BUNDESANSTALT FÜR GEWÄSSERKUNDE
Koblenz
(German Federal Institute of Hydrology)

BUNDESANSTALT FÜR WASSERBAU
Karlsruhe
(German Federal Waterways Engineering and Research Institute)

Studies on Alternative Technical-Biological Bank Protection Measures Applied on Inland Waterways

Part 1:
Motivation, Survey and International Research

R & D project
(BAW – BfG)

May 2006

Participants of the R&D project

FLEISCHER, Petra - *Primary responsibility*	Dipl.-Ing., Bundesanstalt für Wasserbau Karlsruhe
HERZ, Hans-Werner	Dipl.-Ing., Bundesanstalt für Gewässerkunde Koblenz
KOLB, Siegfried	Dipl.-Ing., Bundesanstalt für Gewässerkunde Koblenz
KOOP, Jochen	Dr. rer. nat., Bundesanstalt für Gewässerkunde Koblenz
LIEBENSTEIN, Hubert	Dipl.-Ing., Bundesanstalt für Gewässerkunde Koblenz
SCHÄFER, Kai	Dipl.-Ing., Bundesministerium für Verkehr, Bau und Stadtentwicklung Bonn *(German Federal Ministry of Transport, Building and Urban Affairs, Bonn)*
SCHLEUTER, Michael	Dr. rer. nat., Bundesanstalt für Gewässerkunde Koblenz
SOYEAUX, Renald	Dr.-Ing., Bundesanstalt für Wasserbau Karlsruhe
SUNDERMEIER, Andreas	Dr. rer. nat., Bundesanstalt für Gewässerkunde Koblenz

Contents

1 Motivation

Navigation on the German federal waterways always causes a greater or lesser hydraulic load on the banks. In order to prevent erosion damage, most of the banks are therefore protected by appropriate measures, e.g. by rip-rap. Technical design principles for this are the *Code of Practice "Use of Standard Construction Methods for Bank and Bottom Protection on Waterways" (MAR)*, 1993, and the *Principles for the Design of Bank and Bottom Protection in Inland Waterways (GBB)*, published in *Mitteilungsblatt (Bulletin) No. 88 of /BAW* 2005/. The purpose of the guidelines and recommendations included in these publications is to guarantee bank stability under the hydraulic load present on the waterways. In this context it is not always possible to take ecological aspects sufficiently into account. However for many construction measures – especially in regions of high relevance regarding environment protection – ecological aspects are becoming more and more important. In the context of maintenance, development and construction of waterways, the German Federal Waterways and Shipping Administration (*Wasser- und Schifffahrtsverwaltung des Bundes, WSV*) is being more and more confronted with the task of also considering alternative bank protection methods closer to nature.

A crucial element of alternative bank protection measures is to include plants too (trees, shrubs, reed beds). So traditional – merely technical – bank protection measures can be complemented or even replaced by alternative methods closer to nature if no lining close to the surface exists which is sensitive to root growth. For small to medium running waters numerous experiences with bioengineering bank protection measures exist /Patt et al. 2004; Begemann, Schiechtl 1994/. However, the load is not comparable to the loads occurring on waterways with navigation. On German federal waterways, initial test sections have been arranged in some areas where technical-biological measures are being realised and monitored by the responsible local Offices of the German Federal Waterways and Shipping Administration (WSV). However, the experiences gained in the different sections have so far not been collected and interpreted in a central place. Systematic studies of the hydraulic load carrying ability of alternative bank protection measures on German inland waterways have so far not been undertaken either. Furthermore, there is no detailed knowledge of possible changes in bank load caused by navigation due to the use of alternative revetment types. Knowledge gaps ought to be closed here, and bases for a more general acceptance and application of technical-biological bank protection measures as an alternative to traditional revetment types should be created.

The long-term aim of the studies is to provide WSV planning staff with sound bases and recommendations for the application of alternative technical-biological bank protection measures. These will be an important decision-support in order to increase the use of

alternative protection methods closer to nature for maintenance, development and construction measures instead of traditional bank protection methods.

The project is being implemented by the BAW Earthworks and Bank Protection Section (G4 – having the primary responsibility) and the Interaction ship/waterway, field investigations Section (W4) together with the BfG Departments U3 “Vegetation Studies, Landscape Management” and U4 “Fauna and Ecology”. Furthermore, very intensive collaboration with the local Offices *(Ämter)* and regional Directorates *(Direktionen)* of the German Federal Waterways and Shipping Administration (WSV) is required. In this context we would like to acknowledge the provision of documentation and information by all participating administrations as well as the practical support for the on-site studies.

2 Documentation

All project-specific documents that have been used to work on this project as well as all sub-reports and intermediate results gained in the context of this project are given below. General technical literature, relevant directives and regulations and similar are listed under “Literature” at the end of this report.

/IWS-TB 6/2005/ Franke, J., Kengatharam, T., Wieprecht, S.
Alternative, naturnahe Ufersicherungen an schiffbaren Gewässern - Internationale Literatur, Vorschriften und Erfahrungen - (Alternative, nature-oriented bank protection on navigable water bodies – International literature, regulations and experiences)
Technischer Bericht Nr. 6/2005, erstellt im Auftrag der BAW
Eigenverlag, Stuttgart 2005, 43 S. (Technical report no. 6/2005, commissioned by BAW; self-published, Stuttgart 2005, 43 pages)

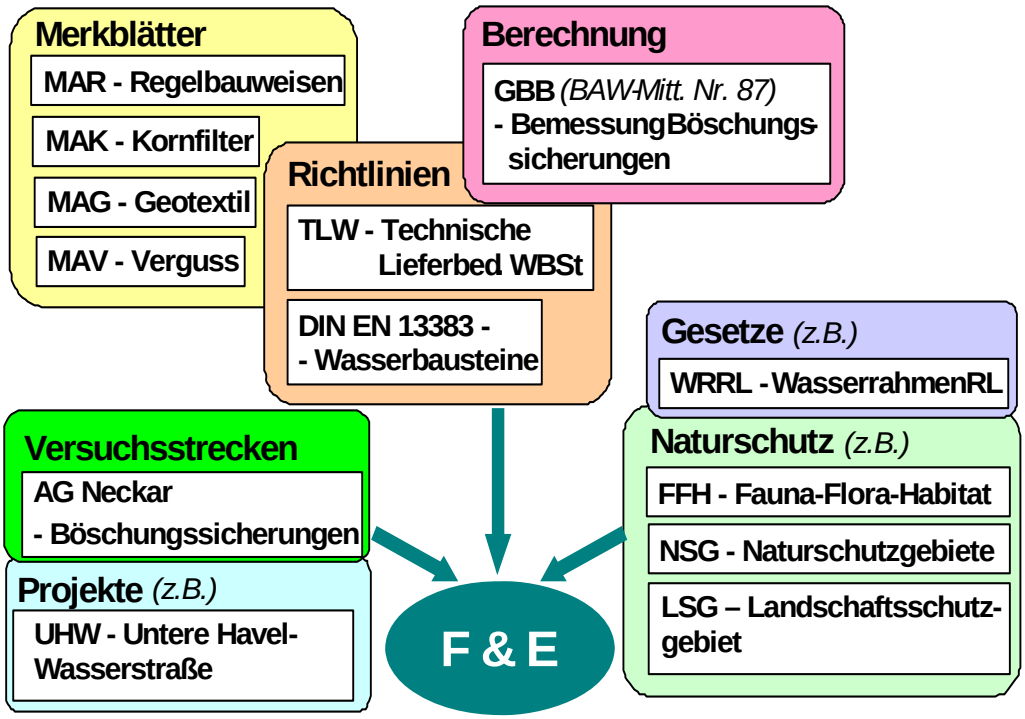
3 Background, Initiation and Purposes

3.1 General

Freight, passenger and recreational navigation on the German federal waterways – i.e. rivers, reaches and canals – result in a hydraulic load on the banks. In most cases bank protection is necessary in order to

- prevent bank damage and slope failure
- exclude danger for riparian residents and their properties
- prevent the sediment input into the bed and the respective change of the bed-load balance
- avoid danger to navigation.

The most important aspect for all measures is to guarantee bank stability. But also ecological aspects are becoming more and more important in the context of waterways maintenance, development and construction and therefore need to be taken into appropriate consideration for maintenance and construction measures. So far no recommendations or guidelines for alternative technical-biological bank protection methods on navigation-loaded waterways exist.



Merkblätter **= Codes of Practice**
MAR Regelbauweisen = MAR Standard Construction Methods
MAK Kornfilter = MAK Granular Filters
MAG Geotextil = MAG Geotextiles
MAV Verguss = MAV Grouting
Berechnung **= Design**
GBB = GBB (BAW-Bull. No. 88) - Design Bank Protection
Richtlinien **= Guidelines**
TLW - Techn Lieferbed. WBSt. = TLW – Techn. Suppl. Cond. Armourst.
DIN EN 13383 Wasserbausteine = DIN EN 13383 Armourstones
Versuchsstrecken **= Test stretches**
AG Neckar – Böschungssicherungen = AG Neckar – Slope protection
Projekte (z.B.) **= Projects (e.g.)**
UHW-Untere Havel-Wasserstraße = LHW – Lower Havel Waterway
Gesetze (z.B.) **= Laws (e.g.)**
WRRL – WasserrahmenRL = WFD – Water Framework Directive
Naturschutz (z.B.) **= Environment protection (e.g.)**
FFH – Fauna-Flora-Habitat = FFH – Fauna-Flora-Habitat
NSG – Naturschutzgebiete = NSG – nature conservation areas
LSG – Landschaftsschutzgebiet = LSG – landscape protection area

F&E = R&D

Figure 3.1: Technical and legal aspects, new design approaches, ongoing projects and working-groups as an impetus for the R&D project

Accordingly, the need to establish an R&D project called “Studies on alternative technical-biological bank protection measures” resulted from numerous technical and legal aspects, new design approaches /BAW 2005/ and from ongoing project work and working groups (cf. Figure 3.1).

3.2 Background

3.2.1 Technical Aspects

Current bases for choosing and dimensioning bank protection measures are, amongst others, different BAW *Merkblätter (Codes of Practice)* and *Empfehlungen (Recommendations)*.

- Code of Practice “Use of Standard Construction Methods for Bank and Bottom Protection on Waterways” /MAR 1993/
- Merkblatt Anwendung von Kornfiltern an Wasserstraßen (Code of Practice “Use of granular filters on waterways”) /MAK 1989 / available in German
- Code of Practice “Use of Geotextile Filters on Waterways” /MAG 1993/
- Code of Practice “Use of Cement Bonded and Bituminous Materials for Grouting of Armorstones on Waterways” /MAV 1990/
- Principles for the Design of Bank and Bottom Protection for Inland Waterways (GBB), published in *Mitteilungsblatt (Bulletin) No. 88 of BAW*, 2005

The objective of all these guidelines, recommendations and design suggestions is to guarantee bank stability under the given hydraulic loads with the well-known geometrical and geotechnical parameters.

When determining bank protection measures, from a technical point of view, the following – binding – guidelines and standards are important too:

- Zusätzliche Technische Vertragsbedingungen – Wasserbau für Böschungs- und Sohlsicherungen (Leistungsbereich 210) /ZTV-W 2000/ (Supplementary technical contract conditions – Hydraulic Engineering (ZTV-W) for bank and bottom protections, service area 210) / available in German

- Technische Lieferbedingungen für Wasserbausteine /TLW 2003/ (Technical supply conditions for armourstones) / available in German
- Technische Lieferbedingungen für Geotextilien /TLG 2003/ (Technical supply conditions for geotextile filters, English version: 1993)
- Richtlinien für Regelquerschnitte von Schifffahrtskanälen /BMV 1994/ (guidelines for standard cross-sections of navigation canals)
- Wasserbausteine /DIN EN 13383/ (Armourstones)

3.2.2 Legal Aspects

From an environmental protection point of view, decrees, instructions, laws and guidelines of German, European and international relevance need to be considered, such as:

- German Federal Waterways Act (*Bundeswasserstraßengesetz WaStrG*) § 8 (1): For maintenance actions, nature balance needs to be taken into consideration. The appearance as well as the recreational value of the riparian zone need to be considered too. Natural life bases need to be kept.

- Erlass BW 16/52.01.00-0/58/VA 91 ("ecology decree"): Decree BW 16/52.01.00-0/58/VA 91 of 6 September 1991 requires that ecological interests need to be considered in the maintenance of German federal waterways. At the same time it clarifies that navigation-related maintenance measures do not principally aim at ecological improvements as these are the competence of the German *Länder*. A variation improving the ecological situation can be opted for if it is self-financing or if its purpose is e.g. to guarantee a longer lifetime of the structure or a reduction in maintenance.

- *Handlungsanweisung für die Berücksichtigung von Naturschutz und Landschaftspflege bei der Unterhaltung von Bundeswasserstraßen (HANATSCH-WSV)*. (Instructions for taking nature protection and landscape management into account when maintaining German federal waterways)

- *Bundesnaturschutzgesetz (BNatSchG)* (German Federal Nature Conservation Act): Pursuant to § 6 (2) BNatSchG, German Authorities at the Federal level shall support the implementation of the aims and principles of nature conservation and landscape management within their respective scope of responsibility. When managing land in public ownership or possession (e.g. by WSV), particular attention shall be given to the aims and principles of nature conservation and landscape management (§ 7 BNatSchG). Furthermore the German Federal *Länder* may specify that – pursuant to § 9 BNatSchG – owners and authorized users of land are obliged to tolerate measures of nature

conservation and landscape management on their land to the extent that this will not unreasonably restrict utilization of the land concerned. Pursuant to § 31, the *Länder* shall ensure that surface waters, including their littoral zones and strips of vegetation cover alongside water courses, are preserved as habitats and sites for native species of fauna and flora and are further developed in such a way that they are able to fulfil their extensive interlinking functions to ensure connectivity and permeability on a lasting basis.

- Designations as protected areas based on § 22 BNatSchG and corresponding nature conservation laws of the German *Länder*: *Naturschutzgebiet* (nature conservation area), *Nationalpark* (national park), *Biosphärenreservat* (biosphere reserve), *Landschaftsschutzgebiet* (landscape protection area), *Naturpark* (nature park), *Naturdenkmal* (natural monument), or *geschützter Landschaftsbestandteil* (protected landscape component).

- Legally protected biotopes pursuant to § 30 BNatSchG or respective nature conservation laws of the *Länder*.

- *Bundesartenschutzverordnung* (Federal Ordinance on the Conservation of Species).

- Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for Community action in the field of water policy (Water Framework Directive WFD). In § 4, Member States commit themselves to the aim of achieving a good ecological and chemical condition of the bodies of surface water. For all artificial and heavily modified bodies of water they commit to the aim of achieving a good ecological potential and a good surface water chemical condition.

- Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (Habitats Directive): The aim is to ensure the maintenance of natural habitats and species of Community interest in a favourable conservation condition. For this purpose a coherent EU-wide network of nature protection areas called “NATURA 2000” should be established. Within this system of nature protection areas, any deterioration of the conservation status of habitats and species is prohibited.

- Council Directive of 2 April 1979 on the conservation of wild birds (79/409/EEC) (the “Birds Directive”): This Directive relates to the conservation of all species of naturally occurring birds in the wild state in the European territory of the Member States to which the Treaty applies. The nature protection areas that should be established for this purpose are part of the EU-wide network of nature protection areas called “NATURA 2000”. Bird habitats inside and outside the protected zones should be preserved, maintained and created by means of the upkeep and management in accordance with the ecological needs.

- Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora as well as Council Directive 79/409/EEC on the conservation of wild birds are transposed into German law by §§ 32, 33 and 34 of the *Bundesnaturschutzgesetz* (German Federal Nature Conservation Act).

- Convention on Biological Diversity (Rio Convention) § 8 (h): Each Contracting Party shall, as far as possible and as appropriate, prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species.

3.2.3 Projects

From completed and ongoing projects of the BAW and BfG it becomes obvious that there is a need for research in the field of alternative technical-biological bank protection on waterways. Here only two projects each of the BAW and BfG shall be presented as examples.

In chapter 3.2.3.1, studies at the Lower Havel Waterway undertaken by BAW are presented, whereas chapter 3.2.3.2 considers the use of alginate on the *Mittellandkanal*. Also the BfG has been increasingly addressed concerning technical-biological bank improvement. Studies undertaken on the *Mittellandkanal (MLK)* (chapter 3.2.3.3) and the River Neckar (chapter 3.2.3.4) are presented as examples.

3.2.3.1 Lower Havel Waterway (LHW)

Within the framework of the development of existing waterways towards achieving a uniform European waterways network, the *Verkehrsprojekt Deutsche Einheit – Projekt 17* (Transportation project “German reunification” – Project 17) is of special importance for connecting the new German *Länder* as well as countries further east. This concerns the 260 km long waterway connection of Hanover and Berlin. A section of this is the Lower Havel Waterway also called “Flusshavel” (UHW-km 32.6100 – 54.250).

The River Havel is a typical lowland river which is additionally regulated with impoundments with a small gradient and therefore low flow velocities. The section mentioned between the locations Ketzin and Brandenburg is characterized by several large lakeside areas, river bends, shorter canal-like cut-offs as well as numerous small islands. It is an old natural landscape that has for a long time been formed by man. With its banks rich in vegetation, this stretch has a highly nature-like character over its entire length. Along this stretch there are many protection areas – landscape protection and nature conservation areas, Fauna-Flora-Habitats (FFH) and Important Bird Areas (IBA) of European relevance.

BAW Section W4 was commissioned by the *Wasserstraßen-Neubauamt WNA Berlin* as early as 1999 to provide a new alignment and fairway design for the *Flusshavel* – with the objective of realising Project 17, to evaluate the respective wave load on the banks and to suggest necessary bank protection measures. In this context, the development guidelines currently valid as well as technical-biological construction methods ought to be considered.

3.2.3.2 Mittellandkanal (MLK) section in the city of Hanover

In the area of the city of Hanover, the Mittellandkanal (km 159.350 to km 173.465) was developed in 1999. Due to very close settlements, a combined rectangular trapezoidal profile with low space needs was chosen. In some sections the sheet pile wall ends a little below or above the water level with a slope continuing above. Locally this gives way to small shallow-water zones in the bank area that could be arranged in a more nature-like way with plants. In order to enable vegetation quickly, alginate was additionally pumped into the voids between the partially grouted armourstones mounted in the bank areas. This is a fluid topsoil treated in a specialized mixing plant to which a soil stabilizing material e.g. bio-algen is added. Contrary to the vegetation measures otherwise undertaken where topsoil is only “broomed” into the riprap layer and therefore no contact is built-up to the dam or soil body, in this case a continuous and homogeneous body has been created. Bio-algen is a vegetable soil stabilizing material that is produced in combination with montmorillonite colloids. When mixed with water it forms a water-insoluble clay-humus-complex. In suspension, bio-algen has thixotropic characteristics and therefore achieves a certain erosion stability. The experiences with alginate – which in the meantime has been applied in other fields too – should be evaluated within this research project in order to enable well-founded recommendations for further applications.

3.2.3.3 Phytosociological studies of different revetment types on the *Mittellandkanal (MLK)*

In the middle of the 90's the BfG studied – commissioned by the regional Waterways and Shipping Directorate *Mitte* (Centre) – different revetment types on the *Mittellandkanal (MLK)* between km 125 and km 159.2 /BfG 1995/. This study was aimed at evaluating the different revetment types as regards their suitability as a biotope for plants in the bank zones. Loose riprap, partially and fully grouted armourstones were studied.

Partially and fully grouted revetments differ as regards their layer build-up, the size class of the armourstones applied and the type and quantity of the grouting material used. Some revetments had a topsoil topping and were planted to different degrees. Within this study, the zone of fluctuating water level and the terrestrial slope were considered separately.

At the moment of the study, the revetments were between a few months and 15 years old so that highly different durations had been available for vegetation development.

On parts of the older partially grouted revetments, species-rich vegetation had developed on the terrestrial areas. However, plants existed only to a moderate extent on all revetments studied in the zone of fluctuating water level. Due to the varying revetment ages, it was not possible at that point in time to provide a concluding evaluation of the revetments from a phytosociological point of view.

The study is used as the basis for further investigations of the nature-conservation classification of revetments and bank protections on the *Mittellandkanal* as they are planned for 2006.

3.2.3.4 Experiences gathered on the River Neckar

Fauna: *Ecological classification of different bank protection types (River Neckar km 44.2 – 44.6), shown by macrozoobenthos re-naturalization behaviour; 1988 - 1997*

The direct comparison, which is necessary for an ecological evaluation of the different bank protection types, is complicated by the generally limited number of different slope protection types at a specific water body section and by the different ages of the various protection measures. So far, studies were predominantly focused on specific bank protection types (e.g. /Tittizer, Kothe 1983; Leuchs, Schleuter 1990 and 1991a; Leuchs et al. 1993; Kallenbach, Altvater 1995; Geier 1994/).

Therefore in 1988 within the framework of the Working Group “Untersuchung naturnaher Böschungssicherungsarten am Neckar” (*Investigation of nature-like bank protection types on the River Neckar*), within the Neckarsteinach reach of the River Neckar, a test section was established, under the direction of the German Federal Institute of Hydrology (*Bundesanstalt für Gewässerkunde BfG)*, near Neckar-km 44 with four bank protection measures in order to check the ecological classification of different bank protection types (cf. chapter 3.2.4). Within the subsequent 10 years, quantitative studies of the development of macrozoobenthos on different bank protection types were carried out. Detailed results of the different years studied can be found in /Leuchs, Schleuter 1989, 1991b, 1992 and 1994; Schleuter 1995; Leuchs et al. 1998/.

The test section is located on the right River Neckar bank at Ne-km 44.2 – 44.6 in a slight right hand bend. The different test lots are each 50 m long. In the flow direction, first comes a bank section protected by a “stone mattress”, then a “grouted riprap”, a “loose riprap” and a “shallow-water zone with breakwaters”. Most of the shallow-water zone is separated from the river by a dam consisting of loose riprap, and in its lower section it is connected to the river by

several perturbance stones acting also as wave breakers. The unmodified bank areas upstream and downstream of the test lots that were protected by “riprap which has in the meantime reached an advanced deterioration stage”, were included in the study as reference surfaces (reference lots as so called “zero lots”). The structure of the test section is described in more detail in /Leuchs et al. 1998/.

Vegetation: *Observation of different revetment types and different bank sections with differentiated maintenance by means of phytosociological studies*

In a pilot section at Neckar-km 76 - 80 downstream of Obrigheim, the left bank is operated as a slip-off slope section without any further maintenance and is studied with regard to its phytosociological and bank-morphological development. The wire mesh mattresses (gabions) present on the bank with 1:2 gradient are subject to time-dependent deterioration and provoke a long-term bank regression with formation of steep banks with the effect that in parts of the immediate zone of changing water level, slim shallow-water zones have formed with vegetation growing that is typical of rivers.

In the test section at Neckar-km 44, the renaturation of the above bank sections protected in different manners has also been studied from a phytosociological point of view with the immediately adjacent land surfaces being considered too.

For straightening the current in a flatter bank section near Ladenburg in the River Neckar area around km 13.6 – 13.9, a stone line was installed on the left bank and its effects on vegetation and fauna were observed. Especially in the downstream area, in the free-flowing River Neckar, rare submersed macrophytes have been discovered which offer important habitats within the running waters system for the faunistic inhabitants.

The accompanying of further projects, even if they have already been finalised – such as a newly planted reed surface near Eberbach – is connected with the monitoring activities of the Working Group “Untersuchung naturnaher Böschungssicherungsarten am Neckar” *(Investigation of nature-like bank protection types at River Neckar)* (cf. 3.2.4).

3.2.4 Working Groups

In 1988 the local Waterways and Shipping Office (WSA) Heidelberg created the Working Group “Untersuchung naturnaher Böschungssicherungsarten am Neckar” *(Investigation of nature-like bank protection types at River Neckar).* The motive for establishing this WG was the WSA’s wish to apply, if possible, alternative technical-biological bank protection measures within the framework of necessary maintenance works at the River Neckar banks. Therefore in the same year a section at River Neckar-km 44.2 – 44.6 was arranged on the left bank, consisting of (cf. 3.2.3.4)

- existing development with old riprap (zero lot; > 50 m),
- stone mattresses (gabions; 50 m),
- grouted riprap (50 m),
- loose riprap (50 m),
- shallow-water zone with breakwaters (50 m) and
- existing development with old riprap (zero lot; > 50 m).

Furthermore in the entire area of the local Waterways and Shipping Office, alternatives to technical bank protection have been tested from time to time, e.g. (double) row of piles, hurdle, shallow-water zone, stone line, bank left in its natural state etc.

In order to ensure that the measures are accompanied by experts, annual meetings combined with on-site visits are organised. Participating parties are always:

- local Waterways and Shipping office (*WSA*) Heidelberg,
- BAW, Karlsruhe
- BfG, Koblenz.

Depending on the bank section considered, they are complemented by

- the regional Waterways and Shipping Directorate *Nördlicher Oberrhein*,
- a lower nature-protection authority (*Rhein-Neckar-Kreis*, *Heidelberg* or *Nördlicher Oberrhein*) and
- municipal administrations.

Core aims of the WG are

- to accompany the different measures by experts,
- to evaluate measures from a geotechnical, hydraulic, fauna-, flora- and nature-protection-related point of view (including the realisation of the necessary studies and observations), and
- to elaborate concepts for other River Neckar stretches.

The experience the WG has acquired jointly within the past 15 years shall be included in this R&D project and thereby become the basis for considerations covering all Germany.

3.3 Initiation

The project was started at the BAW in March 2004 on the basis of a R&D application. Shortly afterwards, the BfG was addressed for possible and necessary collaboration – since the expert knowledge and the experiences of BfG would be imperative for the problems of alternative, technical-biological bank protection.

The BAW is rather focused on the technical aspects of bank improvement whereas the BfG deals with the biological aspects of alternative bank protection measures.

In the first joint meetings (Karlsruhe: 15.09.04, Koblenz: 15.03.05) of all parties involved (3.3.1) and in the subsequent first site surveys (River Weser/Stolzenau: 15.11.04, River Rhine/Walsum-Stapp: 19.04.05) it has been determined what should be understood as “alternative technical-biological bank protection” (3.3.2) in the sense of the R&D project and how the investigation efforts shall first be limited (3.3.3).

3.3.1 Parties Involved

The project is being implemented by the BAW Earthworks and Bank Protection Section (G4 – having the primary responsibility) and the Interaction ship/waterway, field investigations Section (W4) together with the BfG Departments U3 “Vegetation Studies, Landscape Management” and U4 “Fauna and Ecology”. Project managers and participants are listed in Table 3.1.

Table 3.1: Project managers and participants of the R&D project

Authority	Section / Department	Name	Function	Phone / email
BAW	G4	Ms. P. Fleischer	Project management (primary responsibility)	+49 (0)721/9726-3570 petra.fleischer@baw.de
BAW	W4	Dr. R. Soyeaux	Project management	+49 (0)721/9726-3650 renald.soyeaux@baw.de
BfG	U3	Mr. S. Kolb	Participant	+49 (0)261/1306-5316 kolb@bafg.de
BfG	U3	Mr. H. Liebenstein	Participant	+49 (0)261/1306-5445 liebenstein@bafg.de
BfG	U3	Mr. H.-W. Herz	Participant	+49 (0)261/1306-5341 herz@bafg.de
BfG	U3	Dr. A. Sundermeier	Participant	+49 (0)261/1306-5151 sundermeier@bafg.de
BfG	U4	Dr. J. Koop	Participant	+49 (0)261/1306-5404 koop@bafg.de
BfG	U4	Dr. M. Schleuter	Participant	+49 (0)261/1306-5469 schleuter@bafg.de
BMVBS	EW 23	Mr. K. Schäfer	Participant	+49 (0)228/300-4235 kai.schaefer@bmvbw.bund.de

3.3.2 Definitions

General

In natural running waters, biotopes and biocenoses develop without human impact. Here the formation of longitudinal gradient, cross-section, bank etc. is subject to the laws of nature. The ecosystems depending on this maintain an equilibrium-like state by self-regulation.

Due to the modification from natural to man-made landscapes and the related growing use – amongst others – by navigation, large running waters have strongly been modified and cannot be called “natural running waters” any more.

Considering current bank design and protection for large running waters, the situation that has formed due to the wave load caused by navigation must be characterized as “man-made”. Apart from individual areas with a more nature-like design, e.g. gravel or sand banks, often connected with a low-water regulation by groynes, large parts are protected by merely technical means, with artificial or natural paving, loose or grouted riprap, sometimes also with sheet pile walls or asphaltic concrete.

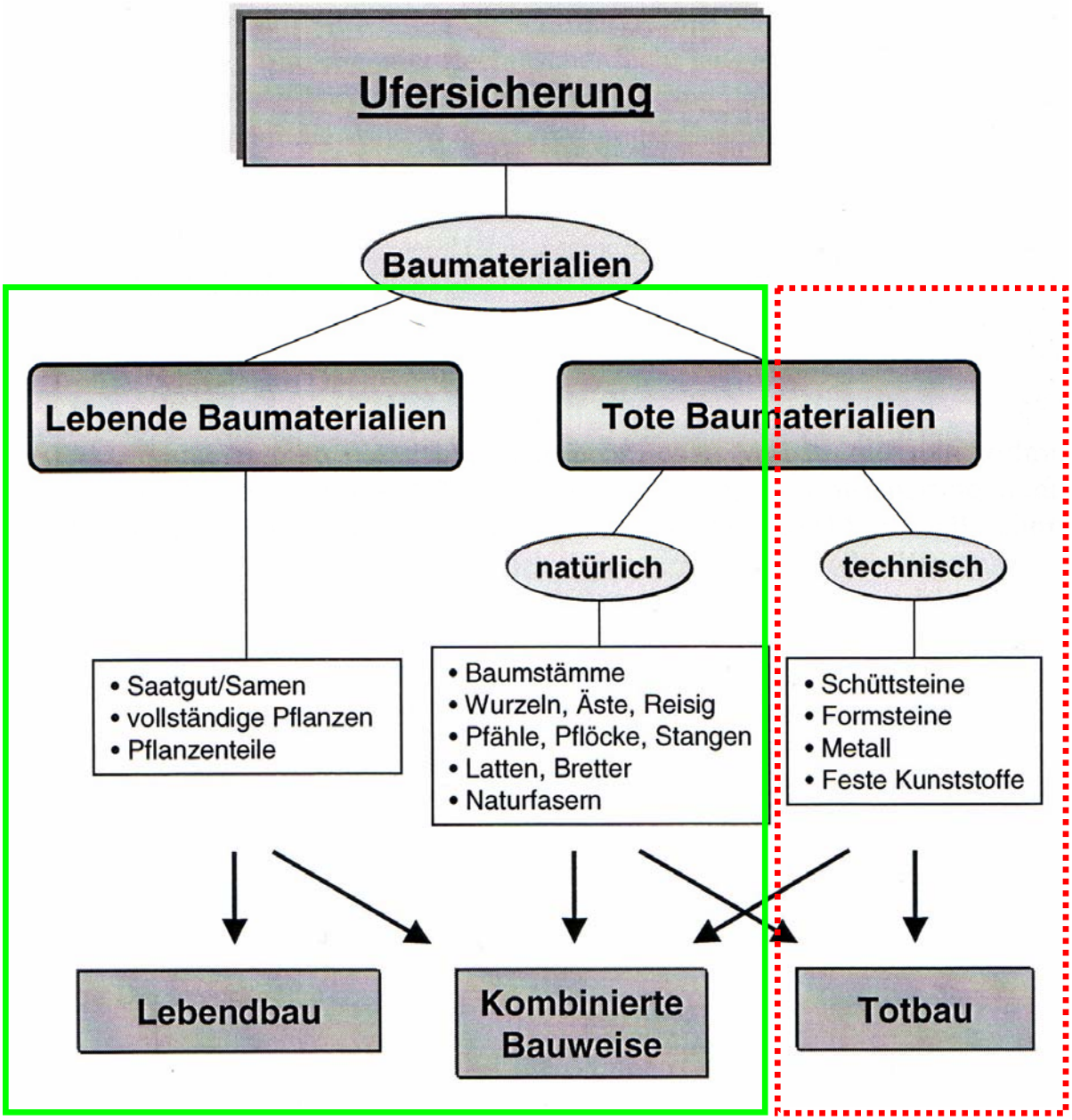
Alternative bank protection

With the growing change of awareness that not only the use, but also the consideration of ecological aspects are highly relevant for running waters, the requirements of bank improvement and protection have also changed. And additionally the national law (*Bundesnaturschutzgesetz* – German Federal Nature Conservation Act) as well as international law (EU Habitats, Bird Protection and Water Framework Directive) underline more and more the function of running waters.

In order to meet – especially when considering banks and their protection – technical requirements and to consider ecological aspects at the same time, it is necessary to study, develop and apply alternative bank protection methods.

In this context, the term “nature-oriented bank protection” is often used. This term is contradictory as in the case of bank protection it cannot be presumed that we are considering banks that have evolved without direct human impact or that have not been modified substantially by humans. Also the use of natural materials (such as natural stones, deadwood or plants) does not justify this term.

Therefore, alternative bank protection measures on large running waters with navigation are, depending on the wave load, construction methods meeting technical requirements and including living and/or dead plants or plant components (e.g. trees, shrubs, sets, live brush mattresses and plants of reed collectives). Therefore all construction types concerned are classified as “**Technical-biological bank protection measures**” with bank protection measures consisting of purely vegetable building materials being considered besides combined methods using stones and plants (cf. Figure 3.2).



Ufersicherung	= Bank protection
Baumaterialien	= Building materials
Lebende Baumaterialien	= Living building materials
Tote Baumaterialien	= Dead building materials
natürlich	= natural
technisch	= technical
Saatgut/Samen	= Seeds
vollständige Pflanzen	= Entire plants
Pflanzenteile	= Plant components
Baumstämme	= Tree trunks

Wurzeln, Äste, Reisig	= Roots, branches, brushwood
Pfähle, Pflöcke, Stangen	= Piles, spiles, stakes
Latten, Bretter	= Laths, boards
Naturfasern	= Natural fibres
Schüttsteine	= Riprap
Formsteine	= Shaped stones
Metall	= Metal
Feste Kunststoffe	= Solid plastics
Lebendbau	= Vegetative construction
Kombinierte Bauweise	= Combined construction method
Totbau	= Dead construction

Figure 3.2: Building materials that can be used for bank protection. Materials dealt with in this R&D project are bordered in **green**; cf. /Schillinger 2001/.

3.3.3 Limitations

In order to set limits before working on the research project, the parties involved first of all decided to confine bank protection measures to the fairway's immediate surrounding where they are directly exposed to the effects of hydraulic load (Table 3.2).

Table 3.2: Definition of alternative bank protection measures considered and not considered within the framework of this R&D project

Considered by the R&D project	**Not** considered by the R&D project
- Banks left in their natural state - Banks improved with vegetable materials - Banks with plants - Combinations of all above possibilities - Combination of technical and biological bank protection measures - Variations of slope inclination or profile	- Groynes - Groyne fields - Shallow water zones, separated from the waterway

3.4 Procedure

First of all, it was decided that the procedure would consist of the following steps:

- Research regarding the use of alternative technical-biological bank protection methods on waterways on the basis of international literature, information from the web and contacting authorities or research institutions abroad (call for tenders)
- Carrying out a survey in regional Directorates and local Offices on stretches already existing within the WSV's area of responsibility where alternative bank protection measures have already been applied (BAW + BfG)
- Documentation of survey results and international research (BAW + BfG)
- Visiting some carefully chosen representative WSV stretches (BAW + BfG)

- Choosing stretches for extensive detailed studies (see below for focuses) amongst these representative WSV stretches (see below for criteria) and documentation in individual reports (BAW, BfG, local Waterways and Shipping Offices + call for tenders)
- Establishing and monitoring new test sections on the basis of expertise acquired so far (BAW, BfG, local Waterways and Shipping Offices + call for tenders)
- Quantifying the load-bearing capacity of alternative technical-biological bank protection measures suitable for waterways (BAW + call for tenders)
- Establishing recommendations of possible applications of alternative technical-biological bank protection measures on waterways as a function of hydraulic load in the form of simple specifications up to measure types and reference stretches (BAW + BfG)
- Enabling exchange amongst experts and practitioners (workshops)

Criteria for choosing representative WSV stretches are:

- Diversity regarding waterway cross-section, navigation and measure type,
- A documentation state as high as possible at BAW, BfG and local Waterways and Shipping Offices,
- Already realised studies of fauna, flora and navigational load, as well as
- A maximum service life of the stretch.

The following *focuses* are considered in the detailed studies:

- If the *topography* (cross-sections, site plan) of the selected stretch is missing or not up-to-date, it needs to be newly recorded. Also the *current stock of flora and fauna* needs to be determined. These data allow the drawing of important conclusions about change and developments of the stretches.
- Additionally a time-restricted *traffic survey* of the ship traffic (freight, passenger, and recreational traffic) is executed with recording of crucial data (ship dimensions, bank distance, travel speed, water level changes at the bank) to enable calculation of hydraulic load at the bank.
- Documentation of the studies regarding the bank protections' stability and observations on bank changes is being drawn up.

3.5 Objectives

First of all the following **short-term objectives** of the project are aimed at:

- Realisation and interpretation of the survey in the WSV area
- Awarding the international research to a university institute

- Documentation of WSV stretches as well as results of the survey and of the international research in a first sub-report
- Information encompassing the entire WSV on the first results of the research project (e.g. with a BAW letter or an article in a specialized magazine)
- Exemplary detailed study of first WSV stretches and documentation

The following **long-term objectives** are aimed at:

- Detailed studies and documentation of further selected WSV test stretches
- Drawing up technical specifications of appropriate alternative bank protection measures for waterways and reference stretches
- Drawing up recommendations on the potential application of alternative technical-biological bank protections on waterways
- Holding workshops for exchange between researchers and practitioners

The **main objective** of the studies is, on a long-term basis, to provide WSV planning staff with sound bases and recommendations for the application of alternative technical-biological bank protection measures. These will be a decision-support in order to increase the use of alternative, technical-biological protection methods for maintenance, development and construction measures instead of traditional bank protection methods. So the acceptance level of such measures can be augmented on a long-term basis and their application can be increased as far as this is technically feasible.

4 Survey within the Area of WSV

4.1 Questionnaire Design and Dispatching

In March – April 2004, BAW and BfG agreed upon a 3-page questionnaire that was sent out as an introduction to the research project in the entire area of WSV in order to gain an up-to-date overview of alternative technical-biological bank protection measures already applied on German waterways. These were first referred to as “bank protection measures close to nature” in the questionnaire and defined as “technical-biological” only during further dealing of this topic (see 3.3.2).

Most of the questions referred to 4 main fields:

- **Location** (serial identification number of the measure, regional Directorate, local Office and surrounding district *(Außenbezirk)*; water body, kilometre marking and bank)
- **Measure** (name, description, production procedure, executing body, year of construction, time of construction, costs)
- **Boundary conditions** (type of water body, dimensions and type of cross-section, navigation, hydrology and special events)
- **Experiences** (bank stability, fauna and vegetation, maintenance of bank protection and plant cover)

Further questions covered

- **photos** – if respondents were able to provide
- already **existing reports** that may have been drafted under technical or biological aspects
- the **need** for further studies and information regarding the use of alternative technical-biological bank protection measures in the local Waterways and Shipping Office concerned

The questionnaire is provided in **Appendix 1**.

The questionnaire was sent out on 30 April 2004 – together with an explanatory letter and a table of the 24 test stretches that were known at that time – to all 7 regional Waterways and Shipping Directorates that distributed it to their subordinate local Waterways and Shipping Offices. It was possible to fill in the questionnaire in written or digital form.

4.2 Return Rate and Answers

The questionnaire was answered between July 2004 and May 2005. Many answers were sent by the regional WSV Directorates to BAW in summarised form. Some were sent directly by the local Offices. Unclarities detected during a first very rough screening could in all cases be solved over the phone.

Regarding the questionnaire interpretation it needs to be taken into consideration that most but not all Offices and Directorates answered and returned the questionnaire. This means that not all stretches where alternative technical-biological bank protection measures have already been applied could be recorded and considered in the following results and interpretations. Furthermore, the way the Offices and Directorates understood and treated the questionnaires sometimes differed. This not only refers to the comprehensiveness of the descriptions and the size of individual stretches but also to the differences in the terminology used. This had been expected since no uniform definitions of specific measures or constructions exist so far within the WSV. Therefore in many cases, designations are not really precise and the measures declared are not to be classified as alternative (e.g. “sheet pile wall”). However, they were initially kept in the interpretation. In general, however, the existing data allow a good estimate of the technical-biological measures applied so far under various boundary conditions.

4.2.1 Matrix of Answers

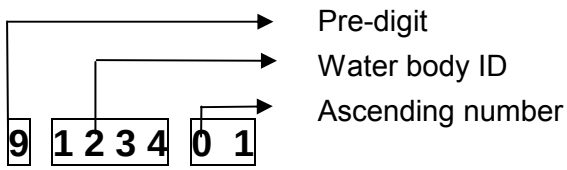
First, from the returned and answered questionnaires, all information was collected in a large EXCEL sheet that can be regarded as a “matrix” of the answers. Like a table, this matrix is composed of rows and columns explained below. Then the matrix was transposed into an Access database in an extended form by BfG. The matrix is enclosed with this report as Appendix 4 on a CD.

Rows

The different rows list all test stretches and measures declared. The first box of each row contains an unambiguous (7-digit) code composed of

- the pre-digit 9 in order to avoid a zero in the first place
- the (4 digit) water body identification number
- an ascending (2-digit) number per water body which, however, is not consecutive but oriented according to the surrounding districts in order to allow later addition of rows.

The structure is as follows:



Columns

The first columns contain the geographical information:

- Measure ID (digit 9 + 4-digit water body ID + 2-digit ascending number)
- Regional Waterways and Shipping Directorate
- Local Waterways and Shipping Office
- Surrounding district
- Water body
- Respective kilometre marking
- Stretch
- Bank (left/right)

Then follows the measure-related information:

- Location and name of the measure
- Short description of the measure
- Year of completion

As regards the boundary conditions, geometrical data such as

- water surface width,
- water depth,
- maximum water level fluctuation, and
- distance between fairway edge and measure,

data regarding the type, such as

- type of water body (canal/river/lake),
- bank geometry (T-profile / RT-profile / R-profile; slope / steep bank / shallow bank / shallow-water zone / others),

and navigation density data on

- freighters
- passenger ships,
- recreational vessels

were included in the matrix.

Then follow columns where the needs of continued studies and information on the application of alternative, technical-biological bank protection are given from the respondent's perspective:

- high
- average
- low
- no needs

Information on the vegetation was given in the columns

- Plant cover
- Maintenance_plant cover
- Report_vegetation

The column "Report_vegetation" indicates if phytosociological studies on the measure have already been executed.

The column

- New_planning

contains information on whether further bioengineering bank protection measures are being planned within the scope of the responding surrounding district.

The content of the matrix – so far presented in rows and columns – represents the informative part which is based on the answers from the questionnaires and is enclosed on a CD. The questionnaire is processed further and complemented by means of well-aimed visits and studies of specific stretches.

In order to interpret the questionnaire from a vegetation point of view, the columns

- *Anm_Vegetation* (Notes_vegetation)
- *Bew_Vegetation* (Evaluation_vegetation)
- *Vorgehen_Vegetation* (Procedure_vegetation)

are added in an ACCESS version of the table. The columns *Anm_Vegetation* and *Bew_Vegetation* are used for registering large texts and are therefore drafted in the Memo format. The column first mentioned contains all crucial additional information on vegetation that can be gathered from the questionnaires' appendices and from the supplied photos. Open questions on the measures are included here too. In the *Bew_Vegetation* column, the measures are evaluated argumentatively from a phytosociological point of view. The *Vorgehen_Vegetation* column defines the procedure regarding the measure (e.g. if site visit is necessary, if double-checking with the local Office is necessary, etc.).

For the evaluation of the fauna, further columns are added on the following subjects:

- Estimation of the faunistic value in the terrestrial area (*Wert_Ist_terra* / Value_Is_terra)
- Estimation of the future faunistic value in the terrestrial area (*Wert_Prog_terra* / Value_Forec_terra)
- Estimation of the faunistic value in the aquatic area (*Wert_Ist_aqua* / Value_Is_aqua)
- Estimation of the future faunistic value in the aquatic area (*Wert_Prog_aqua* / Value_Forec_aqua)
- Basic notes on the fauna (*Bemerkfauna* / Statement_fauna)
- Notes on risk factors for the fauna (*Faunrisiko* / Faun_risk)
- Notes on the vegetation structures faunistically relevant (Vegetation)
- Names of photos existing on the areas mentioned (Photo_name)
- Introduction of a characteristic figure of this area (*Bild* / Figure)

Additionally, both BAW and BfG add their own columns and rows for the presentation of plans and for statistical interpretation. BAW includes the following dimensions in columns:

- Average kilometre of the measure
  (calculated from the information given in the questionnaires)
- Easting and northing at the medium kilometre
  (calculated on the basis of hectometre files that could in most cases be sent on specific request from the local Waterways and Shipping Offices)

The areas registered until the end of May 2005 were categorized in 12 groups as explained in 4.2.2. According to these groups, 2 columns are added in the matrix each time, where first the group association and second the respective stretch are given. A few concluding lines are added on the number and stretches of the sites reported.

In the chosen table structure, each measure corresponds to only one row. Therefore it can be completely integrated into ACCESS and offers convenient possibilities for graphical representation in combination with ArcGIS (e.g. Figure 4.1).


Bundesanstalt für Gewässerkunde
BUNDESANSTALT FÜR WASSERBAU
ABTEILUNG WASSERBAU IM BINNENBEREICH
Übersicht Naturnahe Ufersicherungen
Schleswig-Holstein
Hamburg
Mecklenburg-Vorpommern
Bremen
Niedersachsen
Brandenburg
Berlin
Sachsen-Anhalt
Nordrhein-Westfalen
Thüringen
Sachsen
Hessen
Rheinland-Pfalz
Saarland
Bayern
Baden-Württemberg
Legende
Naturnahe Ufersicherungen
Bundeswasserstraßen
Uferstelle
1:750'000

Übersicht Naturnahe Ufersicherungen	= Nature-oriented bank protection measures
Legende	= Legend
Naturnahe Ufersicherungen	= Nature-oriented bank protection measures
Bundeswasserstraßen	= German federal waterways
Uferstelle	= Bank site

Figure 4.1: Map showing all stretches and measures reported

4.2.2 Overview of Measures

A total of 157 individual measures were reported by the end of May 2005 – all shown in Figure 4.1. For a better overview of the huge number of stretches and for a clearer presentation of comparative statements, the measures were categorized into 12 main groups (cf. Table 4.1). This classification is first of all based on the reportings. BfG started to visit all stretches, to document them by photos and to describe the banks. Based on these data it should be checked later if the categorizations by the following groups can be retained. Already for the classification as “nature-oriented”, differences arise after having visited 40 % of the sites.

Table 4.1: List of the 12 groups of measures for the sites

Nr.	Farb-code	Maßnahmengruppe
1		Lebendbau und Bepflanzung
2		Vergossenes Deckwerk und Bepflanzung
3		begrüntes Deckwerk (+Steinschüttungen)
4		Pfahlreihen (einfach, doppelt)
5		Faschinen (Röhrichtwalze)
6		Flachwasserzone
7		flacher Böschungsübergang
8		naturbelassen
9		Parallelwerke
10		Spundwand
11		Rauhwehr
12		Buhnen

Nr.	= No.
Farbcode	= colour code
Maßnahmengruppe	= measure group
Lebendbau und Bepflanzung	= vegetative construction and planting
Vergossenes Deckwerk und Bepflanzung	= grouted revetment and planting
begrüntes Deckwerk (+ Steinschüttungen)	= vegetative bank protection (+ riprap)
Pfahlreihen (einfach, doppelt)	= rows of piles (single, double)
Faschinen (Röhrichtwalze)	= fascines (reed fascine)
Flachwasserzone	= shallow-water zone
flacher Böschungsübergang	= flat slope transition
naturbelassen	= nature-oriented
Parallelwerke	= longitudinal groynes
Spundwand	= sheet pile wall
Rauhwehr	= branch packing
Buhnen	= groynes

According to these 12 groups, 2 columns were added to the matrix each time where the first column is the assignment to the group and the second one the respective stretch. Plans where only registrations of a single group are presented are enclosed as **Appendix 2**.

The chosen assignment to the groups of measures is applied in the statistical interpretation given in Chapter 4.2.3.

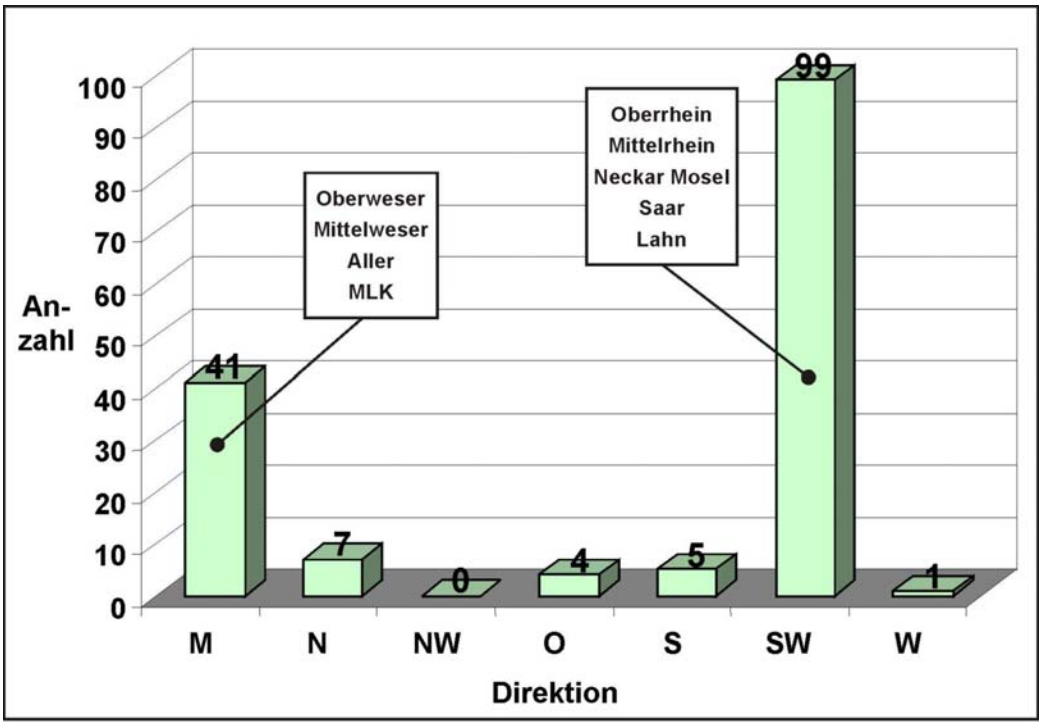
4.2.3 Statistics

First and obvious statistical interpretations of the replies are: according to the Directorates and water bodies, according to groups of measures for the entire German territory (i.e. not separated according to water bodies), and according to the type of water bodies, the bank geometry and the needs.

- According to the regional WSV Directorates

Most reportings (41 and 99 corresponding to 89.2 %) came from local WSV Offices of the regional Directorates *Mitte* (Centre) and *Süd-West* (South-West) (cf. Figure 4.2).

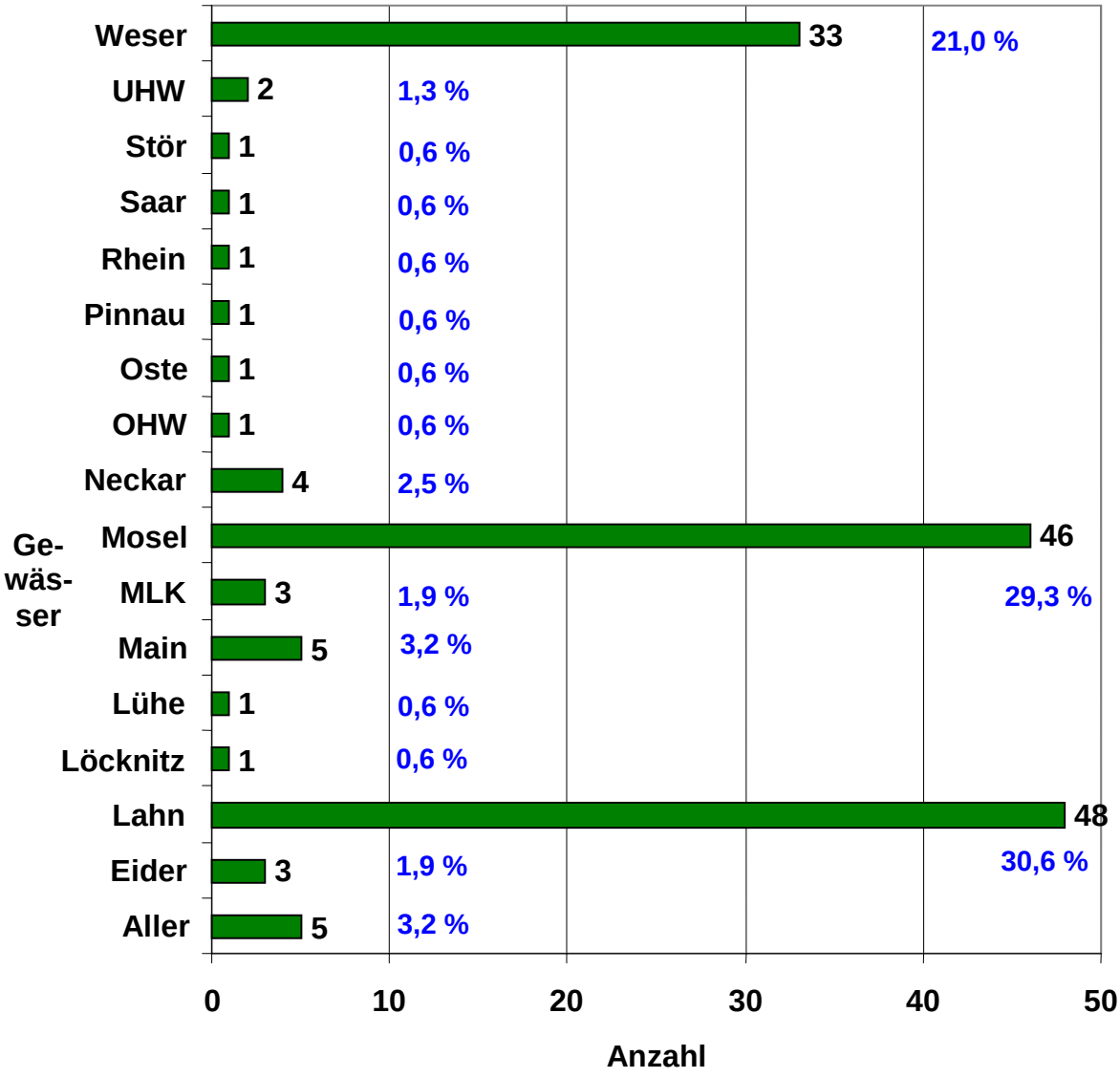
Some reportings (4, 5 and 7 corresponding to 10.2 %) came from the WSV Directorates *Nord* (North), *Ost* (East) and *Süd* (South). No to few registrations (0 and 1 corresponding to 0.6 %) came from the WSV Directorates *Nord-West* (North-West) and *West* (West). There is a relationship between the number of reportings of the different Directorates and the type, size and traffic load of the water bodies within their respective areas of responsibility.



Oberweser	= Upper Weser
Mittelweser	= Middle Weser
Oberrhein	= Upper Rhine
Mittelrhein	= Middle Rhine
Mosel	= Moselle
Anzahl	= Number
Direktion	= Directorate
M = C	
O = E	

Figure 4.2: Assignment of the reported stretches to the Directorates

- According to the water bodies



Gewässer	= Water body
UHW	= Lower Havel Waterway (LHW)
OHW	= Upper Havel Waterway (UHW)
MLK	= MLK
Rhein	= Rhine
Mosel	= Moselle
Anzahl	= Number

[Bitte in den Prozentangaben jeweils Kommas durch Punkte ersetzen.]

Figure 4.3: Distribution of the reported stretches according to water bodies

The distribution of the reported stretches according to water bodies is presented in Figure 4.3. Altogether 17 water bodies are considered: free-flowing and impounded river sections as well as canal stretches; sections of these are marked in the diagram, with their (absolute) number and their fraction (relative to 157 sites reported) given by bars. 80.9 %, i.e. more than ¾ of all reported stretches, are to be found on the three Rivers Lahn, Moselle and Weser (rivers controlled by weirs or other works) alone. The remaining 19.1 % of the stretches are part of the remaining 14 water bodies – with an average of about 2 stretches per body of water.

- According to measure groups

Table 4.2: Assignment of the reported stretches to the 12 groups of measures with the respective overall length of the stretch considered

Maßnahme	**Anzahl [-]**	**Anteil [%]**	**Strecke [km]**	**Anteil [%]**
Lebendbau und Bepflanzung	49	22,7	47,8	22,8
Vergossenes Deckwerk und Bepflanzung	1	0,5	16,3	7,8
begrüntes Deckwerk (+ Steinschüttungen)	35	16,2	50,57	24,2
Pfahlreihen (einfach, doppelt)	7	3,2	2,17	1,0
Faschinen (Röhrichtwalze)	15	6,9	4,63	2,2
Flachwasserzone	6	2,8	2,49	1,2
flacher Böschungsübergang	20	9,3	18,77	9,0
naturbelassen	64	29,6	48,93	23,4
Parallelwerke	10	4,6	11,9	5,7
Spundwand	1	0,5	0,3	0,1
Rauhwehr	3	1,4	2	1,0
Buhnen	5	2,3	3,35	1,6
Summe:	**216**	**100**	**209,21**	**100**

Maßnahme	= Measure
Anzahl	= Number
Anteil	= Part
Strecke	= Stretch
Lebendbau und Bepflanzung	= vegetative construction and planting
Vergossenes Deckwerk und Bepflanzung	= grouted revetment and planting
begrüntes Deckwerk (+ Steinschüttungen)	= vegetative bank protection (+ riprap)
Pfahlreihen (einfach, doppelt)	= rows of piles (single, double)
Faschinen (Röhrichtwalze)	= fascines (reed fascine)
Flachwasserzone	= shallow-water zone
flacher Böschungsübergang	= flat slope transition
naturbelassen	= nature-oriented
Parallelwerke	= longitudinal groynes
Spundwand	= sheet pile wall
Rauhwehr	= branch packing
Buhnen	= groynes
Summe	= Total

[Bitte bei den Prozentangaben jeweils Kommas durch Punkte ersetzen.]

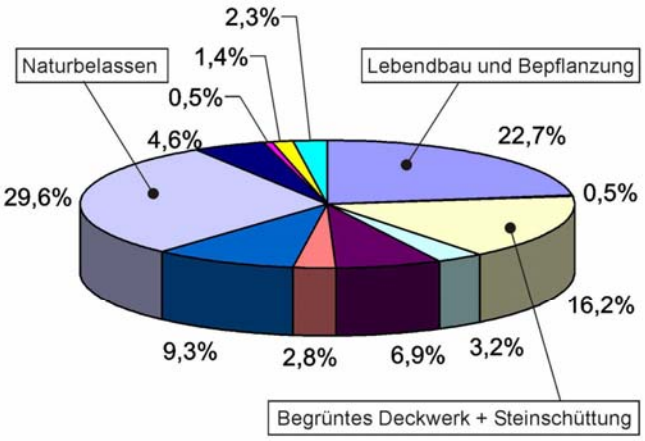
Referring to the groups of measures defined in 4.2.2 and assigning the different stretches to these measures gives a clear impression of the distribution of the measures applied. First of

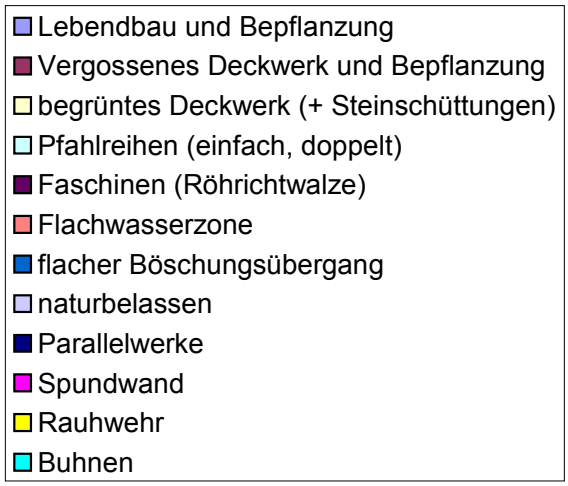
all the interpretation was done for the entire German federal territory. The results are summarized in Table 4.2 and presented in Figure 4.4 in two pie charts. The interpretation was done in parallel for the mere number of measures (cf. Figure 4.4 above) on the one hand and for the respective stretches (cf. Figure 4.4 below) on the other.

In Table 4.2 it can be seen that the number 216 is higher than the number of sites reported (157). This is due to the fact that on some stretches several methods were applied so that some stretches were classified in several groups. So interpreting the groups of measures tells us how often each of these groups occurs.

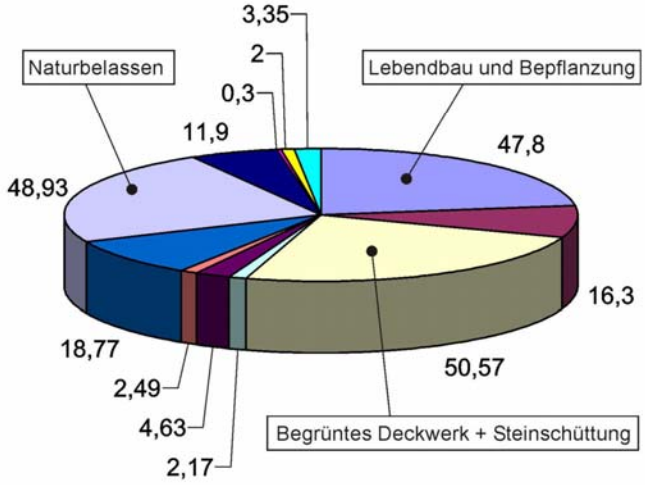
In the interpretation regarding the existing length of the stretches, parallel applications due to unclear assignments become relevant. As a result, the mentioned total length of 209.2 km is greater than the reported length of 160 km. This must be considered in the pie diagram in Figure 4.4 below.

Anteil der Maßnahmen alle Gewässer [%]





Strecken der Maßnahmen / alle Gewässer [km]



Anteil der Maßnahmen alle Gewässer [%]	= Shares of the measures for all water bodies [%]
Strecken der Maßnahmen / alle Gewässer [km]	= Stretches of the measures / all water bodies [km]
Lebendbau und Bepflanzung	= vegetative construction and planting
Vergossenes Deckwerk und Bepflanzung	= grouted revetment and planting
begrüntes Deckwerk (+ Steinschüttungen)	= vegetative bank protection (+ riprap)
Pfahlreihen (einfach, doppelt)	= rows of piles (single, double)
Faschinen (Röhrichtwalze)	= fascines (reed fascine)
Flachwasserzone	= shallow-water zone
flacher Böschungsübergang	= flat slope transition
naturbelassen	= nature-oriented

Parallelwerke	= longitudinal groynes
Spundwand	= sheet pile wall
Rauhwehr	= branch packing
Buhnen	= groynes

[Bitte in den Prozentangaben jeweils Kommas durch Punkte ersetzen.]

Figure 4.4: Assignment of the reported stretches to the 12 groups of measures (above) according to the share of the measures and (below) according to the related overall stretch lengths – each in total for all water bodies

For those water bodies of which several stretches were reported – i.e. Rivers Aller, Lahn, Main, Moselle, Neckar and Weser – the assignments according to the groups of measures have been presented in Table 4.3 and are given graphically in **Appendix 3**.

Table 4.3: Assignment of the reported stretches to the 12 groups of measures for 6 chosen rivers (Rivers Aller, Lahn, Main, Moselle, Neckar and Weser) with the respective length of the stretch

Maßnahme	**Aller**		**Lahn**		**Main**	
	Anzahl [-]	**Anteil [%]**	**Anzahl [-]**	**Anteil [%]**	**Anzahl [-]**	**Anteil [%]**
Lebendbau und Bepflanzung	1	10	6	10	2	25
Vergossenes Deckwerk und Bepflanzung						
begrüntes Deckwerk (+ Steinschüttungen)	1	10	2	3		
Pfahlreihen (einfach, doppelt)			1	2		
Faschinen (Röhrichtwalze)	4	40	3	5		
Flachwasserzone			2	3	2	25
flacher Böschungsübergang			3	5	1	13
naturbelassen			38	63	1	13
Parallelwerke			3	5	1	13
Spundwand						
Rauhwehr	2	20			1	13
Buhnen	2	20	2	3		
Summe:	**10**	100	**60**	100	**8**	100

Maßnahme	**Mosel**		**Neckar**		**Weser**	
	Anzahl [-]	**Anteil [%]**	**Anzahl [-]**	**Anteil [%]**	**Anzahl [-]**	**Anteil [%]**
Lebendbau und Bepflanzung	4	5			33	89
Vergossenes Deckwerk und Bepflanzung			1	13		
begrüntes Deckwerk (+ Steinschüttungen)	27	36			3	8
Pfahlreihen (einfach, doppelt)			1	13		
Faschinen (Röhrichtwalze)					1	3
Flachwasserzone			2	25		
flacher Böschungsübergang	14	19	2	25		
naturbelassen	24	32	1	13		
Parallelwerke	5	7	1	13		
Spundwand						
Rauhwehr						
Buhnen						
Summe:	**74**	100	**8**	100	**37**	100

Maßnahme	= Measure
Anzahl	= Number
Anteil	= Part
Lebendbau und Bepflanzung	= vegetative construction and planting
Vergossenes Deckwerk und Bepflanzung	= grouted revetment and planting
begrüntes Deckwerk (+ Steinschüttungen)	= vegetative bank protection (+ riprap)
Pfahlreihen (einfach, doppelt)	= rows of piles (single, double)
Faschinen (Röhrichtwalze)	= fascines (reed fascine)
Flachwasserzone	= shallow-water zone
flacher Böschungsübergang	= flat slope transition
naturbelassen	= nature-oriented
Parallelwerke	= longitudinal groynes
Spundwand	= sheet pile wall
Rauhwehr	= branch packing
Buhnen	= groynes
Summe	= Total

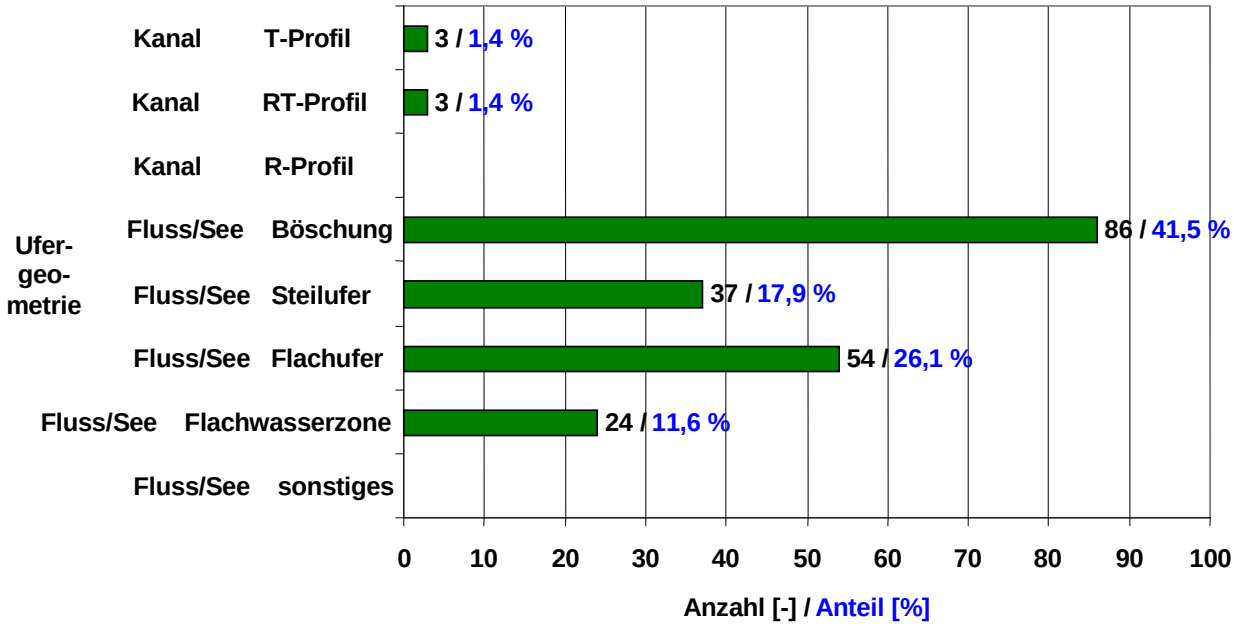
- According to the type of water body

Looking at the correlation between the type of water body and the number of stretches reported results in the following numbers:

Canal	7	corresponding to	5.3 %
River	124	corresponding to	94.7 %
Lake	0	corresponding to	0 %

It becomes obvious that most of the stretches reported are to be found in river sections – i.e. in river sections controlled by weirs or other works – where the possibilities of applying alternative bank protection methods would probably be highest. Here in most cases the expected bank load caused by navigation is less compared to canals where stretches were earmarked in only a few cases (5 %). In the case of canals this is due to the narrow cross-section ratios (canal cross-section / ship cross-section) that can cause strong bank load caused by navigation. In most cases, the resistance of alternative bank protection measures to them is insufficient. For rivers, however, a higher load can be expected temporarily, i.e. during floods.

- According to the bank geometry



Ufergeometrie	= Bank geometry
Kanal	= Canal
Fluss/See	= River/lake
T-Profil	= T-profile
RT-Profil	= RT-profile
R-Profil	= R-profile
Böschung	= Slope
Steilufer	= Steep bank
Flachufer	= Shallow bank
Flachwasserzone	= Shallow-water zone
sonstiges	= other
Anzahl	= Number
Anteil	= Share

[Bitte bei den Prozentangaben jeweils Kommas durch Punkte ersetzen.]

Figure 4.5: Assignment of the reported stretches to the different types of bank geometry

The answers to the question concerning the bank geometry of the reported stretches reveal once more what already becomes obvious from Figure 4.3. The largest part of the stretches is located along the banks of rivers (cf. Figure 4.5). Banks with the usual slope inclination are found in about 41 %, steeper banks in some 18 % and flatter banks in about 26 % of the reported stretches. Real shallow-water zones were reported in about 12 % of the replies.

- According to the needs

Also the need for basic studies and recommendations regarding the application of alternative technical-biological bank protection measures was surveyed. The question aimed at any further basic needs within the scope of the respective local Waterways and Shipping Office. The results show that the need for this kind of study is seen by most of the interested parties all over Germany – as confirmed by the following numbers:

44 (34 % ≅ 1/3)	no need
84 (66 % ≅ 2/3)	need (with different priorities)

4.2.4 Interpretations

When it comes to interpreting the results, the limitations mentioned under 4.2 need to be taken into consideration: no 100 % response rate, different lengths of the stretches, and different terminology and assignments. This means that no complete picture valid for the entire WSV can be given. Also the local distribution of the stretches with alternative bank protection measures applied is probably not representative of the entire WSV. For example, individual parts with alternative bank protection measures applied almost over the entire length were reported for some river stretches, whereas other river sections were not reported at all although they are known to bear comparable stretches too.

Furthermore, besides the various natural preconditions existing at the German Federal waterways and the different load situations caused by navigation, the experiences, the financial situation and the staff situation of the participating parties are relevant too. Current construction types often follow local historical examples. As the possibilities regarding finances and staff also strongly impact the construction mode, it is often decisive if the respective measure is meant for construction, development, maintenance, compensation, testing or as part of vocational training.

Comparing the local distribution of the reported stretches with an up-to-date application of the tonnages shows (cf. Figure 4.6) that alternative bank protection measures are very often tested on waterways with low to medium traffic volume and only rarely on stretches with a high traffic volume. Furthermore, Figure 4.6 (left) clearly indicates that apparently more alternative bank protection measures have been applied so far on rivers than on canal sections. The reason for this will probably be the fact that the cross-section of canal sections is normally constant and relatively narrow as dimensioned for the sailing vessels. In most cases, the admissible ratio of canal cross-section to ship cross-section is fully exploited with the bank load being correspondingly high. Here it will presumably become difficult to

implement alternatives to purely technical bank protection. On the other hand, river cross-sections are less uniform and provide local extensions where hydraulic load is lower. However, bank load and thereby the possibility to apply technical-biological bank protection is influenced by various factors. Besides the cross-section ratios these are, amongst others, the ship speed (or the speed limits imposed), the type of navigation (e.g. predominantly recreational boats or large freighters), bends (e.g. slip-off slope or undercut slopes in the case of rivers), or potential flood events (mainly in the case of rivers). However a well-founded statement on the use of technical-biological bank protection measures under these boundary conditions can only be given once the planned studies have been completed.

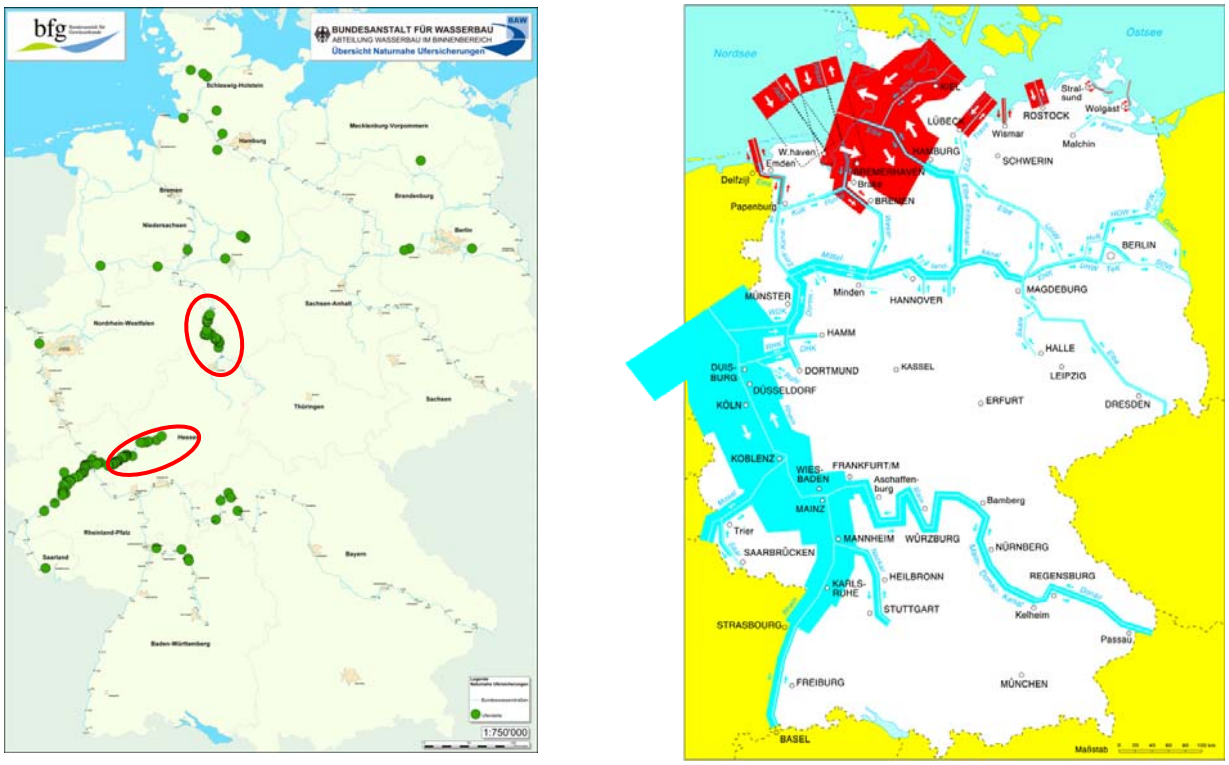


Figure 4.6: Comparison of the reported stretches with up-to-date application of the tonnages

5 International Research

5.1 Objectives and Methods

In October 2004, the Department of Hydraulic Engineering and Water Resources Management (*Lehrstuhl für Wasserbau und Wassermengenwirtschaft*) at Stuttgart University was commissioned to carry out international research on the issue of alternative bank protection on waterways. The main objective of this scientific study was to find out what measures have been or are being used in different parts of the world to avoid erosion in riverine zones caused by navigation. The following countries were selected and focussed on:

- France
- Great Britain
- Netherlands
- Austria
- Romania
- Switzerland
- Hungary
- Russia
- Ukraine

Europe

- China
- United States of Amerika

Outside Europe

Germany was not considered since the BAW and BfG have sufficient knowledge. The main selection criterion worldwide was that the bank protection needed to be directly exposed to navigational load.

The study contained the following tasks:

- Compiling and screening existing literature
- Addressing the waterways and shipping administrations of the different countries, requesting information on experiences, application examples and research undertaken on alternative bank protection in their respective country
- Requesting universities and research institutes for theoretical considerations, model tests undertaken or practical applications (e.g. pilot tests)
- Interpreting documents and catalogizing the different methods
- Compiling and evaluating the existing experiences, classified according to the categorized methods

Three methods were used to research information:

(1) Literature research in libraries
Available literature on methods to avoid erosion was aimed at. Research was done in all German libraries. Both publications and books were considered.
(2) Internet research
Several websites deal with the monitoring of erosion processes. On websites of environmental protection agencies, universities, research institutes and other organisations active in this field, their investigations are often displayed too.
(3) Direct contact with institutions, agencies, universities and organisations
Experts in bank protection on navigable water bodies from various countries were asked to collaborate by post. In some cases there was also contact over the phone in order to research the relevant works. The embassies of some countries in Germany were sent letters requesting the contact addresses of persons or authorities active in this field. If no answer was received within a couple of weeks, a reminder was sent out asking for replies.

5.2 Results

The results of the study are compiled in the Technical Report No. 6/2005 of May 2005 named *Alternative, naturnahe Ufersicherungen an schiffbaren Gewässern – Internationale Literatur, Vorschriften und Erfahrungen* (Alternative, nature-oriented bank protection on navigable water bodies – International literature, regulations and experiences) /IWS-TB 6/2005/. A rough overview of the results is given in Figure 5.1.

(1) Literatur	
Deutschland	5
Großbritannien	2
Indonesien	1
Niederlande	2
Österreich	1
USA	3
	14

(2) Internet	
Australien	1
Europa	2
Frankreich	1
Großbritannien	6
Kanada	1
Niederlande	1
USA	7
	19

(3) Email, Post		
China	1	1
Frankreich	3	3
Großbritannien	7	3
Niederlande	7	3
Rumänien	2	0
Schweiz	1	0
USA	25	1
	46	11

Literatur	= Literature
Deutschland	= Germany
Großbritannien	= Great Britain
Indonesien	= Indonesia
Niederlande	= Netherlands
Österreich	= Austria
USA	= US
Australien	= Australia
Europe	= Europe
Frankreich	= France
Kanada	= Canada
China	= China
Rumänien	= Romania
Schweiz	= Switzerland

Figure 5.1: Overview of the results of the international research
Explanations: Shown are the number of books on this topic, the number of internet sources consulted and the number of addressees contacted – with the response rate from the respective persons

5.2.1 Literature Research

The list of the 14 books found is enclosed in the appendix of the report quoted. However, the topics dealt with in the books mainly cover the general biological construction methods, such as bank erosion processes, construction, evaluating erosion problems etc. No literature on the actual problem has been found, i.e. technical-biological bank protection on waterways.

5.2.2 Internet Research

In the course of this research, 19 sources from Europe and 3 countries outside Europe were found. Most of the information found corresponds to the respective books, although often only abbreviated versions could be found on the internet. In most cases, the contact details of the persons working on these topics can be found on the websites. These persons were then contacted within the framework of this project, via email or by post. In general it took a long time before answers were received. Most of them never replied – although contacted several times. With several companies, contact is only possible via forms to be completed on the internet. But also in these cases there were no or very few replies.

5.2.3 Contact with Institutions, Universities and Organisations

An attempt was made to contact 46 different addressees in 7 countries. Only 11 of them replied, most of them corresponding to negative answers. A list of all persons contacted with the corresponding organisations in the different countries can be found in Section 2 of the mentioned technical report (/IWS-TB 6/2005/).

5.2.4 Technical-Biological Construction Methods on Waterways abroad

Only two European countries – France and Great Britain – provided detailed information material on technical-biological construction methods on waterways.

France

The French waterways administration authority “Voies Navigables de France (VNF)” provided a ‘Manual on bioengineering methods (French: *Guide des techniques végétales*) /VNF 2003/. This includes a brochure on the *application of bioengineering bank protection methods on waterways* covering the following items:

- Purposes of the banks
- History of VNF bank protection methods
- Legal background
- General on the methods
- Geotextiles
- Toe protections
- Plants
- Unwanted plants
- Maintenance
- Causes of failure
- Selection criteria

Furthermore, the manual contains – for more detailed information
10 Technical Specifications on the different methods and
13 Reference Sheets with execution examples.

- Technical Specifications

Here the following points are briefly explained for the various methods:

- Brief description of the method
- Hydraulic resistance
- Potential protection height
- Cost
- Material
- Execution
- Important notes
- Schematic sketch

- Reference Sheets

Here several methods are presented by individual or multiple application examples from the VNF scope according to the following scheme:

- Situation
- Problem
- Boundary conditions (hydrology, navigation)
- Solution
- Result
- Data (year of execution, costs)

A brief overview of the methods applied by VNF regarding name, load-bearing capacity, costs, stretch where applied, navigation is given in Table 5.1.

Great Britain

British Waterways provided the *Waterway bank protection guide* commissioned in 1999 by the Environment Agency and drafted by Cranfield University. It mainly covers small canals where only recreational shipping (recreational boats, house boats and similar) takes place. However, it contains only little information on alternative bank protection and the use of plants for bank protection.

British Waterways Environment Department provided a few photos and descriptions of technical-biological bank protection methods; however, it cannot be clearly recognized if these measures have been applied on navigational waterways or on other running waters.

Table 5.1: Overview of bioengineering methods applied by VNF for bank protection on waterways, /VNF 2003/

Designation	Water body, Location	Costs	Navigation
		€ / running metre	ships/year
planted rock-filled log cribs	Deule, Dép. Nord	about 300 (depending on the height)	200 freighters few recreational boats
willow fascines, branch layers, seedlings	Deule, Dép. Nord	61 (fascines) 76.20 (branch layers) 2.30 (1 seedling)	12500 freighters and recreational boats
shallow-water zone with initial planting	Deule, Dép. Nord	n/a	n/a (Lille harbour area)
willow hurdle (toe of the slope), branch layers, willow cuttings	Lys, Dép. Nord	46 (hurdle) 76.20 (branch layers)	n/a
shallow-water zone behind willow hurdle with initial planting	Lys, Dép. Nord	46	n/a
fascines with aquatic plants	Lys, Dép. Nord	61	n/a
fascines with aquatic plants	Sambre, Mun. Val du Sambre, Dép. Nord	150 - 230	1500 freighters and recreational boats
toe revetment of riprap and initial planting with aquatic plants in zone of fluctuating water-level or willow seedlings on the slope	Sambre, Mun. Val du Sambre, Dép. Nord	150 - 230	1500 freighters and recreational boats
fascines with aquatic plants	Developed River Moselle, Mun. Aingeray, Dép. Meurthe et Moselle	125	1300 recreational boats 3700 freighters
fascines with aquatic plants	Marne-Rhine-Canal, Mun. Dieue-sur-Meuse, Dép. Meuse	69	2000 recreational boats 650 freighters
willow fascines and initial plantings	Marne-Rhine-Canal, Mun. Einville, Dép. Meurthe et Moselle	57.5	2000-4000 recreational boats 650 freighters
initial planting (seedlings, layers)	Canal de Colmar, Mun. Colmar, Dép. Bas-Rhin	150 (seedlings) 15-25 (layer)	1800 recreational boats (summer semester), few freighters
initial planting	Marne-Saône-Canal	60 - 75	400-450 recreational boats 400-450 freighters
fascines with aquatic plants (prefabricated tubes)	Canal de l'Est (southern branch), Mun. Freland-Ambieviller, Dép. Haute-Saone	160	1000-3000 recreational boats 400 freighters

Abbreviations

Dép. Département
Mun. Municipality
WW changing water level

6 Conclusion

As result of the literature research it should be stated that obviously around the globe only few well-founded experiences, recommendations and application limits exist for technical-biological bank protection measures on waterways subject to navigational load. Of particular interest for further studies are documents drafted by the French waterways administration authority which has already published a brochure with recommendations for the application of “bioengineering methods”. These will have to be checked for their transferability to the situation on the German federal waterways.

The results of the survey performed in the German Federal Waterways and Shipping Administration on the use of alternative bank protection measures reveal that the methods used to apply alternative solutions differ a lot from one region to another. The differences are due to the different natural situations on the German federal waterways, to the different navigational load conditions, experiences and budget, as well as staff situations of the participating parties. Current construction types often follow local historical examples. Since the possibilities regarding finances and staff also impact the construction mode it is decisive if the respective measure is meant for construction, development, maintenance, compensation, testing or as part of vocational training.

The reported measures concern bank slope areas subject to different load situations. Some technical-biological measures ensure protection of the bank slope around the highest navigable water-level whereas slope areas situated below continued to be protected by conventional means. Far fewer of the reported measures also consider bank slopes around the mean water-level for protecting this zone of fluctuating water-level influenced by ship-induced waves using technical-biological measures.

And also bank sections were reported where for the time being it is not yet clear if the applied measures can be classified as alternative bank protection. Here, current ecological evaluations of the bank sections contrast with declarations as test sections or banks bearing alternative bank protection measures. However, this is often due to the interpretation possibilities of the question.

However, the feedback when presenting the research project also revealed a huge need of well-founded solutions and recommendations for the application of alternative technical-biological bank protection measures within the WSV. In the questionnaires, this need is explicitly confirmed by 2/3 of all answers received from the local Offices and regional Directorates.

Furthermore the survey pointed out that the local Offices have already applied alternative bank protection measures on a relatively high number of stretches on their own and have already gathered first experiences. Further studies within this research project can rely on these experiences and on existing research results of BfG from the preceding years.

However, from an ecological and technical point of view, final evaluation of the alternative bank protection measures will only be possible in many of the reported cases on the various waterways when additional studies have been completed.

7 Outlook

Based on the results of the WSV survey and the international literature research, individual stretches are being studied where technical-biological bank protection measures have already been applied. It is planned to examine the current state of the bank protection applied in these sections, to take stock of the vegetation and fauna, and to measure navigation-induced hydraulic load over a limited time period. So the experiences can be quantified and included in general recommendations. First, it is planned to study the following stretches:

- Test section Stolzenau (Middle River Weser km 241.55 to km 242.30),
- Longitudinal groyne Walsum-Stapp (River Rhine km 793.5 to km 795.0),
- Mittellandkanal (km 159.3 to km 173.4; km 180.0 to km 182.5; km 189.6 to km 190.1).

Further stretches are planned to follow. The results of the studies will be documented in written reports for the various sections. Furthermore it is planned to arrange new test sections that will be subject to extensive monitoring.

As final results, recommendations for alternative, technical-biological bank protection measures will be given and boundary conditions will be determined under which an application on waterways subject to navigational load is possible and useful.

Karlsruhe/ Koblenz, 04 May 2006

By order	By order	Primary responsibility
(Dr.-Ing. Kayser)	(Dipl.-Ing. Kolb)	(Dipl.-Ing. Fleischer)
(BAW)	(BfG)	(BAW)

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Glossary

Biocenosis: Ecological community of plants and animals that can be found in the same (→) biotope due to similar biotope requirements and unilateral or reciprocal dependencies.

Biotope: An environment or habitat populated by a characteristic assemblage of flora and fauna; characterized by certain uniform conditions separated from its surroundings.

Biotope: Habitat of a (→) biocenosis i.e. all abiotic factors acting upon a biocenosis.

Branch packing: In general classified as packed twigs and branches; application of one or several layers of mostly live willow branches e.g. to level out faults in the bank area; sometimes used as part of a longitudinal groyne (roughness elements in areas of the longitudinal groynes subject to wave overtopping can help reduce the wave overtopping velocity, e.g. in the River Main).

Brushwood Fence ("Lahnung"): Bank protection construction (e.g. to protect reed) as a double row piling, filled with stones or branches of willows capable of sprouting and/or brushwood which is not capable of sprouting.

Constancy: Frequency of a species, a species' age group or similar on several test sites (in percent of the test sites with the occurrence of the respective species, age group).

Cycles of matter: Flow of materials, elements and energy within and between individual spheres of the earth (e.g. carbon, oxygen, nutrient, nitrogen cycle).

Diversity: Measure of instars (species and structures) and of their uniform distribution in ecosystems related to the number of organisms, to a (→) biocenosis, an (→) ecosystem or a unit of space.

Dominance: Term used for the predominance of a species in a unit of surface or space compared to the other species. Dominant species can e.g. be conditioned by the best-adapted life-form, by physical strength, life expectancy or resistance.

EC Birds Directive: Directive aimed at the conservation of native wild birds and their habitats in Europe.

Ecosystem: Functional unit of (→) biotope and (→) biocenosis.

Evenness: Ratio of a biological community's (→) diversity to the maximum diversity for the given number of species.

Geographical Information System (GIS): Totality of hardware and software components necessary for collecting, maintaining, interpreting and presenting space-related data. Geographical data (maps) are processed together with technical data (descriptive data) and linked to each other within a GIS.

Habitats Directive (more formally known as **Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora**) **(FFH):** Directive aimed at creating a pan-European network of protected areas for the conservation of animal and plant species and their habitats.

Hydraulic load: Banks of water bodies are subject to natural impacts such as flow, wind waves and flood discharge and to man-made impacts such as waves, drawdown and return flow caused by navigation.

Important Bird Area (IBA): Bird conservation areas of international relevance according to § 4a of the (→) EC Birds Directive.

Invertebrates: Animals without an inner bone skeleton (e.g. planarians, snails, insects).

Live fascine: Cylindrical body of willow rods and branches in accordance with the location used to protect the bank at the toe and the mean water level; on a medium-term basis a seam of scrubs will establish that will ensure bank protection with gradual rooting of the subsoil.

Macroinvertebrates: (→) Invertebrates which can be seen with the naked eye and live in or on the bottom of water bodies and on the bank as well as on aquatic plants and reed beds.

Macrozoobenthos: (→) Macroinvertebrates living on the bottom of water bodies; “bottom fauna” in water bodies.

Man-made (anthropogenic): Consciously created by humans or dependent on humans.

Montmorillonite: Highly swellable clay mineral, main component of bentonite.

NATURA 2000: European system of conservation areas (as described in Art. 3 of the Habitats Directive) which should link all areas protected so far by the EC Birds Directive as well as all areas to be protected in the future according to the Birds Directive and the Habitats Directive within a functional network.

Natural: Not modified by man, left in the original state.

Nature-oriented / Close to nature: Development without direct human impact and only slightly modified by man, quite close to the natural state.

Reed (Reed bank zone): Plant communities mostly of high growth of the siltation zone in the aquatic area of running and stagnant water bodies; some species of the reed bank zone have their roots mainly in the soil substrate below the water-level and develop the green biomass predominantly above the water-line.

Reed fascine: Also called vegetal fascine; cylindrical geotextile rolls filled in the lower third with gravel and stones to provide safety of buoyancy and in the upper third with plant plugs e.g. consisting of reed to be found in the surroundings to encourage vegetation, the whole

enveloped in coir mats and wire netting; applied on stagnant and slow running waters with low water-level changes in the submerged and mean water level zone.

Revetment: Banks can be protected from unwanted erosion e.g. by permeable loose or grouted (→) riprap, impermeable surface linings, or alternative technical-biological protection measures as studied in this report.

Rip-rap: Form of technical bank protection with crushed stones – mostly with average dimensions of 20 – 30 cm – "poured" onto the sloped embankment over a filter; in most cases this is done in loose form, in specific cases also (partially) grouted.

Row of piles: Construction of weathering-resistant single timber piles in bank areas of low water depth; as single rows of piles driven directly next to each other to protect banks against wave run-up; also as double row piling – e.g. consisting of piles set apart from each other and linked by a hurdle – possible with stone filling and, if applicable, planting; use e.g. as (→) Brushwood Fence "Lahnung".

Self regulation: In the undisturbed final state, ecosystems regulate by themselves. Their components interact in such a way that a balance of the (→) cycles of matter is caused.

Shallow-water zone (in inland areas): Locally limited, unprotected bank section within an otherwise protected slope; inland from an (imaginary continuous) bank line – with a markedly lower water depth than the main water body and, if necessary, protected against the main water body by wave deflectors or smootheners e.g. in the form of a stone mound.

Sinking fascine: Cylindrical body of branches, in the interior of the bundles mostly filled with stones or weighted with gravel and stones to avoid buoyancy. Sinking fascines have diameters of some 0.8 to 1.2 m.

Smooth slope transition: As opposed to a uniform, steeper slope inclination which is normally to be found (e.g. around 1:2 – 1:3.5 in canals), here different slope inclinations alternate; mostly steeper under the water-level and passing into a flatter slope inclination e.g. below/above the mean water level.

Thixotropic: Semifluid materials becoming runny by mechanical impact (churning) and returning to their original higher viscosity when left immobile.

Vegetative bank protection: Bank protection using riprap or shaped stones containing initial planting or which will be vegetated with grass and herbs once the voids have been filled with soil.

Appendices

Appendix 1

Questionnaire (Form)

Appendix 2 to BAW letter of 30/04/2004

Questionnaire on existing test stretches with nature-oriented bank protection measures

Bundesanstalt für Wasserbau/ Bundesanstalt für Gewässerkunde

Studies on alternative, nature-oriented bank protection measure

Research project

Contact persons:

BAW: Ms. Fleischer, Dept. Geotechnical Engineering, Earthworks and Bank Protection Section, phone: +49 (0) 721/9726-3570, primary responsibility

Dr. Soyeaux, Dept. Hydraulic Engineering in Inland Areas, Interaction ship/waterway, field investigations Section +49 (0) 721/9726-3650

BfG: Mr. Kolb, Ecology Division, Vegetation Studies, Landscape Management Department, phone: +49 (0)261/1306-5316

Dr. Koop, Ecology Division, Fauna and Ecology Department, phone: +49 (0)261/1306-5404

Questionnaire to take stock of existing test stretches with nature-oriented bank protection measures applied within WSV – 2004

1 Site

Body of water			Regional WSV Directorate	
km	from	to	Local WSV Office	
Bank	right ☐	left ☐	Surrounding District	

2 Measure

2.1 **Name**

2.2 **Description**

2.3 **Production method**

2.3.1 Bank protection [1)]

2.3.2 Vegetation [1)] *(Species, distances between plants, planting plans, particularities, etc.)*

1) Vegetation may be the bank protection – in this case only explain here.

2.4 **Executing firm/s** 2.4.1 Bank protection [1)] 2.4.2 Planting [1)] *1) Vegetation may be the bank protection – in this case only explain here.*	
2.5 **Institutions involved** *(e.g. environment protection agencies, offices, research institutes, BAW, BfG)*	
2.6 **Year of construction** *(completion)*	
2.7 **Time of construction**	
2.8 **Costs**	Material
	In-house work *(staff)*
	Third-party work *(staff)*
	Total costs

3 Boundary conditions

3.1 **Type of water body**	Canal ☐	River ☐	Lake ☐
3.2 **Dimensions**	Water surface width [m]		
	Water depth in the area of the fairway [m]		
	Smallest distance of the measure to the fairway edge [m]		
3.3 **Bank geometry**	Canal	Trapezoidal profile	☐
		Rectangular/trapezoidal profile	☐
		Rectangular profile	☐
	River/ Lake	Slope	☐
		Steep bank	☐
		Shallow bank	☐
		Shallow water zone	☐
		Other	
3.4 **Navigation density** *(since production)*			
	sailing vessel types [ships per day]	pushing-units large motor vessels Europa Ships Passenger vessels Recreational boats Other	
	Most frequent ship types		
3.5 **Hydrology**	Water levels Canal	BW_u	

in [NN+m]		NoSt
		BW_o
	River/	NW
	Lake	MW
		HSW
		HW
Flood events	Year	
(since production)	Water level [NN+m]	
	Discharge [m^3/s]	

3.6 **Special events** *(since production)*

Averages

Ice load

Other

4 Experiences

4.1 **General**

4.2 **Bank stability** *(erosion, bank scars, silting up, etc.)*

4.3 **Animals**

Aquatic invertebrates (macrozoobenthos)
Fish
Small terrestrial animals (insects, amphibians etc.)
Birds
Mammals

4.4 **Vegetation**

Grass and herbs plantings
Reed bed *(reed grass, sedges, iris, etc.)*
Tall forbs
Groves

4.5 **Maintenance of bank protection** *(repair, restoration, etc.)*

4.6 **Maintenance of vegetation** *(type of care, e.g. mowing, frequency)*

5 Photos *(please enclose)*	
6 Existing reports *(please enclose)* 6.1 Bank protection 6.2 Vegetation 6.3 Fauna	
7 Checking the need How high do you estimate the need of well-founded recommendations for the application of nature-oriented bank protection measures in your area of waterways? High needs ☐ Average needs ☐ Low needs ☐ No need ☐	Are any nature-oriented bank protection projects in preparation within your area of responsibility? Yes ☐ No ☐ If yes, please explain briefly
Date	Person in charge
Phone number *(for any further queries)*	

Appendix 2

Maps of waterways showing the reported measures

Group 1: Vegetative construction and planting

Group 2: Grouted revetment and planting

Group 3: Vegetative bank protection

Group 4: Rows of piles (single, double)

Group 5: Fascines (reed fascines)

Group 6: Shallow-water zones

Group 7: Flat slope transition

Group 8: Banks left in their natural state

Group 9: Longitudinal groynes

Group 10: Sheet pile wall

Group 11: Branch packing

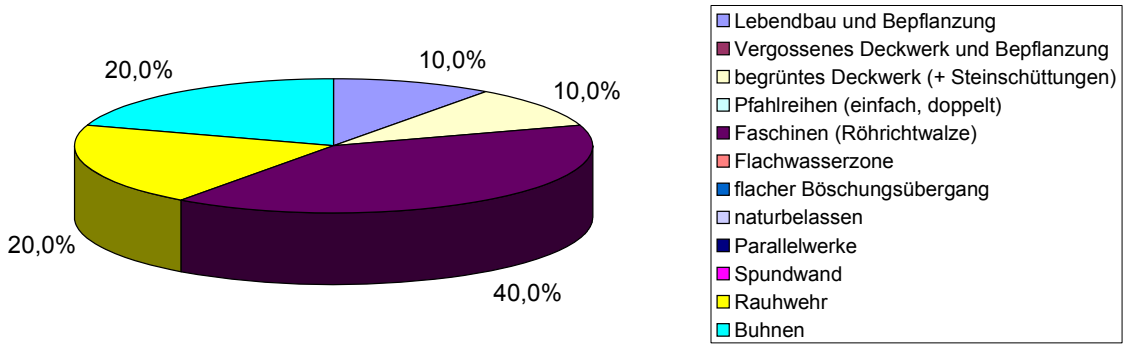
Group 12: Groynes

Appendix 3

Statistics of the reported measures on the Rivers Aller, Lahn, Main, Moselle, Neckar and Weser and on the Mittellandkanal

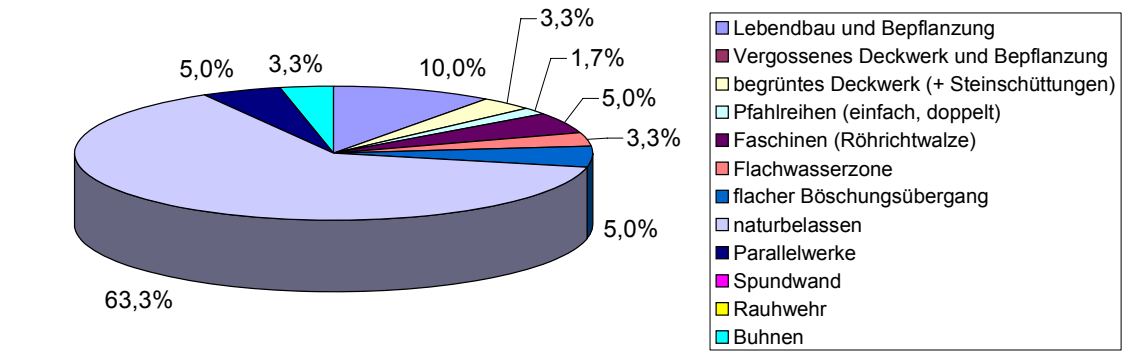
Measures applied on River Aller

Anteil der Maßnahmen / Aller [%]



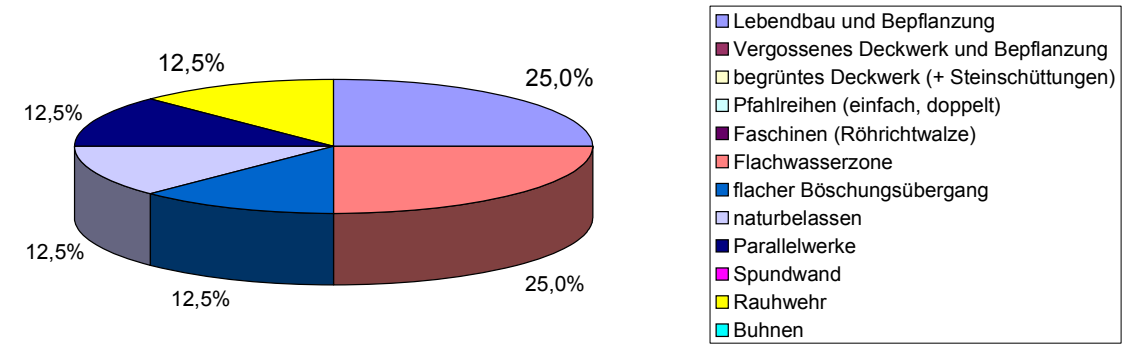
Measures applied on River Lahn

Anteil der Maßnahmen / Lahn [%]



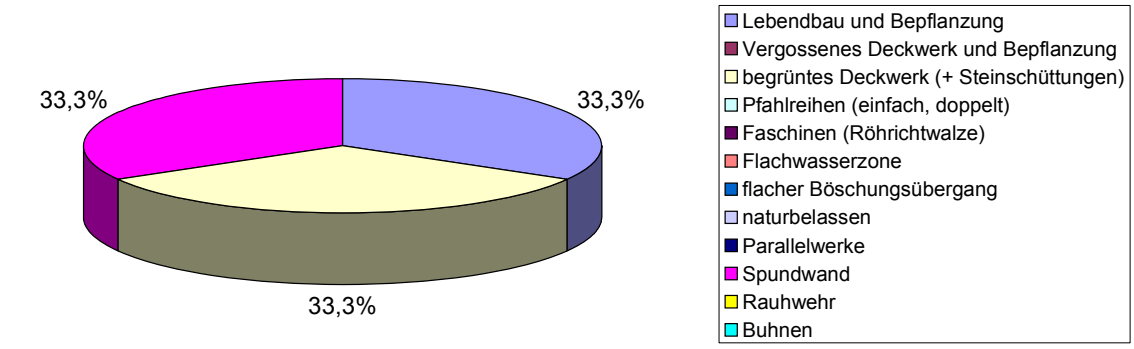
Measures applied on River Main

Anteil der Maßnahmen / Main [%]



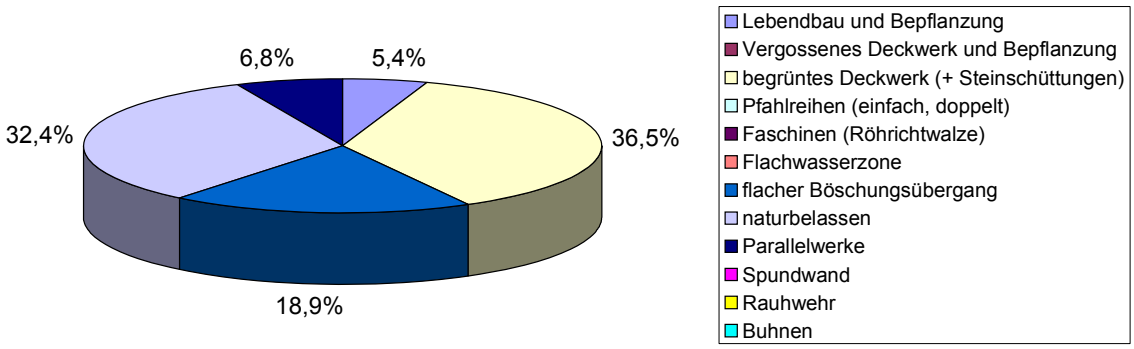
Measures applied on Mittellandkanal

Anteil der Maßnahmen / MLK [%]



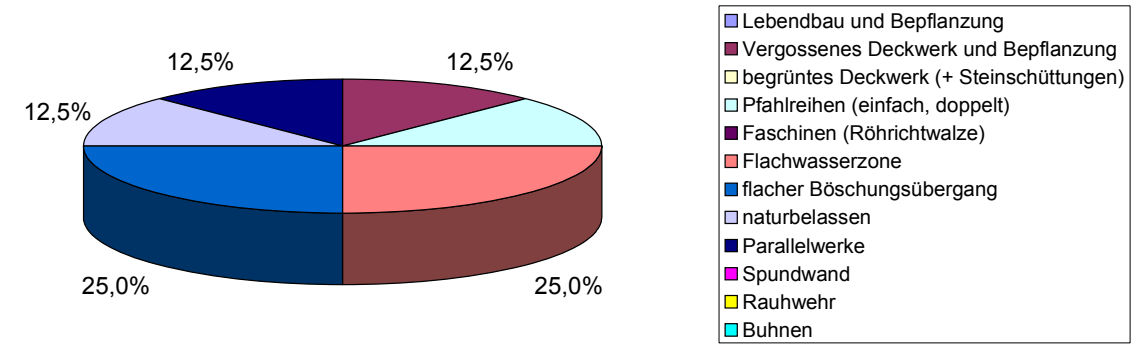
Measures applied on River Moselle

Anteil der Maßnahmen / Mosel [%]

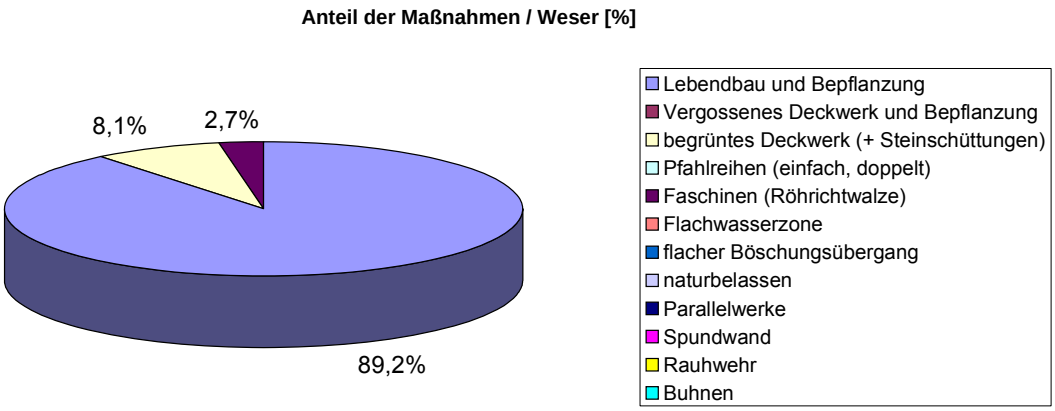


Measures applied on River Neckar

Anteil der Maßnahmen / Neckar [%]



Measures applied on River Weser



Anteil der Maßnahmen	= Part of measures
Lebendbau und Bepflanzung	= vegetative construction and planting
Vergossenes Deckwerk und Bepflanzung	= grouted revetment and planting
begrüntes Deckwerk (+ Steinschüttungen)	= vegetative bank protection (+ riprap)
Pfahlreihen (einfach, doppelt)	= rows of piles (single, double)
Faschinen (Röhrichtwalze)	= fascines (reed fascine)
Flachwasserzone	= shallow-water zone
flacher Böschungsübergang	= flat slope transition
naturbelassen	= nature-oriented
Parallelwerke	= longitudinal groynes
Spundwand	= sheet pile wall
Rauhwehr	= branch packing
Buhnen	= groynes

[Bitte in den Prozentangaben jeweils Kommas durch Punkte ersetzen.]

Appendix 4

Interpretation of questionnaires in tabular form (on CD)

CD:

Interpretation of questionnaires in tabular form