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586 – G/W

Investigations into alternative, technical-biological methods of bank protection on waterways in Germany – Results of a survey of waterways operated by the Federal Waterways and Shipping Administration

1 Content and objective

Shipping on inland waterways gives rise to hydraulic actions on the banks which are therefore protected by the appropriate measures, e.g. riprap revetments, to prevent damage due to erosion. The design of bank protection measures is currently based on the Code of Practice "Use of Standard Construction Methods for Bank and Bottom Protection on Waterways" [1] and the "Principles for the Design of Bank and Bottom Protection for Inland Waterways" [2]. It does not generally take ecological issues into account. However, greater importance is now being attached to ecological aspects in many construction projects, particularly in areas in which the conservation of nature is a high priority. The Federal Waterways and Shipping Administration (WSV) is increasingly faced with the need to consider alternative, technical-biological methods of bank protection when maintaining or upgrading existing waterways and constructing new ones.

The integration of plants (trees, shrubs, reeds) is an essential aspect of alternative methods of bank protection and can supplement, or even replace, conventional, purely technology-based methods. A good deal of experience with technical-biological methods of bank protection has already been gathered for small to medium-sized rivers. However, the actions to which such waterways are subjected cannot be compared with those on

waterways exposed to actions due to shipping. Some first trial sections in which the relevant authorities are implementing and observing technical-biological methods of bank protection already exist on federal waterways. However, the experience gathered at individual sections has not yet been pooled and evaluated centrally. There have not yet been any systematic investigations to the resistance to hydraulic actions of alternative methods of bank protection as used on federal waterways in Germany. Nor is any detailed information available on the possible changes in the ship-induced actions on banks that may be caused by the alternative revetments themselves. It is essential that the gaps in our knowledge are closed and a basis is created for the broad acceptance and application of technical-biological methods of bank protection as an alternative to conventional revetments.

It is for these reasons that the Federal Waterways Engineering and Research Institute (BAW) initiated, early in 2004, an R&D project which is now being conducted jointly by the Earthworks and Bank Protection Section (Section G4, which is in charge of the project) and the Interaction Ship/Waterway and Field Investigations Section (Section W4) of the BAW and by the Vegetation Studies and Landscape Management Department (Dep. U3) and the Fauna and Ecology Department (Dep. U4) of the Federal Institute of Hydrology (BfG). The long-term aim of the investigations is to draw up sound principles and recommendations for the use of alternative, technical-biological methods of bank protection and to make them available to planners at the Federal Waterways and Shipping Administration.

2 Justification

Past and current projects conducted by the BAW and the BfG clearly indicate that there is a need for research into alternative, technical-biological methods of bank protection for waterways. Two projects will be described below by way of illustration.

2.1 Untere Havel-Wasserstraße (UHW) [Lower Havel waterway]

The waterways linking Magdeburg and Berlin are being upgraded in order to connect the federal states in the eastern part of Germany and the countries lying further to the east to the European waterway network. The Untere Havel-Wasserstraße, also referred to as the Havel River section (UHW-km 32.610 to 54.250), forms part of that waterway link.

The Havel is typical of rivers that flow through flat land. It is also canalised, has a slight gradient and a correspondingly low flow velocity. The Havel River section is located between the towns of Ketzin and Brandenburg and is characterised by several large lakes, river bends, short canal-like cut-offs and numerous small islands. The river banks are rich in vegetation and the natural character of the entire section is well preserved (see Figure 1). Many important European conservation areas – areas of outstanding natural beauty and nature reserves, special areas of conservation (SACs) and important bird areas (IBAs) – are located along this stretch of the waterway.



Figure 1: Bank of the Untere Havel-Wasserstraße at km 35.700

The BAW (Sections W2, W4 and K1) has been studying the upgrading of this section of the waterway on behalf of the Waterways Construction Authority (WNA) in Berlin for some time. The fairway needs to be recomputed in its layout of the line and the associated wave actions on the bank must be assessed so that proposals for the required bank protection measures can be put

forward. Current directives concerning the upgrading of waterways will be followed and technical-biological methods of construction taken into account.

2.2 Mittellandkanal (MLK) [Mittelland Canal] – Section flowing through the city of Hannover

The section of the Mittelland Kanal that flows through the city of Hannover (MLK-km 159.350 to 173.465) was upgraded in 1999. Owing to its close proximity to built-up areas, a combined rectangular-trapezoidal profile requiring a minimum of space was chosen. In some of the sections, the sheet-pile wall ends just below or just above the water level and there is a slope above it. As a result, there are small local shallow water zones along the edges of the canal and plants have been used to create natural-looking banks. Topsoil containing a soil conditioner, such as alginate, is pumped into the cavities between the partially grouted armourstones placed on the slope to enable vegetation to become established as quickly as possible (Figure 2). The alginate-enriched topsoil mixture is produced in a specialised mixing plant and has a high degree of flowability. This method produces a continuous, homogeneous structure, by contrast to other methods of establishing vegetation in which topsoil is only spread over the riprap layer and does not extend down to the embankment itself. The algae suspension has thixotropic properties and therefore achieves a certain degree of erosion stability. The experience gathered with alginate-enriched topsoil, which has since also been used in other sections, will be evaluated during the research project so that sound recommendations for further applications can be made.

3 Procedure

The following stages have been specified for the R&D project:

- Commissioning a survey of the use of alternative, technical-biological methods of bank protection on waterways exposed to ship-induced actions, based on international literature, information found on the Internet and contacting authorities or scientific institutions abroad (external contract),
- conducting a survey by sending a questionnaire to regional and local waterways and shipping authorities to find out where

alternative methods of bank protection have already been used (BAW and BfG),



Figure 2: *Rapid establishment of vegetation on the bank protection on the MLK, using alginate-enriched topsoil*

- documenting the results of the above surveys (BAW and BfG),
- visiting selected representative sections of waterways operated by the Federal Waterways and Shipping Administration (BAW and BfG),
- selecting sections of waterways for extensive and detailed investigations (topography, populations of flora and fauna, observations of traffic, structural stability) from the representative sections of waterways operated by the Federal Waterways and Shipping Administration (see below for the criteria) and documentation in separate reports (BAW, BfG, waterways and shipping authorities and external contracts),
- setting up and observing new trial sections based on the findings of the above stages (BAW, BfG, waterways and shipping authorities and external contracts),
- quantifying the potential load of alternative, technical-biological methods of bank protection that are suitable for waterways (BAW and external contracts),
- drawing up recommendations for the possible applications of alternative, technical-biological methods of bank protection on waterways, depending on the hydraulic actions that occur, ranging from simple data sheets to the different types of bank protection project and reference sections (BAW and BfG),
- promotion of the exchange of information between specialists and practitioners (workshops).

The criteria for selecting representative sections of federal waterways are as follows:

- variety of waterway cross-sections, shipping and type of bank protection project,
- availability of ample documentation at BAW, BfG and the waterways and shipping authorities,
- previous investigations into fauna, flora and ship-induced actions and
- if possible, the section should have been in operation for a long time.

4 Survey

4.1 Questionnaire

A three-page questionnaire was drawn up jointly by the BAW and the BfG in early 2004 with the aim of obtaining an up-to-date overview of existing methods of alternative, technical-biological bank protection on federal waterways. The majority of the questions concerned four main aspects:

- **location** (identification number of the project, regional or local authority in charge of the project, branch office, waterway, kilometerage and side of banks),
- **project** (name, description, method of construction, contractors, year of construction, length of construction period and cost),
- **boundary conditions** (type of waterway, dimensions and type of cross section, shipping, hydrology and any special occurrences),
- **experience** (stability of the banks, fauna and vegetation, maintenance of the bank protection and plant cover).

Other questions concerned

- **photos**, if the respondents were able to provide them,
- any **existing reports** dealing with technical or biological aspects and
- the **need** for further investigations and information on the use of alternative, technical-biological methods of bank protection by the authority concerned.

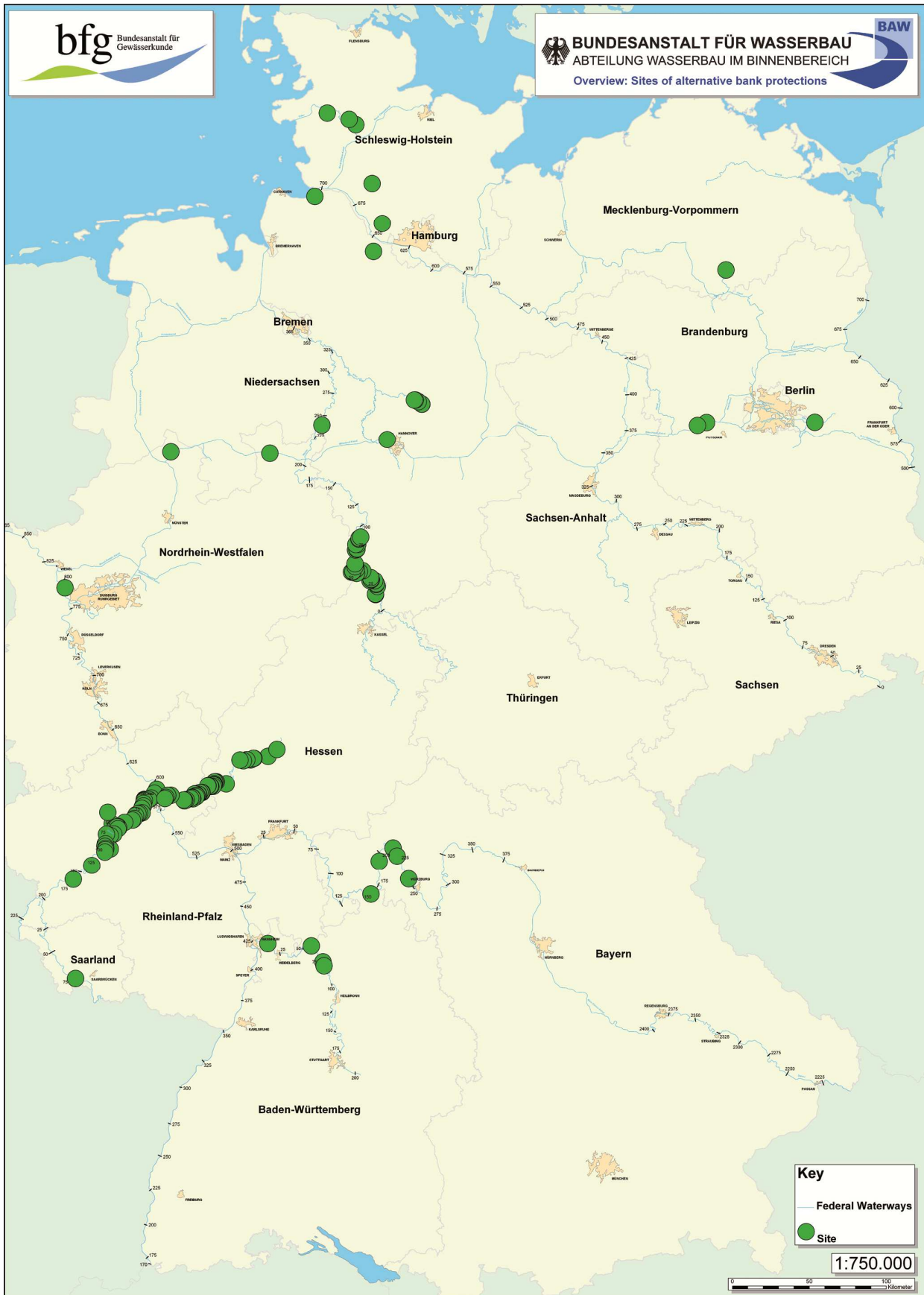


Figure 3: Survey of the reported sections of waterways and bank protection projects

The questionnaire was sent (electronically and on paper) to each of the seven regional waterways and shipping authorities, who were asked to forward it to the local waterways and shipping authorities, on 30 April 2004. A cover letter explained the questionnaire, which was also accompanied by a table of the 24 test sections already known at that time.

The completed questionnaires were returned between July 2004 and May 2005. In many cases, the replies were collected by the regional waterways and shipping authorities and then forwarded to the BAW. However, some of the local waterways and shipping authorities sent their answers to us directly. Any ambiguities identified during the initial examination were clarified by telephone.

At this point we wish to thank all of the authorities that participated in the survey for answering the large number of questions and providing documentation and information.

4.2 Overview of the projects

A total of 157 individual projects were reported (Figure 3). They were divided into 12 main categories (Figure 4) in order to gain a better overview of the waterway sections and to facilitate comparisons. The breakdown was initially based on the reports that had been received. The BfG then began to inspect selected sections of waterways, to photograph them and draw up descriptions of the banks. On the basis of this data, it will be decided at a later date whether the present categories can be retained. The assignment to a particular category is also taken into account in the statistical analysis.

5 Statistical analysis

The replies were initially analysed statistically according to the regional waterways and shipping authorities, the waterways, the project categories for Germany as a whole (i.e. not according to waterway), the type of waterway, the bank geometry and according to need.

- According to regional waterway and shipping authority

Most replies (41 and 99, corresponding to 89.2%) were submitted by the local offices of the regional waterways and shipping authorities in central and south-west Germany (Figure 5). Some of the replies (4, 5 and 7, corresponding to 10.2%) were submitted by the regional authorities in north, east

and south Germany. Either no or very few replies (0 and 1, corresponding to 0.6%) were submitted by the regional waterway and shipping authorities in north-west and west Germany. There is a correlation between the number of replies submitted by individual regional authorities and the type, size and amount of shipping on the waterways located in the various regions.

No.	Colour code	Project category
1	■	Stabilization by seeding, planting cuttings or planted vegetation
2	■	Grouted revetment with planted vegetation
3	■	Revetment with planted vegetation (+riprap)
4	■	Rows of posts (single or double)
5	■	Fascines (reed rafts)
6	■	Shallow water zone
7	■	Gentle transition to slope
8	■	Natural transition preserved
9	■	Longitudinal dikes
10	■	Sheet pile wall
11	■	Brush matting
12	■	Groynes

Figure 4: List of the 12 categories of reported projects

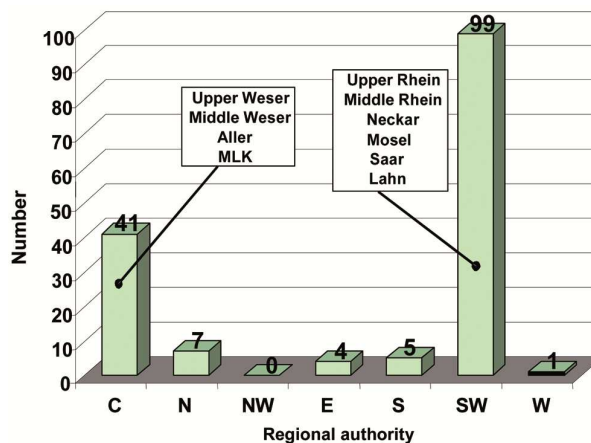


Figure 5: Breakdown of reported waterway sections according to regional authority (abbreviations: C = centre, N, S, E, W = direction)

- According to waterway

The distribution of the reported sections according to waterway is shown in Figure 6. The sections – free flowing reaches, canalised reaches and sections of canal – are located on a total of 17 waterways and the (absolute) numbers and

percentages (of the 157 reported sections) are indicated by the bars in the diagram. 80.9%, i.e. more than three-quarters of the reported sections, are located on three waterways, these being the Rivers Lahn, Moselle and Weser (all canalised rivers). The remaining 19.1% of the sections are located on the remaining 14 waterways, with an average of around two sections per waterway.

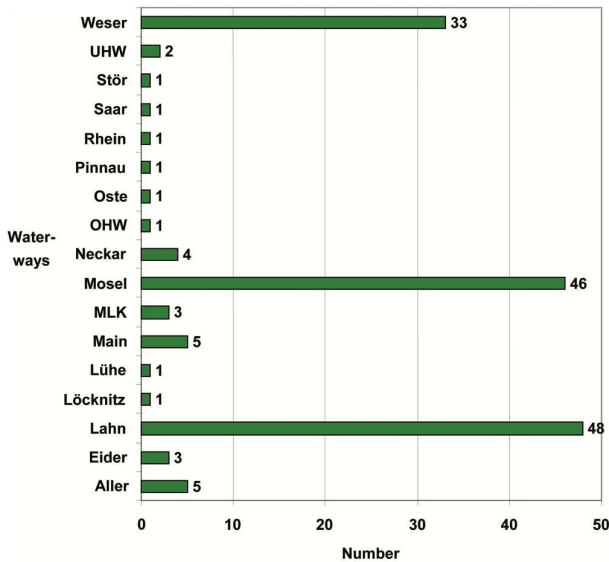


Figure 6: Distribution of the reported sections according to waterway (with German names and abbreviations)

• According to project category

A clear picture of the distribution of the types of bank protection measures used can be obtained by assigning the reported waterway sections to the project categories defined in section 4.2. The analysis was initially conducted for Germany as a whole. The results are summarised in Figure 7 and presented in two pie charts in Figure 8. The analysis was performed both for the actual number of projects (Figure 8, top) and for the length of the sections in each category (Figure 8, below).

Project	No.	Percentage	Section	Percentage
Stabilisation by seeding, planting cuttings or planted vegetation	49	22.7	47.8	22.8
Grouted revetment with planted vegetation	1	0.5	16.3	7.8
Revetment with planted vegetation (+riprap)	35	16.2	50.57	24.2
Rows of posts (single or double)	7	3.2	2.17	1.0
Fascines (reed rafts)	15	6.9	4.63	2.2
Shallow water zone	6	2.8	2.49	1.2
Gentle transition to slope	20	9.3	18.77	9.0
Natural transition preserved	64	29.6	48.93	23.4
Longitudinal dikes	10	4.6	11.9	5.7
Sheet pile wall	1	0.5	0.3	0.1
Brush matting	3	1.4	2	1.0
Groyves	5	2.3	3.35	1.6
Total:	216	100	209.21	100

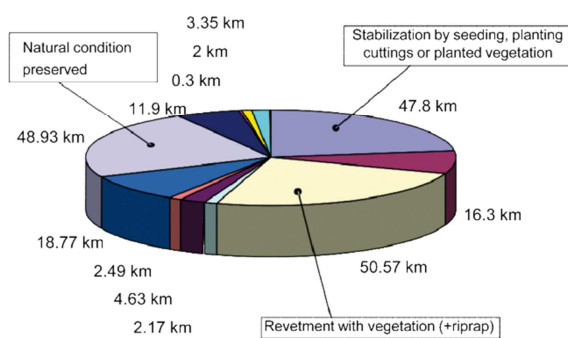
Figure 7: Breakdown of the reported sections according to the 12 project categories

It can be seen that the number of sections stated in Figure 7 (216) is greater than the number of

reported sections (157). This is due to the fact that certain sections were assigned to different project categories as several methods of bank protection had been used there. The analysis according to project category thus reflects the frequency of each category.

The assignment of sections to more than one category also affects the analysis according to the actual lengths of the sections. The overall length of 209.2 km stated in Figure 7 is thus greater than the actual total length of the reported sections (160 km). This must be taken into account when looking at the pie chart in Figure 8 below.

Lengths of bank protection measures / all waterways [km]



Percentage of projects / all waterways [%]

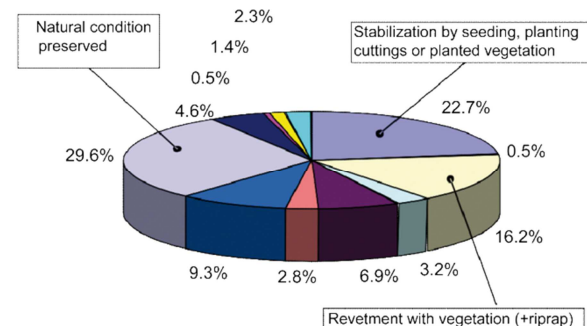


Figure 8: Percentages of reported bank protection projects: (top) according to type of project and (bottom) according to the lengths of the sections

• According to type of waterway

The following figures are obtained if we examine the correlation between the type of waterway and the number of reported sections:

- Canal: 7 corresponds to 5.3%
- River: 124 corresponds to 94.7%
- Lake: 0 corresponds to 0%

It is evident that most of the reported sections are located on stretches of canalised rivers, which is probably where the greatest potential for applying

alternative methods of bank protection lies. In the majority of cases, the ship-induced actions on the banks will not be as severe as on canals for which only a few sections with alternative types of bank protection (5%) were reported. This is due to the tight cross section ratios (ratio of the cross section of the waterway to the cross section of a vessel) on canals which can result in the banks being exposed to high levels of ship-induced actions. In most cases, alternative methods of bank protection cannot withstand such levels of loading. By contrast, higher levels of loading will occasionally occur on rivers (especially free flowing) whenever water levels are high.

- *According to bank geometry*

The replies to the question about the geometry of the banks along the reported waterway sections confirm what has already been shown in Figure 6. By far the largest number of sections are located along the banks of rivers, with 41% of those banks having the usual slope inclinations of around 1:3. Around 18% of the banks along the reported stretches are steeper while around 26% are less steep. True shallow water zones were reported in around 12% of the replies (see Figure 9).

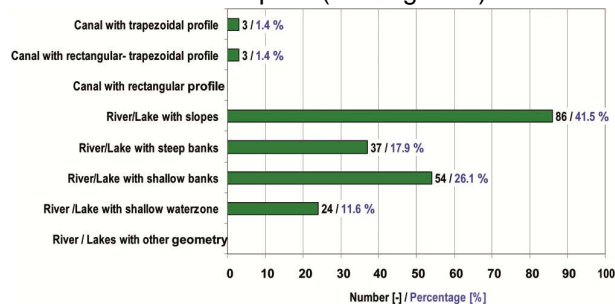


Figure 9: Reported sections grouped according to different types of bank geometry

- *According to need*

It was also asked in the questionnaire whether there is a need for fundamental investigations and recommendations for the application of alternative, technical-biological bank protection measures. The aim of the question was to establish the requirements in the areas covered by each authority. The result shows that the majority of authorities in Germany consider that investigations are required, as illustrated by the following figures:

- 44 (34% \cong 1/3) not required
- 84 (66% \cong 2/3) required (with different levels of priority)

6 Conclusions

The results of the survey summarised above are given in detail in a preliminary report on the R&D project [3]. The results and the responses to presentations of the research project have shown that there is a great need for sound solutions and recommendations for the use of alternative, technical-biological methods of bank protection on federal waterways. Two-thirds of the local and regional waterways and shipping authorities confirmed that there is need for such solutions and recommendations.

In addition, the survey showed that the waterways and shipping authorities have already used alternative methods of bank protection independently on a relatively large number of waterway sections and have gathered a certain amount of experience which will be useful during the further investigations to be conducted during the research project.

7 Outlook

Certain sections on which alternative, technical-biological methods of bank protection have already been applied will be investigated in detail during the R&D project, the selection being based on the results of the survey. It is planned to investigate the current condition of the bank protection in these sections, conduct a survey of the vegetation and fauna at those locations and measure the hydraulic actions due to shipping over a limited period of time. This will enable the experience to be quantified and taken into account in general recommendations. The following sections have initially been selected for the detailed investigations:

- Trial section at Stolzenau/Weser (We-km 241.55 to 242.30) – canalised river section
- Longitudinal dike at Walsum-Stapp/Rhein (Rh-km 793.5 to 795.0) – freely flowing river section
- Mittelland Kanal (MLK-km 189.6 to 190.1) – canal section.

Additional sections will be investigated at a later date. The experience and results of the investigations conducted on each section will be documented in written reports. In addition, it is planned in the long term to develop new trial sections which will be observed by extensive monitoring over a period of several years.

Finally, specific recommendations for alternative, technical-biological methods of bank protection will be made and the boundary conditions defined under which they can be used, or are suitable for use, on waterways subjected to ship-induced actions.

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8 References

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[2] Principles for the Design of Bank and Bottom Protection for Inland Waterways ("Grundlagen zur Bemessung von Böschungs- und Sohlsicherungen an Binnenwasserstraßen", Mitteilungsblatt Nr. 87 (GBB)), Bulletin No. 88 (English translation), Federal Waterways Engineering and Research Institute, 2004.

[3] Investigations into alternative, technical-biological methods of bank protection on inland waterways, Part 1: Background and surveys conducted by questionnaire and international research (Initial report on the R&D project) (Untersuchungen zu alternativen, technisch-biologischen Ufersicherungen an Binnenwasserstraßen – Teil 1: Veranlassung, Umfrage und internationale Recherche (1. Bericht des FuE-Projekts)), BAW-No. 2.04.10151.00/ BfG-No. 1484, 23 March 2006.

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