grid being used as counting cells. Possible vessel encounters can be calculated from vessel position over time being projected to actual river kilometre. In turn, this allows to map specific encounter situations and distances being of specific importance regarding with regard to fairway alignment in narrow sections. Finally, the cumulative traffic density being represented as heatmaps and distribution in cross- sectional profiles (with average and confidence interval) enable an efficient alignment of both fairway and levels of service (Fig. 11). In summary, Module 5 provides viadonau with the capability to optimize waterway availability and fairway path according to actual traffic flows. Based on the results viadonau is also capable of providing actual information to the shipping industry regarding unused availability and loading potentials in order to improve navigation's competitivety on the market.

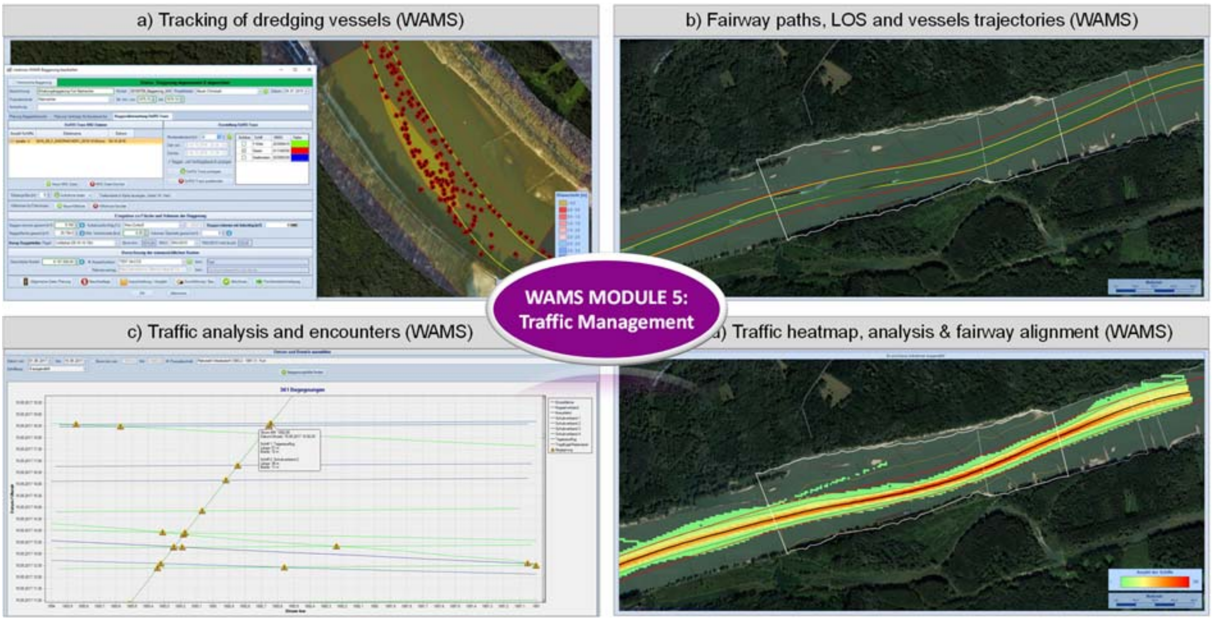


Figure 11: WAMS Module 5 with a) Tracking of dredging measures, b) Fairway paths and levels of service, c) Traffic analysis and encounters, d) Traffic heatmap, analysis & fairway alignment

3. Methods and approaches in Sediment Management (Module 3)

3.1 Assessment of critical fords

The Dredging Management (Module 2) includes the capability to calculate dredging volumes and costs in shallow sections and fords based on single and multi-beam surveys for any defined area and target depth. Surveys of fairway conditions before and after dredging measures allows to check whether targeted depths have been achieved and actual dredging volumes are consistent with billed volumes. However, full life cycle capabilities regarding dredging measures require an assessment of impact duration with backfilling rates on dredging sites and erosion on dumping sites. With Module 3: Sediment Management an automatic analysis of typical sedimentation and erosion rates together with a full-scale documentation of measure implementation becomes feasible (Hoffmann, M. et. al. 2014, 2016; Haselbauer, K. 2016).

Figure 12 provides an overview on the assessment of dredging and dumping impact duration based on a calculation of volume deviations between consecutive surveys either with the cross-section profile-method (single-beam) or a full calculation with TIN-networks (multi-beam). On typical fords there will be an ongoing sedimentation with increasing volume accumulation until implementation of dredging measures. At scour areas there will be an ongoing erosion process that can be mitigated by dumping dredged material from fords. By systematic comparison of discharge levels, flow speed and water levels with changes in the riverbed an empiric calibration of sedimentation and erosion rates for different conditions becomes feasible.

As sedimentation and erosion are cumulative processes these empirical calibrated rates will be a good basis for the prediction of these processes as well. As multi-beam surveys on critical fords or scour areas are conducted at least every 1-2 months the results of future prediction capabilities in the WAMS can be adjusted accordingly. Including these functionalities in the WAMS enables the waterway operator to assess the efficiency of dredging measures for individual fords compared to other e.g. more permanent solutions (e.g. adaptation/construction of groynes). Based on these results it is possible to optimize extent and timing of dredging measures, enabling future condition prediction and stable budget forecasting results. Thus, the implementation of these functionalities will ensure an efficient use of funds and high availability of the waterway.

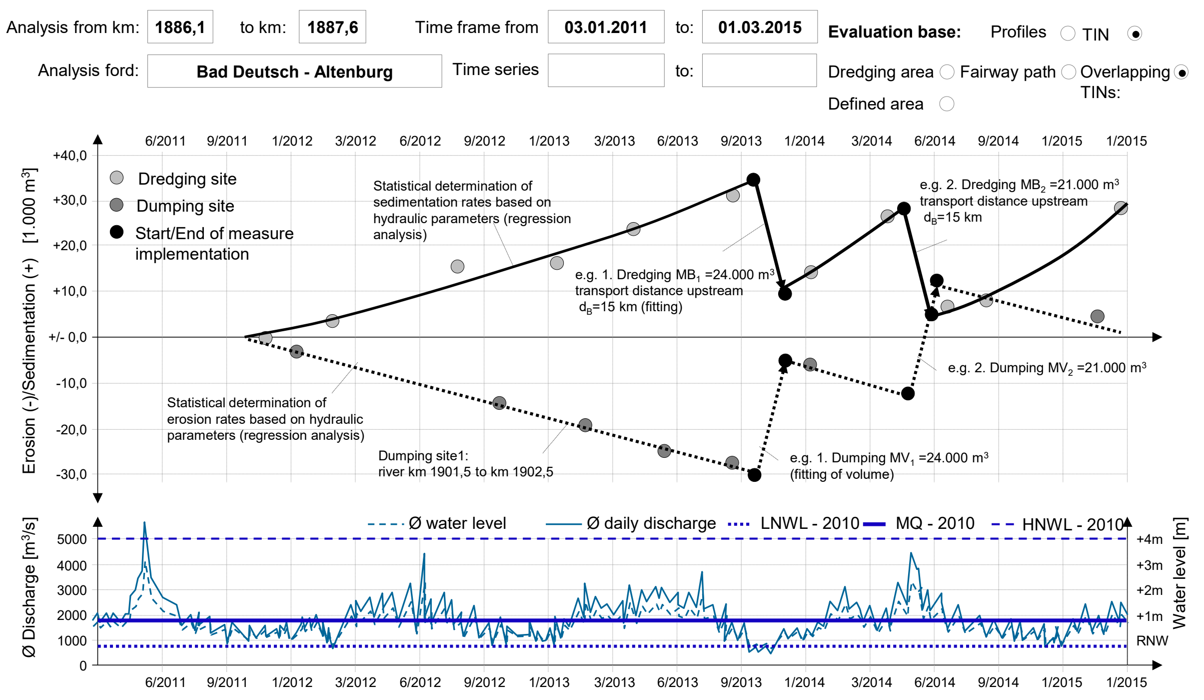


Figure 12: Dredging and dumping impact duration with analysis of typical sedimentation and erosion rates from analysis of periodic multi-beam surveys and dredging/dumping measures

3.2 Assessment of critical scour areas

The river Danube in Austria has a number of consecutive hydraulic power plants and two major free flowing sections in Wachau and east of Vienna down to Hainburg at the border to Slovakia. At these sections the Danube is dominated by natural stretches as well river engineering structures (groyne fields) with substantial impact on river morphology. Thus, long stretches of river banks together with the principal river path are fixed whereas the riverbed remains flexible and malleable. As a result of this river regulation and lack of bed-load there has been an ongoing erosion mainly on the river section from Vienna to Hainburg of roughly 1.0 m from 1950 to 2010. In addition, there are certain scour areas with a low thickness of stable river bed layer and critical erosion rates (Klasz, G. 2013, 2015).

The concept for an assessment of critical scour areas based on thickness of stable layer, sedimentation and erosion rates with systematic dredging in sedimentation areas and dumping in scour areas up-stream with volume balance in longitudinal profiles is described in Figure 13. The basic idea is a systematic backfilling of scour areas upstream with material from dredging measures on critical fords down-stream. The layer thickness of the stable layer is determined based on core-sampling on both sides of the river and at selected positions in the riverbed in critical sections. A systematic analysis of changes in altitude of the riverbed on river sections provides insights into sedimentation and erosion rates. The basis for this analysis are bi-annual multi-beam surveys of the entire free-flowing sections. With this it is possible to detect scour areas with the need to counter critical erosion processes.

With Module 3: Sediment Management it will be possible to determine possible scour areas and critical erosion tendencies automatically providing viadonau with automated warnings if the thickness of the stable layer falls beyond a given threshold. However, from current analysis it can be concluded that the number and extent of critical scour areas in the free-flowing sections of the Danube in Austria is limited despite general erosion tendencies. In addition, current dredging volumes at shallow sections exceed the necessary amount of material for stabilizing these sections. With regular monitoring and systematic dredging and dumping in critical scour areas it is therefore possible to avoid critical developments. If the dredging material is not stable enough it is also possible to counter erosion by dumping additional material with an optimized grain-size distribution and monitor further developments with the WAMS.

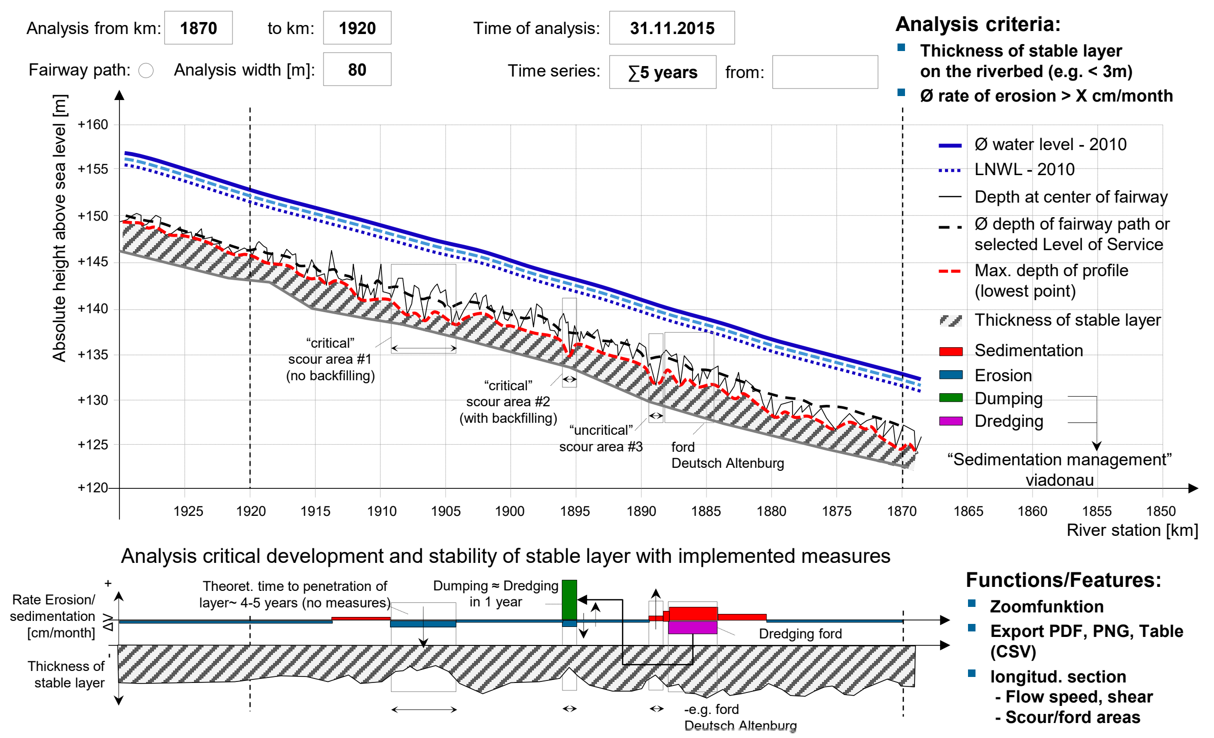


Figure 13: Assessment of critical scour areas based on thickness of stable layer, sedimentation and erosion rates with systematic dredging in sedimentation areas and dumping in scour areas

3.3 Balancing erosion and sedimentation

As previously mentioned the river Danube exhibits certain erosion tendencies in the free-flowing sections due to regulations and a lack of bedload below hydro-electric power plants despite sedimentation on a few shallow sections mainly east of Vienna close to the border of Slovakia. On this short river stretch of roughly 50 river-kilometer the erosion lead to a loss of 2,2 Million cubic meter of bedload from 1996 to 2015 translating in several decimeters of riverbed erosion. Between 1950 to 2015 the riverbed erosion exhibited a progressive growth exceeding 1,2 m in average according to extensive analysis. Apart from the impact on technical structures and the ground water level this development is also critical for the environment with its protected meadows and flood plains (KLASZ, G. 2013, 2015).

Figure 14 provides a concept for an overview and volume balancing in sediment management based on natural erosion tendencies, dumping of addition-al material below a main hydroelectric power plant (Freudenau - VHP) and all dredging measures in sedimentation areas with dumping upstream. Based on actual surveys it is possible to determine a mass equivalence from dredging and dumping upstream depending on transport distance that can be calibrated based on actual data. With this it is possible to calculate cumulative “natural” erosion volumes for an analyzed river section without measures as a baseline being countered to some extent by additional material from VHP and sedimentation management. Minimizing total erosion volumes to acceptable levels either based on additional dumping material up-stream or sedimentation management (e.g. increase in transport distance or dredging volumes) will be subject to an iterative process.

However, implementing these functionalities in WAMS – Module 3: Sediment Management allows viadonau to keep track of all implemented measures and their impact providing the necessary information for decision making on an actual basis. Thus, these functionalities act as an instrument providing information on critical developments on scour and sedimentation areas allowing for timely interventions together with accurate information on necessary extent and costs. In addition, this will provide evidence regarding treatment impact being a basis for optimization. Regarding high level decision making the automatic analysis of achieved results with the given budget and selected measures will provide the necessary evidence for further improvements.

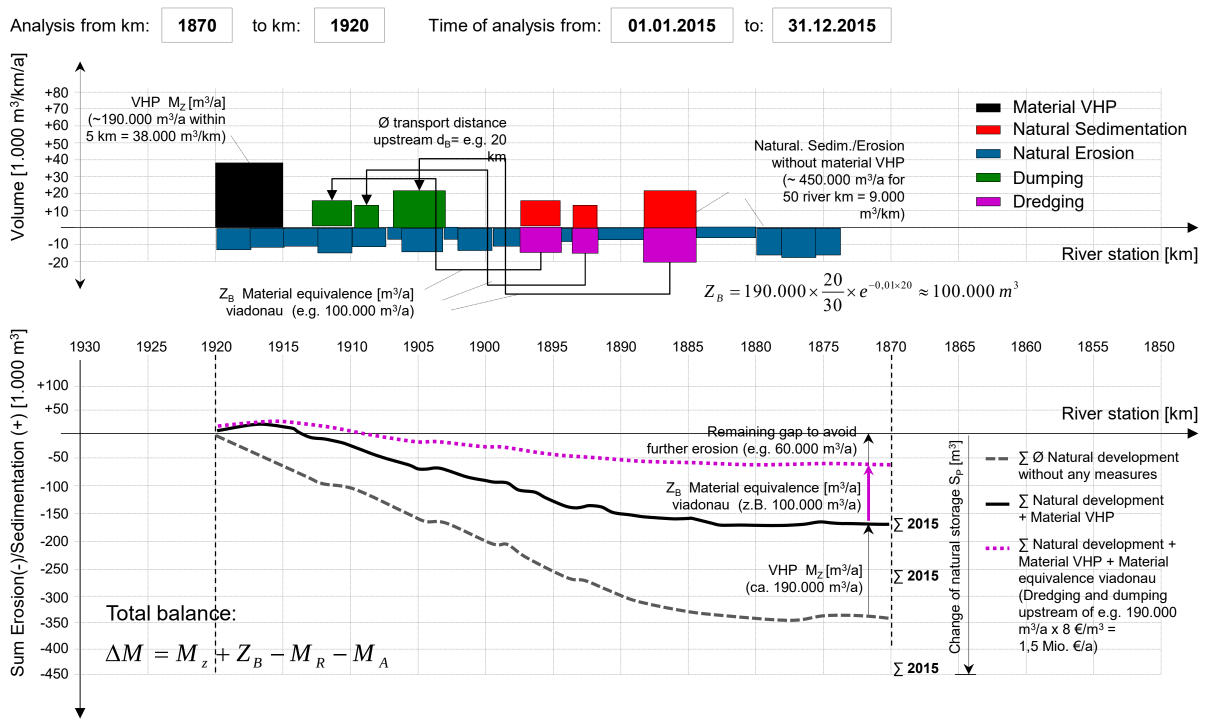


Figure 14: Volume balancing in sediment management with natural erosion, dumping below a hydro-power plant (VHP), dredging in fords and dumping upstream with mass equivalence

4. Conclusions and outlook

For managing a dynamic river as transport infrastructure in a cost-efficient and environmentally friendly way viadonau has teamed up with Vienna University of Technology and Hoffmann Consulting in order to develop a holistic Waterway Asset Management System (WAMS). In a first phase from 2012 to 2015 the principal methodological approaches for Modules 1: Database, core system and availability and Module 2: Dredging Management have been developed (WAMS 1.0). In the second phase from 2016 to 2018 Module 3: Sediment Management, Module 4: Structure Management and Module 5: Traffic Management are being implemented (WAMS 2.0). With the WAMS in operation since July 2015 the development is work in progress providing constant feedback between theoretical considerations and practical results as new functionalities become available. In this regard, the WAMS is becoming an integrator of all kinds of data providing viadonau with the means to move from empiric reactive maintenance approaches towards quantitative asset management strategies with fast semi-automated processing capabilities and pro-active maintenance in a user-friendly environment.

With the introduction the paper provides an insight into investments in inland waterways both in OECD – Countries and Austria. In the second part of the paper an overview of the WAMS – Modules and their functionalities together with the availability concept and implemented levels of service (LOS) are given. The third part of the paper presents further insights into the approaches on concepts behind Module 3: Sediment Management starting with the assessment of critical fords. Based on a comprehensive analysis of sedimentation in fords and erosion in scour areas the stability and impact duration of dredging and dumping measures are analysed. By systematic comparison of discharge levels, flow speed and water levels with morphological changes this functionality will yield empirical sedimentation and erosion rates allowing for a better planning and prediction of treatment impact. The assessment of scour areas together with the thickness of stable riverbed layer provides an insight into critical developments. Based on a thorough analysis it can be shown that critical developments can be mitigated by systematic monitoring and dumping dredging material in critical scour areas.

Regarding sediment management apart from the development of fairway conditions one of the most critical developments on the free-flowing sections has been the constant erosion process in the last decades. From 1950 to 2015 alone the riverbed erosion in the free-flowing section south of Vienna led to a riverbed erosion exceeding 1,2 m in average despite some dumping efforts below a hydro-electric powerplant at the beginning of this river stretch. This negative bed-load balance is especially problematic for protected natural habitats and their flora and fauna with meadows and flood plains falling dry more frequently. By implementing Module 3: Sediment Management the impact of systematic measures countering these erosion processes e.g. by dredging downstream in fords and dumping upstream can be monitored and optimized. The automated analysis of achieved results with different measures not only provides evidence that these erosion processes can be limited but also allows for more accurate measure planning and timing in the future. In summary, the WAMS – Software is a tool providing decision makers in viadonau with the means for a holistic view on the entire waterway Danube allowing balanced and efficient investments.

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