PIANC

Report n° xxx - 2017

Design Guidelines for Inland Waterways

PIANC INCOM WG 141: "Design Guidelines for Inland Waterways" – Status-Information for INCOM, February 1st, 2017; Bernhard Söhngen

Possible layout

No.	Year, Location	Main topic	Main results
1	2010, Liverpool	Subject and TOR, general approach	Start review existing guidelines
2	2010, Karlsruhe	Table of contents	Commercial vessels only
3	2011, Brussels	Collection of existing guidelines	Definition of design vessels
4	2011, Paris	Review existing guidelines	Need to consider safety & ease
I.1	2011, Brussels	Workshop planning	Best practice in rivers instead of using guidelines
5	2012, Bonn	Fairways in canals, rivers, bridge , turning basins	Dimensions for concept design method in terms of ship beam
I.2	2012, Madrid	Application of ship handling simulators (SHS)	Need for case by case design, especially for locks
6	2012, Utrecht	Fairway rivers, turning basins, berthing places	3-step design, best practice fairway rivers
7	2013, Antwerp	Discussion on safety and ease (s&e) and lock approaches	Lock approach dimensions, turning basins
I.3	2013, Maastricht	Workshop Smart Rivers Conference	Positive feedback, especially concerning narrower standards
8	2014, Brussels	Findings Smart Rivers Conference 2013 (SRC)	Agreement how to involve SRC papers in the report, responsibilities to each Chapter
9	2014, Bonn	Practice examples fairway width in rivers according to PIANC World Congress San Francisco 2014 (SFC)	Analysing additional practice data and comparison with guidelines, especially those from US with flow influence
10	2014, Lille	Test of SFC safety and ease approach in the light of examples	Application to examples
11	2015, Brussels	Collection of contributions to the future report and distribution of tasks concerning open points	Agreement to perform a new workshop at SRC in Buenos Aires, simplifying s&e approach
12	2015, Duisburg	Discussion of all the existing contributions to the report	Agreement concerning process recommendation for SHS usage
I.4	2015, Buenos Aires	Workshop Smart Rivers Conference	Presentation and discussion of application examples
13	2016 Cologne (Apr.)	Structure of the report	Special design aspects in one chapter 5
14	2016 Antwerp (June)	Application of the detailed design approach using ship handling simulators	Approach was generally accepted, example from DST (Danube River)
15	2016 Berlin (Oct.),	Balancing Chapter 5 (special design)	Final decisions about concept design
16	2017, Brussels	Results INCOM + finishing the report	Final meeting + reviewers in April

Meetings with decisions

Structure of the report

1 INTRODUCTION

1.1 Background

1.2 Tasks according to the Terms of Reference

1.3 Differences to MARCOM 49 approach

1.4 General approach in waterway design

1.5 Contribution of the guidelines to the planning process of a waterway

1.6 Guide notes to the reader of the report

1.7 Definitions and designations

Need of revised guidelines because of

- larger, but better equipped inland vessels,
- better on-board information systems,
- pressure concerning economics and ecology …

→ **Strong demand for narrower standards!**

To avoid the unsafe side:
"Therefore WG 141 proposes a **more generalized approach**, basing on the

- **review of existing guidelines** and the
- corresponding **Concept Design Method**, the
- consideration of **practice examples** in the so called **"Practice Approach"** and in special cases the
- **use of field experiments or simulation techniques"** → 3 Steps-Approach

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Main Tasks:
- Consider **actual dimensions of vessels** according to international standards.
- Take into account the demands of **climate change and ecology.**
- Consider influences of **wind, visibility, currents …**
- Refer to all relevant PIANC publications, especially to **MarCom WG 49**

Specification and restriction:
We will focus on
- **modern vessels** (future view)
- dimensions of fairways
- lock approaches
- turning basins
- berthing places
- bridge openings

Defining **lower limits** of navigational space based on **nautical aspects only** supports economical, environmental and climate change aspects (**indirect consideration**)

- **Concept Design: basic + extra widths**
- **Special s&e consideration**, either for Concept and Detailed Design …

“s&e” stands for “safety and ease of navigation”

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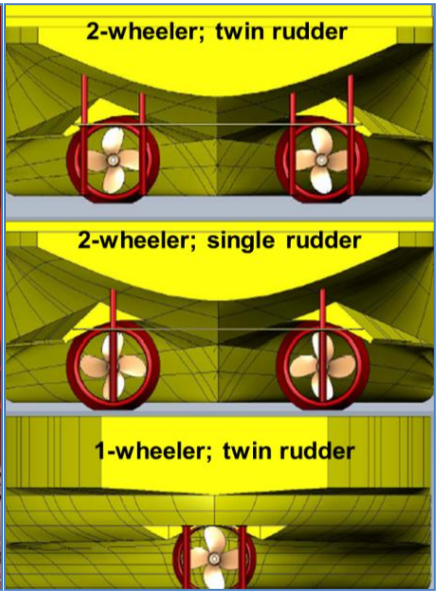
Main differences of sea-going and inland vessels:

- **Speed**
  (threshold extra width by speed 12 knots = 22 km/h >> 14 km/h (usual speed)): factor ≈ 1.6
- **Mass**
  factor ≈ 10 for the largest vessels
  ↓
- **Factor ≈ 40** in **kinetic energy** and **damage potential**
  + very much less effective rudders

- **MARCOM-approach is quantitatively not applicable**
- **But we took over the principles of Concept** (basic dimensions + increments) **and Detailed** Design (how to use ship handling simulators)



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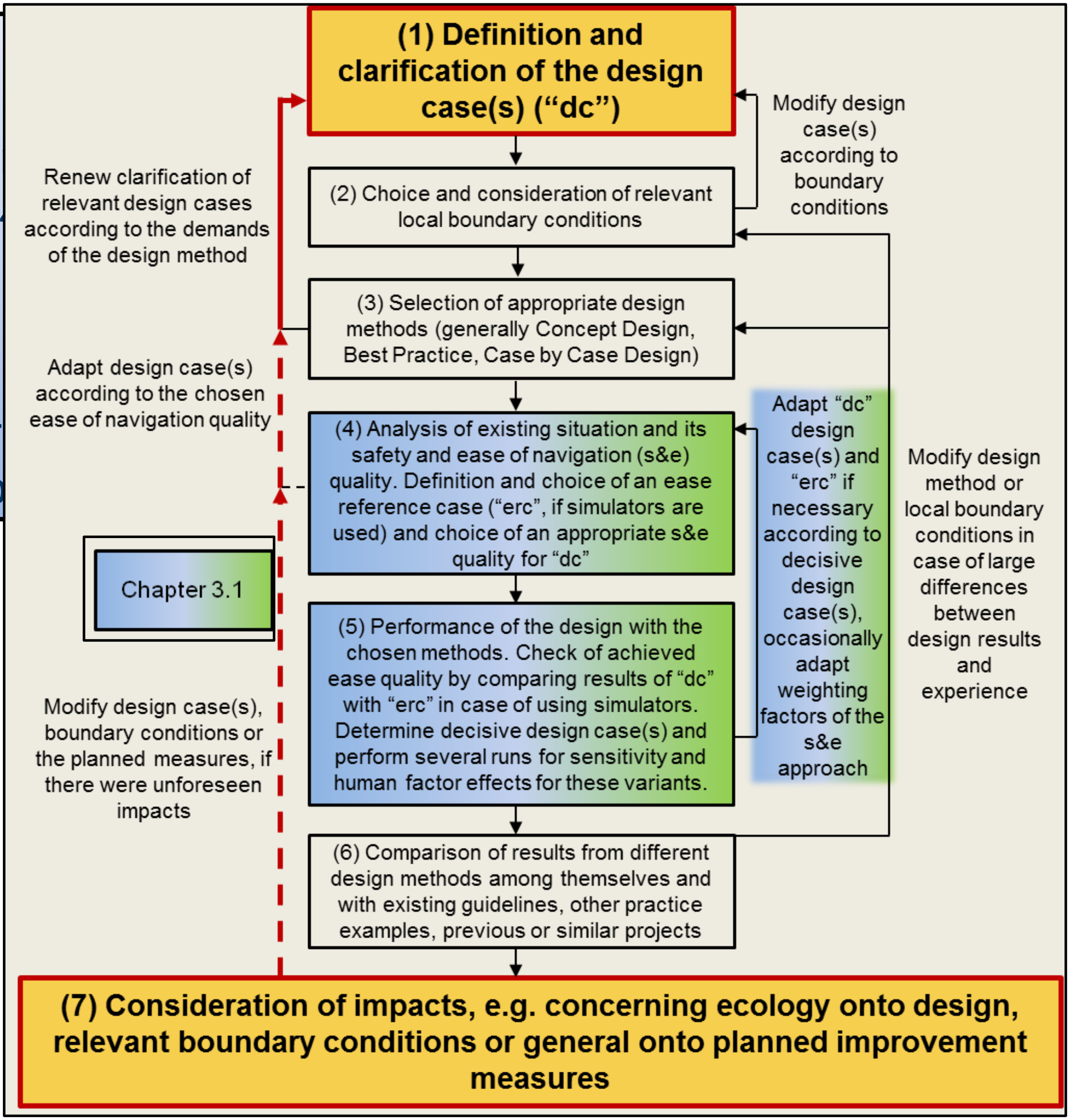
The report offers several of these flow charts.

The main message behind this chart is that **waterway design demands for a looped approach**, meaning e.g. to give feedback to the planners after having first results and to adapt e.g. the design case if appropriate



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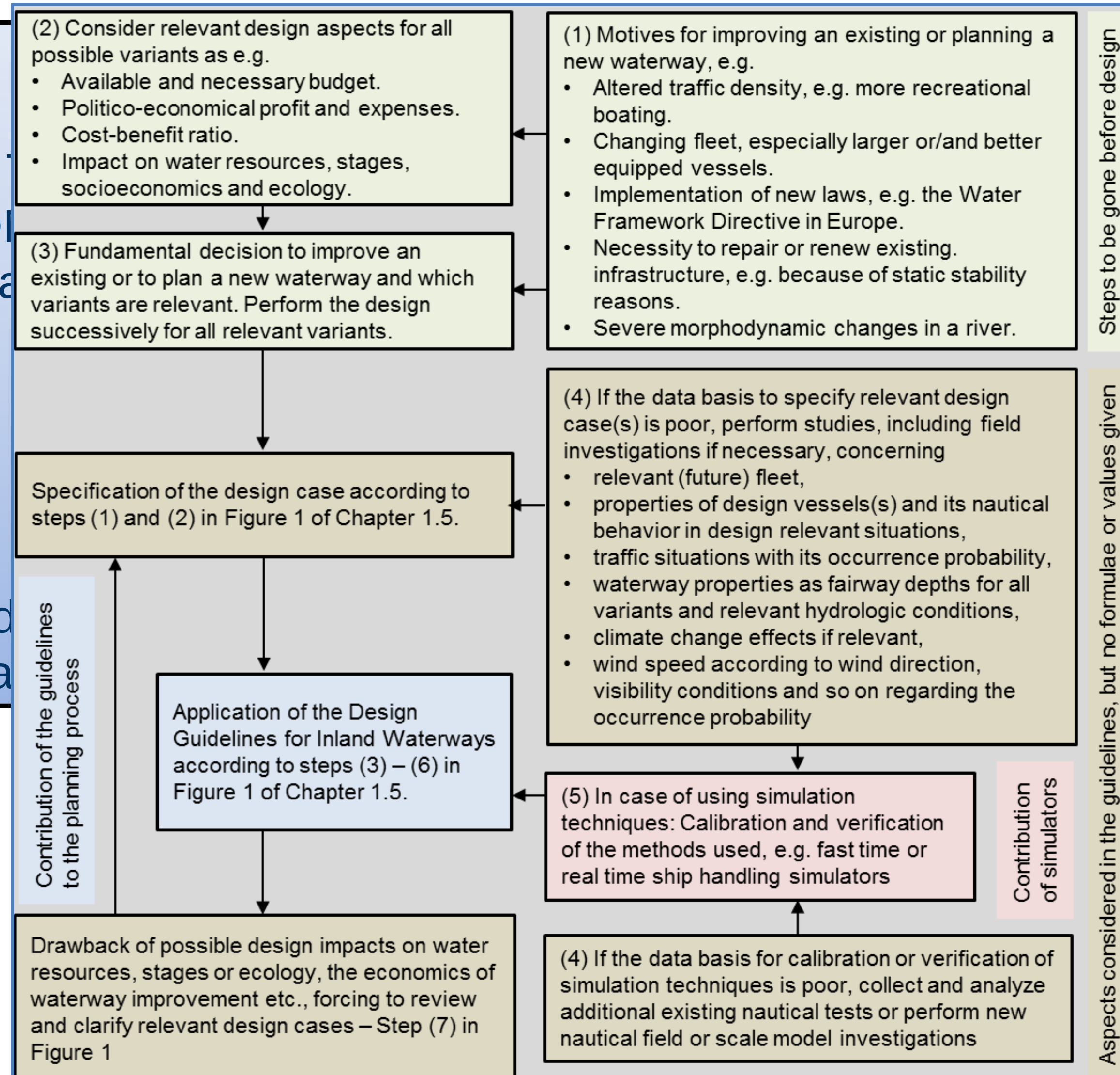

General restriction:
WG 141 focused on ***how*** waterway dimensions has to be designed, not on ***whether*** a measure shall be taken or not!
This is outside of the report, but the chart shows how this decision is linked to the report!

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Expert:

- **Focus on Chapter 5 (+ Chapter 4**: principles 3-steps), which deals with the three-step-approach for all selected design aspects separately (canals, rivers, bridge openings, lock approaches, junctions, turning basins and berthing places) **and the interesting design aspect.**
- **Use appendixes,** e.g. I (existing guidelines), III (s&e) or V (extra widths) **only if necessary**

Layman:

- Read Chapters 2 (fundamentals), 3 (s&e), 4 (3 steps) and 5 first and the corresponding other chapters and only appendixes if necessary.

It is possible to read the report selectively according to the interesting design aspect only because of hundreds of cross-links between chapters and appendixes!

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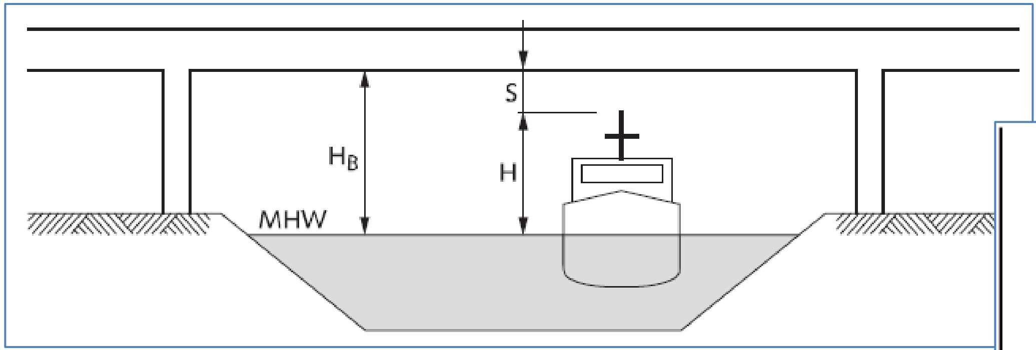
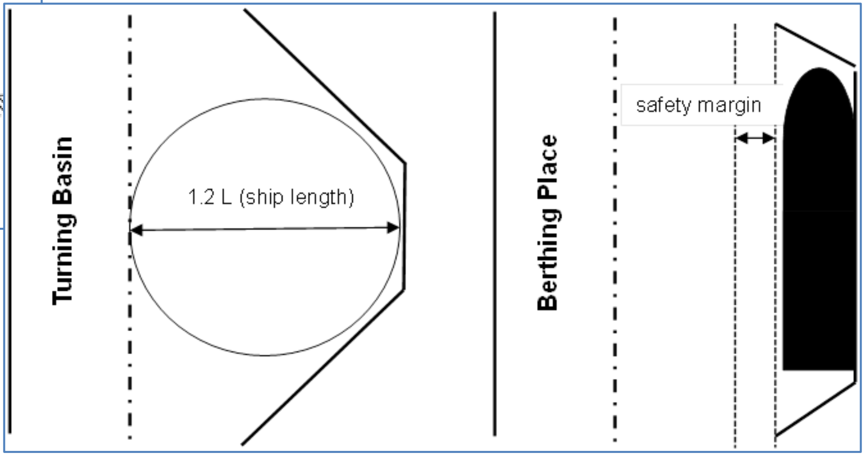


- **Report uses internationally usual designations.**
- **In APPENDIX I (existing guidelines) the original abbreviations will be used.**



Structure of the report

2 TECHNICAL INFORMATION
2.1 Classification of commercial vessels for waterway design

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ata needed

Example: Russian Classification

Class	Height	Typical vessel [m]		
		Length	Beam	Draught
I	> 11.8	135	16.5	3.5
		128.6	16.5	3.5
II	11.8 - 9.0	110.4	13.0	3.5
III	9.0	79.9	15.0	2.25
IV	9.0 - 6.5	63.1	14.0	1.60-1.80
V	6.5	55	12.0	135
VI	3.05	44	7.5	0.8-1.0
VII	3.05 – 1.25	35	7.5	0.8-1.0

Classification according to different countries / guidelines!

Table 6: Characteristics of reference motor cargo vessels

CEMT /ITF class	beam (m)	length (m)	draught (m)		height above waterline (m)	cargo capacity (tonne)	engine power (kW)	bow thruster (kW)
			laden	empty				
I	*5.05*	*38.5*	*2.5*	*1.2*	*3.5*	*365*	*175*	*100*
II	6.6	50 - 55	2.6	1.4	5.25	535 - 615	240 - 300	130
III	8.2	67 - 85	2.7	1.5	5.35	910 - 1250	490 - 640	160 - 210
IV	9.5	80 -105	3.0	1.6	5.55	1370 - 2040	750 - 1070	250
Va	11.4	110 - 135	3.5	1.8	6.40	2900 - 3735	1375 - 1750	435 - 705
VIa	17.0	135	4.0	2.0	8.75	6000	2400	1135

Adapted from the Dutch guidelines

Extended classification, e.g. concerning powering

Structure of the report

2 TECHNICAL INFORMATION

2.1 Classification of commercial vessels for waterway design

2.2 Waterway infrastructure aspects (canals, **impounded rivers,** free-flowing rivers**)**

2.3 Driving dynamics relevant for the design (effects of confined waters, ship-induced waves and currents, human factor, bends, cross currents, groynes, wind)

2.4 Definition and clarification of design case and data needed

Figure 1: Multiple locking of a pushed convoy in the USA

Explaining relevant infrastructure details by practice examples, depending on waterway type**, e.g. lock width, depth over sill, lock length for impounded rivers**

Structure of the report

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ship-induced w… groynes, wind) …

2.4 Definition and d…

Explaining physics behind driving dynamics!

Example:
Engine power needed of a Class Va vessel in different cross sections!

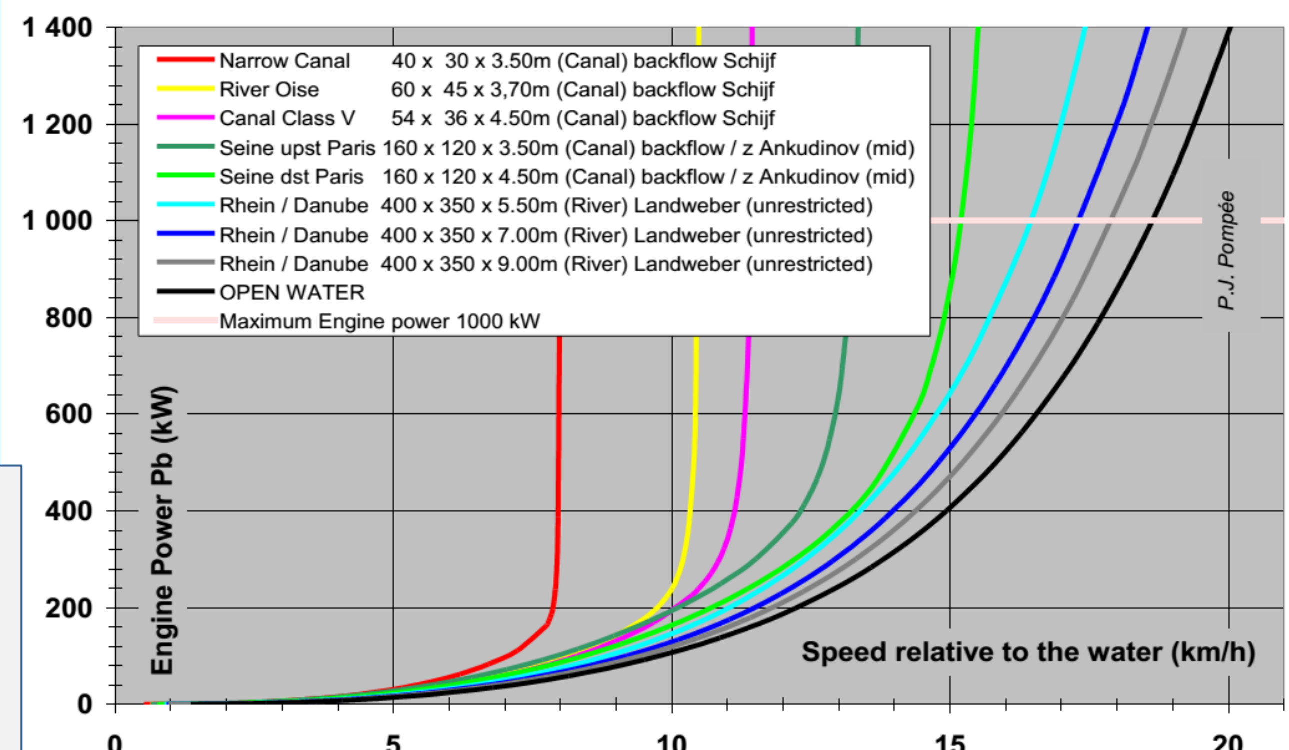

Figure 18: Power needs of a Rhine vessel L=110 x B=11,40m x T=2,80m, in different waterways

Structure of the report

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2.2 Waterway infrastruc
flowing rivers)
2.3 Driving dynamics
ship-induced waves
groynes, wind)
2.4 Definition and clarif

Reference to VBW publication (free download under: **www.vbw-ev.de** & **www.baw.de**

Example:
Class Va vessel passes a groyne head

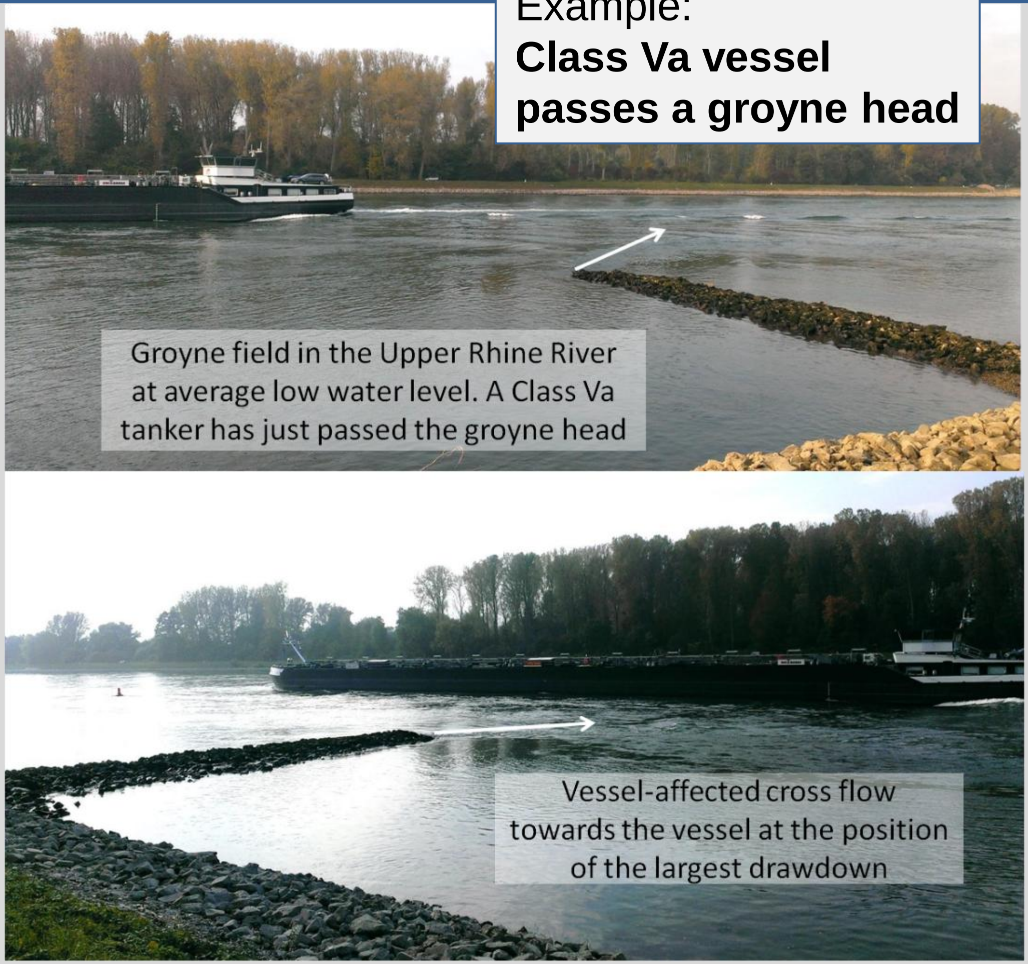

Figure 1: Flow vectors at a groyne head without (upper picture) and with drawdown influence (lower picture)

Structure of the report

Remember: This is the first and most important step in waterway design, e.g. to restrict effort!

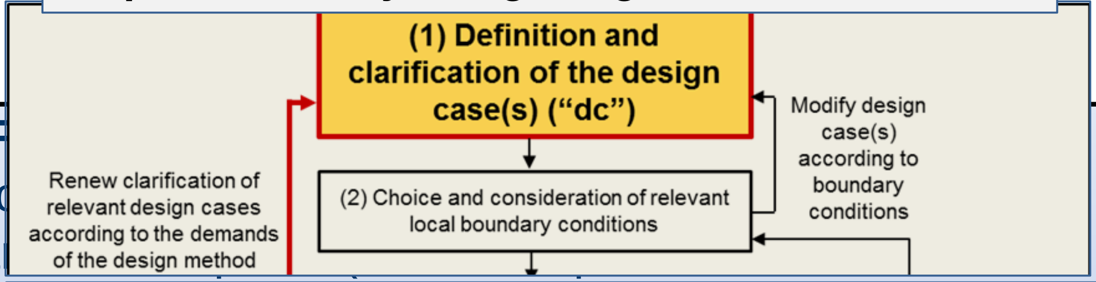

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Table 10: Check list of waterway properties and environment high-volume increment for class VIa and VIb waterways (m)

Waterway properties	Environmental conditions
What about critical reaches at present e.g. concerning existing navigational space, together with the corresponding curvature radius etc. – use information from local authorities and experienced skippers?	Where there accidents due to unfavourable environmental conditions in the past, how often did they happen and what were the consequences?
Extra allowances necessary because of possible leakage problems (dam situation), the granulometry of the canal bottom, sensitive bank protections (asphalt) or structures as bridge piers?	Where is the canal located, in an inland or coastal stretch (definition e.g. according to Dutch guidelines)? Are wind statistics available to define the design wind speed and the corresponding wind gust factor?
How large are relevant water level fluctuations from surges, water management etc.?	Can an efficient wind protection e.g. from vegetation be assumed or ensured with acceptable effort?
What about existing headroom at bridges, stability demands of bridge constructions and corresponding minimum head clearances and thus number of permitted container layers?	What about relevant sight conditions (fog, sailing at night etc.)?
How large is the distance between existing places where special manoeuvres as overtaking are possible or can be foreseen with acceptable expenses?	Are there relevant (probability with respect to other influences) flow velocities (rule of thumb > 0.5 m/s) in the canal, e.g. from lock or power plant operation?

The report provides check lists to support the reader in finding relevant design cases

Are encounters of vessels with empty containers at strong wind design-relevant?

Structure of the report

3 APPROPRIATE ASSESSMENT OF SAFETY AND EASE QUALITY AND ITS USAGE FOR DESIGN

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3.2.1 Para

3.2.2 Exam

3.3 Detailed safety

- There are partly huge differences in national guidelines, e.g. concerning lock approach lengths
  - **How to match these numbers in the report?**

Table 1: Lock approach (L_A) as a factor of ship dimension (*from top of jetty to lock entry), (s) single, (d) double

Lock Approach	BL_A/B	LL_A/L	Quality of driving
China	3.5 - 4.5 (s)	3.5 - 4.0	A - B
	7.0 (d)	3.0 - 3.5*	A - B
Dutch	2.2 (s)	1.0 - 1.2	B - C
French	2.9 (s)	0.5*	C
Germany	3.0 - 4.0 (s) 4.5 - 6.0 (d)	2.8	B

Structure of the report

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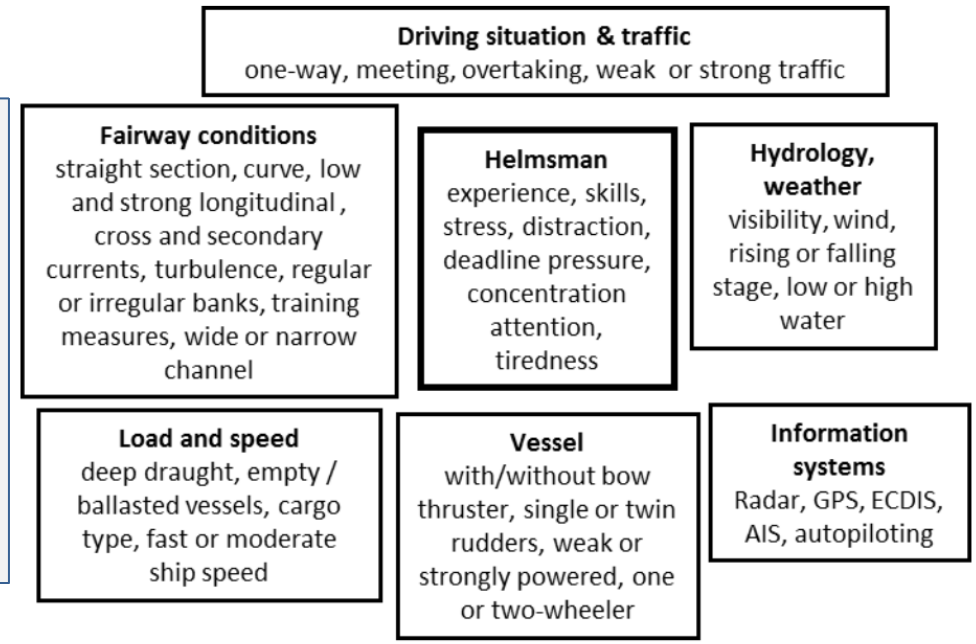
- There are partly huge differences in national guidelines, e.g. concerning lock approach lengths
  - **How to match these numbers in the report?**

- But there are objective reasons for different s&e qualities
  - **How to find the necessary s&e quality?**
  - **How to deal with a huge number of design criteria?**

If the s&e-approach works properly, it should fit with all existing guidelines!
This was the main reason behind the approach!
Everybody must be able to rediscover himself in the report!

Collection of design criteria determining the
- **existing (analysis case) or**
- **necessary (design case)**

s&e quality



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3 APPROPRIATE ASSESSMENT OF SAFETY AND EASE QUALITY AND ITS USAGE FOR DESIGN

3.1 Introduction

3.2 Simplified safety and ease approach supporting concept design

3.2.1 Parameters influencing waterway design

3.2.2 Example

3.3 Detailed safety and ease approach supporting detailed design

- **Simplified approach (Concept Design):**
  - Find an appropriate s&e quality
  - to be used for designing the waterway dimension with the Concept Design
  - The numbers given are related to s&e qualities
- **Detailed approach (Detailed Design):**
  - Use a rational approach to quantify the s&e quality in using simulation techniques
  - Find an appropriate ease reference case
  - and compare it quantitatively with the design case
  - Principle of comparative variant analyses!

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- **Definition of different s&e qualities and explanation by examples**

Class	Designation
A	Nearly unrestricted drive
B	Moderate to strongly restricted drive
C	Strongly restricted drive

Structure of the report

Analysis Case → to check the approach and to find out appropriate ease reference cases
Design Case → for defining an appropriate s&e quality for design

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3.2.2 Example
pro[…]

- **Assess the truth content of different** (waterway-, speed- and traffic-related) **statements,**
- **Leading to an appropriate s&e score, which will be assigned to qualities A, B or C**

Group	No.	Criterion	Arguments speaking for a higher necessary ease score for design			Cases where a lower ease quality may be acceptable for design	Score	Single factor	Group factor
1st rating group: Waterway related criteria		Scoring rules for waterway related criteria: The score is +1, if the argument in the red coloured left column is true, it is -1, if the argument in the right green coloured column is true. If neither the left or right argument is true or if both are true, the score is 0.							7/20 = 35%
	1	Depth exploitation of waterway and type of load	Deep draught vessels, especially with dangerous goods in very shallow water		Empty or ballasted vessels, no dangerous goods, sufficient water depth		0	1/7	
	2	Level of training, personnel skills and experience	Poorly trained pilots, low knowledge on waterway features and infrastructure		Optimally qualified and experienced helmsman		0*	1/7	
	3	Attenti[…] and […]	[…]		[…]ing a […]ning		-1	1/7	
	4	Wid[…] water[…] po[…]	[…]		[…]ed […]s or […]y		+1*	1/7	
	5	Unce[…]	[…] stony river bed, many times wind, fog		[…]or […]wind speed or wind protections		0	1/7	
	6	Traffic situation, ship-ship and ship-bank-interaction	One-way traffic, many manoeuvres as overtaking		2 or more navigational lines, accepted interaction forces		+1	1/7	
	7	Vessel equipment and instrumentation	Main rudders only or weakly powered bow thrusters, sea going ships, low engine power, no information systems		Strongly powered bow thruster or passive bow rudder, high engine power, dual propellers, optimal information systems		-1*	1/7	
2nd rating group: Vessel speed		Scoring rules for vessel speed related criteria: According to the strived vessel speed (1st line below) or the necessary speed range (2nd line below), choose the score according to the numbers given below (in brackets) or interpolate if necessary							4/20 = 20%
	8	Strived vessel speed over ground, individual drive	≥ 13 km/h (1)	10 – 12 km/h (0.5)	5 – 9 km/h (0)	< 4 km/h (-1)	+0.5	1/2	
	9	Feasible speed range relative to water between v_{crit} and minimum speed to ensure steerability	≤ 2 km/h (+1)	3 – 4 km/h (+0.5)	4 – 5 km/h (-0.5)	≥ 6 km/h (-1)	-0.5	1/2	
3rd rating group: Traffic density		Scoring rules for accounting the traffic density: Choose the score according to the values given in brackets below							9/20 = 45%
	10	Hindrance due to recreational boating, especially human powered as rowing boats	Strong negative effect especially on possible average speed (+1)	Average hindrance of commercial navigation (0)		No significant influence on speed of freight vessels (-1)	+1*	4/9	
	11	Restriction of necessary speed reduction in case of high traffic density of commercial navigation	> 30,000 vessels per year (+1)	15,000 – 30,000 vessels per year (+0.5)	5,000 – 15,000 vessels per year (-0.5)	< 5,000 vessels per year (-1)	-0.5	5/9	
Total score: Sum of single scores (second last column), multiplied by the weighting factor (last column) =							**+ 0.075**		

Example passage of Jagstfeld Bridge Neckar River with 123 m long Class Vb vessels

strong	restrictions moderate to strong	almost no
C	**B**	**A**
tricky drive	not really easy	easy sailing
	ease	

score for design case ("dc")
-1.0 -0.8 -0.6 -0.4 -0.2 0.0 +0.2 +0.4 +0.6 +0.8 +1.0
+0.075

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Rationally quantifying s&e!

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3.2.1 Parameters influenc
3.2.2 Example
3.3 Detailed safety and ease approach supporting detailed design

- **Adjust the quantitative s&e approach,**
- **taking results from simulations,**

Specifications in APPENDIX III

- **average the time-series of data over relevant simulation periods**
- **and match it together (weighted average) to a comprehensive s&e score**

Use e.g. so-called "reserves", e.g. concerning rudder angle:

Rudder reserve =
- maximum rudder angle (by construction),
- minus actual rudder angle,
- divided by the maximum rudder angle!

Table 66: Some examples of the approach proposed by to Gronarz (***) for choosing characteristic values defining the nautical easiness in terms of "reserves" (the values are generally between 0 – no reserves – and infinite – maximum reserves, but they may be negative too – drive is not possible), other explanations see *Table 64*

Group	Characteristic values from simulations (examples)	Group weight	Single weight / group
Waterway related	Minimum distance to sideways waterway limits, divided by net available navigational space	3/8	1/2
	Minimum distances to other vessels at encounters, divided by the net available navigational space		1/4
	Fairway width minus swept area width, divided by fairway width		1/4
Vessel and steering related	Maximum rudder angle by construction, minus actual rudder angle of the main rudder, divided by the max. rudder angle	5/8	1/4
	Maximum rudder turning speed by construction (e.g. 8°/s), minus actual turning speed, divided by e.g. 8°/s		1/4
	100% minus actual percentage of bow thruster usage, divided by 100%		1/4
	Maximum possible rpm of main thruster, minus actual speed, divided by max. rpm		1/4

More specific flow chart on how to apply the 3-Steps-Approach

4 RECOMMENDED STEPS IN WATERWAY DESIGN

4.1 Introduction to the three design methods

After specifying the design case and corresponding local boundary conditions (steps 1,2)

Concept Design

- Choose appropriate s&e quality
- Perform the design according to the s&e score (basic dimension) + increments if appropriate
- Check applicability limits

Use national guidelines if available and applicable

Use international guidelines if applicable and accepted instead

If application limits are exceeded (e.g. if flow velocity is too high) or if there are other good arguments for a Case by Case Study

Use Concept Design as **preliminary design** → bathymetry and flow field for the detailed design

Detailed Design

- Choice of method & modelling,
- Performance of the detailed design study
- Interpretation of results
- Check of decisive design cases
- Feedback to planners

Compare all previous results and those from or similar projects if available

Compare results from national and international guidelines as well as practice

Practice Approach

- Use practice data, which are comparable to the design case
- Use data from previous projects
- Check application limits

End of 3-Steps-Approach, if there are no doubts!

Consideration of impacts & feedback to the specification of the design case(s) … (step 7)

Excursus: General agreements from the Antwerp meeting in June (with DST & MARIN)

Absolutely essential fundamentals of WG 141 report
(proposed by B. Söhngen)

General

- We need an **understandable and rational design** approach (based on local boundary conditions, available data, available experience, available modelling techniques, physics etc., not on "voting" or special interests) → **3 steps**
- We should recommend **reasonable design cases only** (probability, risk, preventability) → **new Chapter 2.5** (Definition and clarification of design cases – former Chapter 7.2.3)
- We should consider different design aspects in using the Concept Design reasonably (s&e approach) and assign numbers to a chosen s&e quality → **specified in meeting 15**
- **Everybody shouldn't overrate his preferred approach** and should be open for the best or feasible approach → **3 steps**
- We should be **courageous in demanding for things that we think they are essential**, e.g. performing detailed studies **in a comparable sense** → **Controversial opinions (effort!) solved by restricting to "decisive design cases" and designating our approach to be "the ideal one" with adaptions if appropriate (budget!)**
- Recognize that **we write the report not for us** (we are the experts and should know what to do), **we write it for decision makers who have no idea what is really important, which data are needed, which approach is the best and feasible – and we write it for clients of navigational studies who have to know how costly are navigational studies for waterway design purposes**! → **More details in appendixes**

General agreements from Antwerp – continued

Detailed design

- **Compare results of the design case to a reasonable reference case**
  → Transfer of knowledge, good experience and accepted design standards from the well known reference case to the design case
  → Reduction of inaccuracies by focussing on "differences" instead of absolute numbers for assessing the nautical aspects → **Add examples of reference cases**
- Use a **rational, quantitative approach for comparing variants**, clearly together with absolute results, expert rating etc. → **Tables for quantifying the detailed s&e-approach**
- Use the **"averaging principle"** in case of significant influences of random effects … (several drives instead of one or average of drives with comparable boundary conditions to end up with a comprehensive score) → **Danube study DST, APPENDIX 6**
- Consider that **the chosen approach** (e.g. scale model tests or simulators) **may have significant deterministic inaccuracies**, in using ship handling simulators especially in case of narrow cross sections, T/h close to 1, unsteady turbulence effects and 3D flow effects as those from secondary currents concerning shallow and confined water effects

- **Be aware that the simulations can be very inaccurate!**
- **Solution: Principle of comparative variant analyses,** especially concerning s&e!
- The reader gets hints on how to improve existing methods **in order to "reach the best result with an possibly imperfect tool"**

Structure of the report

4 RECOMMENDED STEPS IN WATERWAY DESIGN

4.1 Introduction to the three design methods

4.2 Definition and aim of the Concept Design method

4.3 Practice Approach – using existing examples

4.4 Detailed or case-by-case design

Fairways in rivers - conclusions from practice data

Waterway	Fairway width for alternate single-lane (basic width)				Fairway width for two-way (basic width)			
	Ease quality			Remarks	Ease quality			Remarks
	C	B	A		C	B	A	
min W_F (straight sections) [1]	3.0 B[2]			For security reasons	4·B	5·B	6·B	3 B can damage the embankments
min D (over entire fairway width)	1.2 d	1.3 d		Because of squat & efficiency of bow-thrusters	1.2 d	1.3 d	1.4 d	Because of squat & efficiency of bow-thrusters
min R (ΔF needed for R ≠ ∞)[3]	2 L	3 L	4 L	Depending on natural condition	2 L	3 L	4 L	Depending on natural condition

The numbers are valid for average equipped and instrumented freight vessels and further restrictions concerning waterway properties as flow velocity (not more than around 1.5 m/s) or moderate wind speeds of an inland stretch (not more than around 5-6 BF).

- **Matching of data from different sources (mainly from existing guidelines, which are collected in APPENDIX I)**
- **Assignation to s&e qualities** (assessment by the members)
- **Application limits** and in which cases a detailed study will be recommended

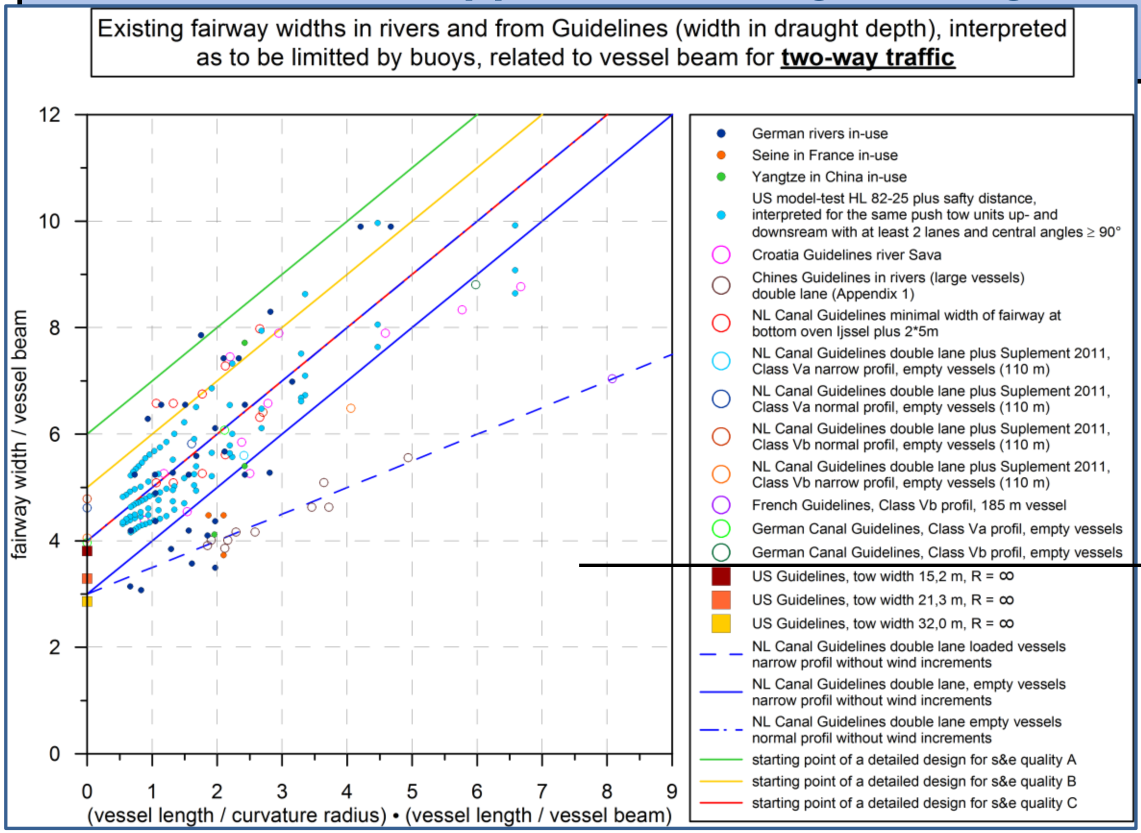
Structure of the report

4 RECOMMENDED STEPS IN WATERWAY DESIGN

4.1 Introduction to the three design methods

4.2 Definition and aim of the Concept Design method

4.3 Practice Approach – using existing examples



- Data are rare and difficult to obtain
- **Relevant data** are mentioned **in Chapter 5** for each design aspect separately
- **Collection of data in APPENDIX 2**
- Scientifically elaboration of fairway data from rivers only

Structure of the report

4 RECOMMENDED STEPS IN WATERWAY DESIGN

4.1 Introduction to the three design m

4.2 Definition and aim of the Concept

4.3 Practice Approach – using existing

4.4 Detailed or case-by-case design

- **Criteria speaking for a detailed study**, e.g. special vessel properties, possible reduction of construction costs, irregular conditions
- **Recommendation on performing an "ideal study" → details in Appendix 5**

Table 1: Criteria speaking for a detailed study (left column) and the use of ship simulation techniques (right column) in the design process

Need for performing a detailed study for design	Ship simulation techniques needed
There are large or inexplicable differences between data from different guidelines, recommendations of WG 141 using the Concept Design Method and those from waterways in use.	There are doubts about the decisive design cases, because e.g. the Concept Design or practice data do not deal with possibly relevant aspects as draught.
The Concept Design does not tackle the design case considered, e.g. because of different local boundary conditions or different s&e demands	The design relevant vessels have special properties, e.g. type, propulsion, steering aids.
The waterway has a difficult layout like sharp or sequential turns, narrow widths, variable depths, junctions, lock approaches, bridges, turning areas, berths etc.	Large discrepancy between space available and navigation needs
The environment plays an important role, e.g. intense or variable longitudinal or cross currents, visibility, turbulence or high water level variations.	Significant construction cost savings seems possible through optimization of engineering works and designs
There is a need to specify the operational limits or to accept higher operational limits than usual in design.	When evaluating risk-based design and traffic management
There are doubts about using a lower standard for design than in comparable projects or relevant waterways in use.	Training of captains to fulfil standards
Human factor effects as visibility or reaction time have great impact on design.	To demonstrate the results and nautical aspects of design
Accounting for high traffic density in design.	Considering special traffic or operations
To plan and check aids to navigation.	To gain acceptance for navigational needs
When evaluating risk-based design and traffic management.	If the design causes severe impacts e.g. concerning river ecology or water stages, leading to a possibly modified design.

Structure of the report

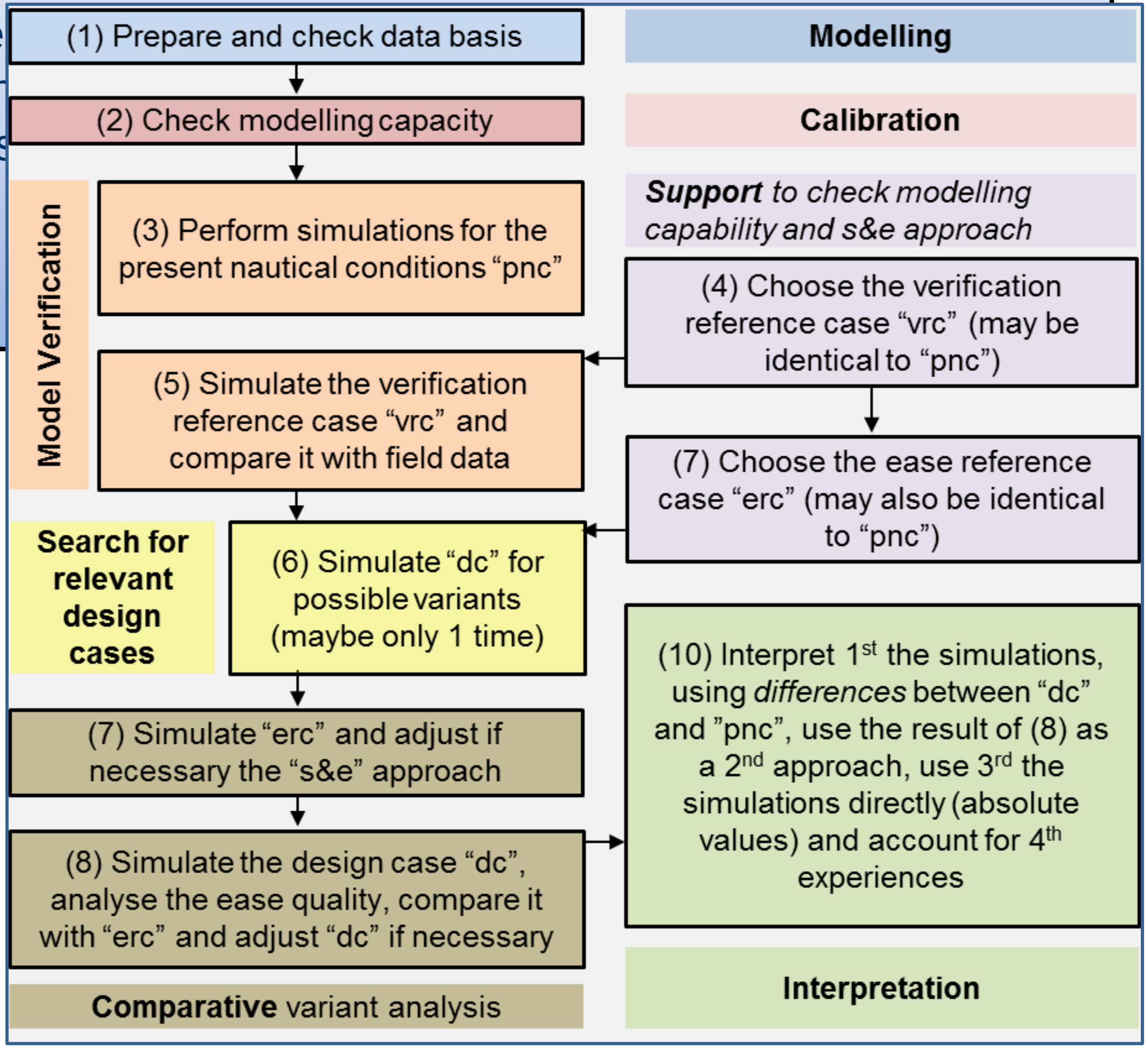
4 RECOMMENDED STEPS IN WATERWAY DESIGN

4.1 Introduction to the thre

4.2 Definition and aim of th

4.3 Practice Approach – us

4.4 Detailed or case-by-case design



- **Don't forget to check the data basis**, to calibrate and verify the models used!
- Encourage Clients to ask for it!
- **Choose relevant reference cases** to adjust the detailed s&e approach.
- **"Scan" relevant scenarios.**
- **Perform several runs for decisive design cases** and **compare it with the reference case**.
- Interpret results properly!

Structure of the report

5 RECOMMENDATIONS FOR SPECIAL DESIGN ASPECTS

5.1 General remarks and guide notes how to use the recommendations in Chapter 5

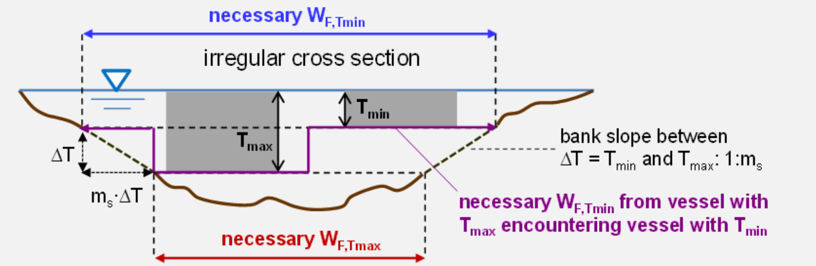
5.1.1 Introduction to the procedure

5.1.2 Determine the necessary quality of driving for design

5.1.3 Determine the waterway dimension

5.1.4 **Account for extra widths**
(Extended Concept Design")

- Explaining the application of the 3-Steps-Approach for selected waterway dimensions.
- **Reference to Appendix V** how to account for "extra widths", which are not treated in Chapter 5.



Single-lane:

necessary $W_{F,Tmin}$ = basic width + sum[1)] (extra widths for vessel with T_{min})
$\geq$ min $W_{F,Tmax} + 2 \cdot m_S \cdot \Delta T$

necessary $W_{F,Tmax}$ = basic width + sum[1)] (extra widths for vessel with T_{max})

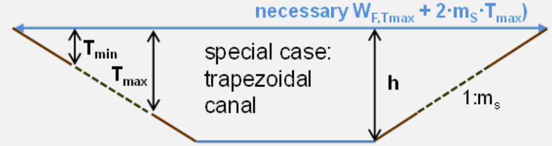
Two-way (standard encounters: both vessels T_{max} or one T_{max}, the other T_{min})

necessary $W_{F,Tmin}$ = basic width + sum[1)] (extra widths for the one vessel with T_{min} and the other with T_{max}) + $m_S \cdot \Delta T$
$\geq$ min $W_{F,max} + 2 \cdot m_S \cdot \Delta T$

necessary $W_{F,Tmax}$ = basic wid$_F$th + sum (increments for vessels both with with T_{max})

[1)] the sum may be arithmetically (deterministic increments) or statistically (root of the sum of squares)

necessary W_W = max (necessary $W_{F,Tmin} + 2 \cdot m_S \cdot T_{min}$; necessary $W_{F,Tmax} + 2 \cdot m_S \cdot T_{max}$)



Structure of the report

5 RECOMMENDATIONS FOR SPECIAL DESIGN ASPECTS

5.1 General remarks and guide notes how to use the recommendations in chapter 5

5.2 Canal fairway width and cross section

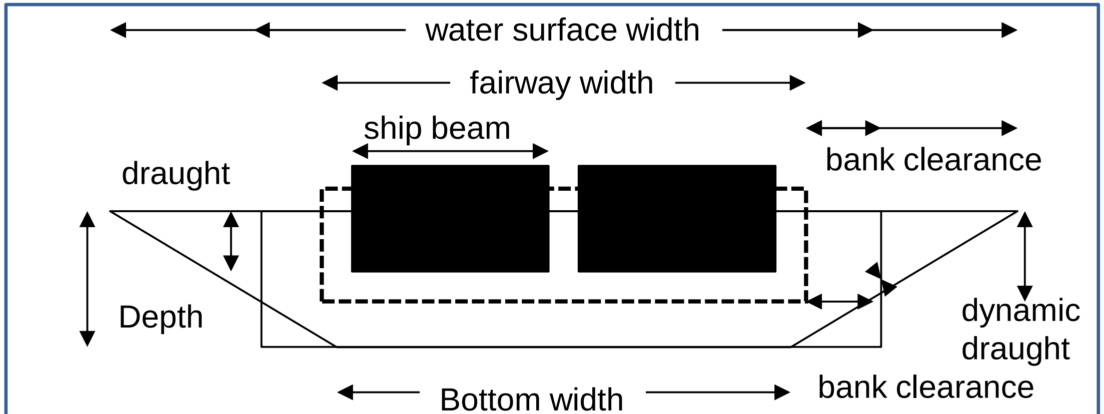
5.2.1 Introduction for canals

5.2.2 Concept Design for canals

5.2.3 Practice approach for canals

5.2.4 Detailed design for canals

You will find the same substructure of the chapters also for other waterway dimensions!



Definition of relevant dimensions

Structure of the report

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5.2.3 Practice approach

5.2.4 Detailed design fo

Summary of considered guidelines!

Table 1:Canal fairway dimension in existing guidelines as a factor of ship dimension for deep-draught vessels (no relevant wind increments), straight sections and no relevant cross flow velocities)

	Ship (B x L x T)	Two-way (bank slope 3/1)			Single-lane		Driving quality
		W_F/B	h/T	n	W_F/B	h/T	Level
China Canal	**Average (Class II – V)**	**4.4**	**1.3**	**4.4**	**-**	**-**	**A-B**
China Channel	**Average (Class II – VII)**	**4.4**	**1.4**	**6-7**	**-**	**-**	**A-B**
China River	Average (Class I – VII)	4.4	1.2	-	2.3	1.2	A-B
Dutch normal	11.45 x 185 x 3.5	4.0	1.4	8.7	2	1.3	A-B
Dutch narrow	11.45 x 185 x 2.8	3.0	1.3	6.7	-	-	B-C
France	11.40 x 180 x 3	3.77	1.5	6.25	-	-	B-C
Germany	11.45 x 185 x 2.8	3.3	1.4	5.6	2	1.4	B-C
Russia	16.5 x 135 x 3.5	2.6	1.3	-	1.5	1.3	C
US River	10.7 x 59.5 x 2.7	~3.3	~1.3	~4.9	~2.2	1.3	B-C

Structure of the report

5 RECOMMENDATI

5.1 General remarks a… recommendations

5.2 Canal fairway widt…

5.2.1 Introduction for ca…

5.2.2 Concept Design … for canals

5.2.3 Practice approach…

5.2.4 Detailed design fo…

Avoidance of "interim s&e-qualities" is still under review (state February 2017)

Recommended "basic" waterway dimensions

Waterway	Fairway width for alternate single-lane				Fairway width for two-way			
	Ease quality			Remarks	Ease quality			Remarks
	C	B	A		C	B	A	
min W_F (straight canal sections)	2·B[1)]			For security reasons	3·B[2)]		4·B[3)]	2.5 B can damage the canal
min n	2.5	3.5	4.5	To keep on speed	3.5	5	7	To keep on speed
min D (over bottom width)	1.3 d			Because of squat & efficiency of bow thrusters	1.3 d		1.4 d	Because of squat & efficiency of bow thrusters
min R (ΔF needed for R ≠ ∞)	4 L	7 L	10 L		4 L	7 L	10 L	
max v_{flow} (longitudinal)	0.5 m/s				0.5 m/s			
max v_{cross} (averaged over L, ΔF needed for $v_{cross} \neq 0$)	0.5 m/s				0.5 m/s			
design v_W (inland) (ΔF needed for empty/ballasted or container vessels at $v_W \neq 0$)	5-6 BF *(8.0 – 13.9 m/s; 10.5 m/s according to Dutch Guidelines)*				5-6 BF *(8.0 – 13.9 m/s; 10.5 m/s according to Dutch Guidelines)*			
design v_W (costal) (ΔF needed for empty/ballasted or container vessels at $v_W \neq 0$)	6-7 BF *(10.8 – 17.2 m/s; 13.5 m/s according to Dutch Guidelines)*				6-7 BF *(10.8 – 17.2 m/s; 13.5 m/s according to Dutch Guidelines)*			

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5 RECOMMENDATIONS FOR SPECIAL DESIGN ASPECTS

5.1 General remarks and guide notes how to use the recommendations
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5.2.4 Detailed design fo…

Further explanations how to account for extra widths:

If higher vessel speeds should be enabled even while encountering, reference is made to Chapter 2.3.1, where safety distances for counteracting the interaction forces are given in its relation to the relative ship v/v_{crit} and to the remarks in Table 20 concerning the parts of extra distances, which are included in min W_F. Because the safety distances increase with v/v_{crit} according to Table 9, the basic width may be increased accordingly if higher v/v_{crit} should be enabled, see example in Chapter 2.3.1. This would e.g. lead to an increase of 2·(0.35 - 0.3)·B = 0.1·B concerning the safety distances to banks and gives 2.1·B for the basic width. This number may be assigned to a s&e quality tending more to A than B. If, on the other hand, the extra widths concerning instabilities of about 0.4·B, which are included in 2·B according to the remarks in Table 20, could be reduced to 0.3·B, which is the number for encounters and assumes a very cautious and attentive drive also over long distances, then the basic width may be reduced to 1.9·B, which may tend to a s&e quality C.

With the same arguments and the numbers given in Table 9 for higher vessel speeds in case of a two-way canal, the basic width, which is assigned to a s&e-quality between A and B of about 4·B, may be further increased by 2·(0.6 - 0.5)·B concerning the increased safety distances to the banks and (0.35 - 0.3)·B between the vessels, leading to 0.25·B more space needed. If we would add the extra widths due to instabilities and human factor not statistically as assumed in Table 20 but arithmetically, which means that both vessels which are involved in an encounter must not take care of each other, there will be another extra width of about (2 - √2)·0.4·B ≈ 0.25·B, leading to 0.5·B more space, giving 4.5·B in total concerning the basic width, which may be assigned to a safety and ease of navigation standard A. If one look for the necessary minimum width for standard C on the opposite, one may use the findings in Chapter 2.3.6, defining a minimum value for the extra width due to instabilities of ≥ 2 m, according to 0.17·B for Class Va or Vb vessels, this leads to √2·(0.3 - 0.17)·B ≈ 0.2·B less necessary width and thus 2.8·B for the entire basic width. This value is more than experiments made in DST, showing that encounters may technically be possible even with 2.5·B only. But this demands for an extremely reduced speed, which standard may be far below C.

Examples how to account for extra widths, e.g.

- **to up- or downgrade the ease level**
- **Leading to 2.1·B for A or 1.9·B for C for one-lane traffic**

Structure of the report

5 RECOMMENDATIONS FOR SPECIAL DESIGN ASPECTS

5.1 General remarks and guide notes how to use the recommendations in chapter 5
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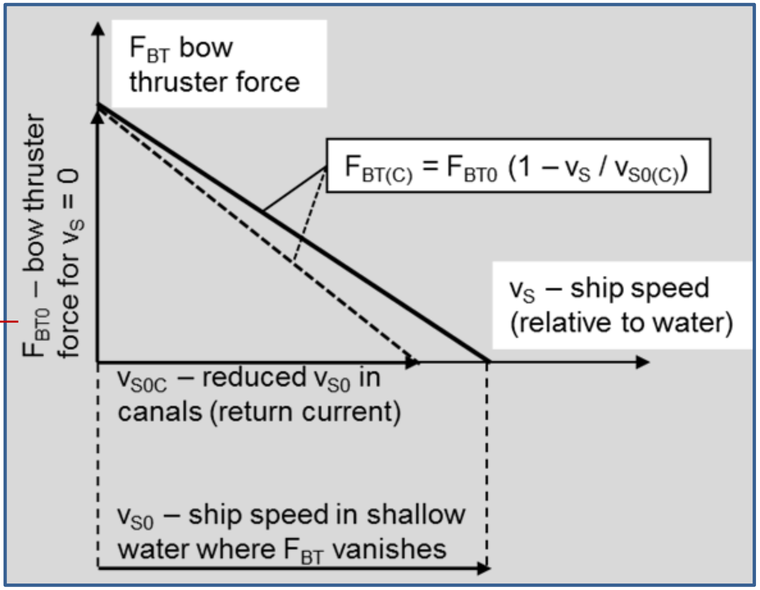
5.2.4 Detailed design for canals

- **Inaccuracies of simulator results are greatest for narrow canals!**
- **But the report offers several hints on how to reduce inaccuracies,**
- **e.g. reduction of bow thruster efficiency by blockage effects**

More hints in Appendix IV



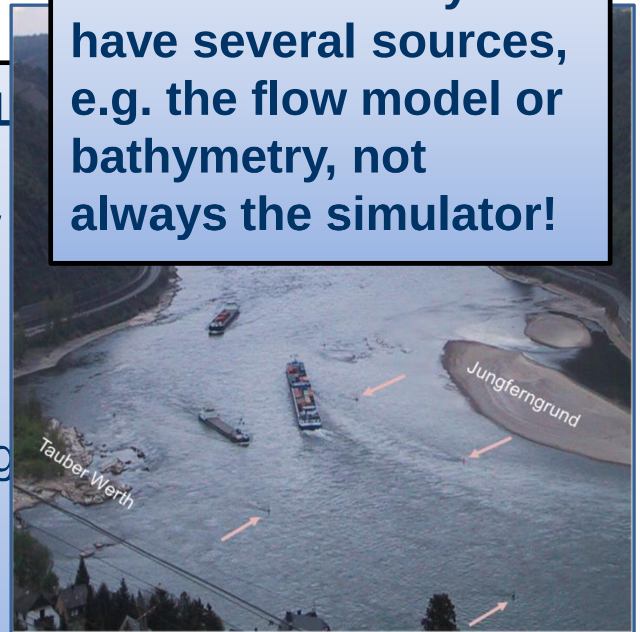
Structure of the report

5 RECOMMENDATIONS FOR SPECIAL

5.1 General remarks and guide notes how recommendations in chapter 5

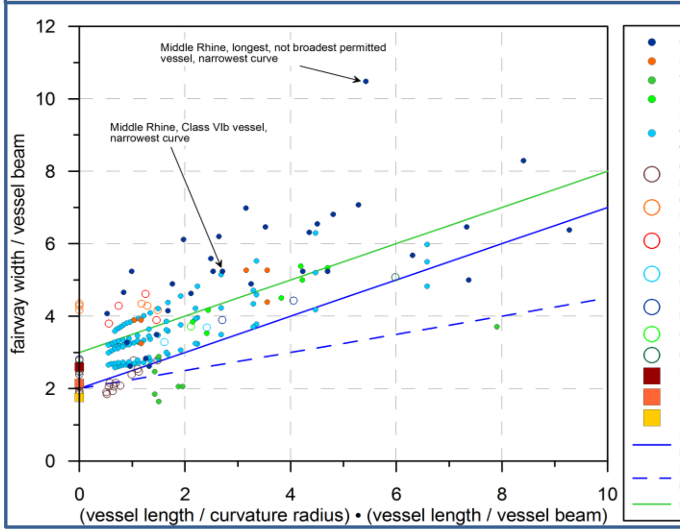
5.2 Canal fairway width and cross section

5.3 Fairway widths in rivers



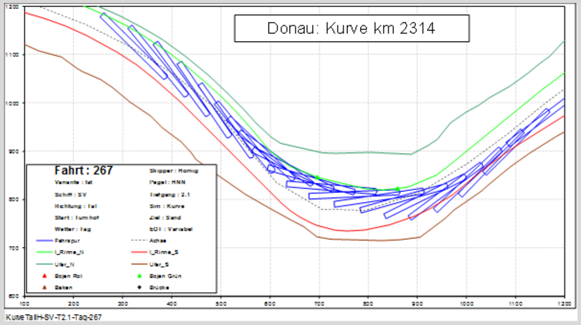
Inaccuracies may have several sources, e.g. the flow model or bathymetry, not always the simulator!

Practice in rivers (fairway marked by buoys)
with conclusions concerning Concept Design
example one lane (3·B for s&e B/C)



Hints on how to improve results + examples for simulations (together with Appendixes 6 and 7)

Main simulation bridge SANDRA with an inland vessel sailing on the river Rhine



Class Vb sailing at mean water on the existing river stretch

DST SANDRA-Simulator: Danube River close to Straubing

Structure of the report

5 RECOMMENDATIONS FOR SPECIAL DESIGN ASPECTS

5.1 General remarks and guide notes how to use the recommendations in chapter 5
5.2 Canal fairway width and cross section
5.3 Fairway widths in rivers
5.4 Width and headroom of bridge openings
5.5 Length and widths of lock approaches
5.6 Junctions
5.7 Turning basins
5.8 Berthing places

Recommended min. bridge opening dimensions

Waterway	Bridge opening single-lane				Bridge opening two-way			
	Ease quality			Remarks	Ease quality			Remarks
	C	B	A		C	B	A	
min W_F	2 B			Minimum safety margin 5.0 m	3 B			Minimum safety margin 5.0 m
min H_B	1.0 H + s			Add minimum safety margin 0.3 m	1.0 H + s			Add minimum safety margin 0.3 m

Advice to look into existing guidelines instead, e.g. Chinese

Decision of INCOM to establish a new WG concerning "Headroom Clearances under Bridges"

- **Weakest part of the report!**
- **It was almost impossible to agree on specific numbers for lateral safety distances!**
- **Detailed Design recommended in many cases!**

Structure of the report

5 RECOMMENDATIONS FOR SPECIAL DESIGN ASPECTS

5.1 General remarks and guide notes how to use the recommendations in chapter 5
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5.4 Width and headroom of bridge openings
5.5 Length
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5.7 Turnin
5.8 Berthi

Practice: bridge opening ratio

River	Section [km]	W_u/B (u)*	W_u/B (d)**
Rhine	424.430 – 595.630	3.3 3.1 (3.1)	2.2 2.6 (2.6)
Neckar	9.746 – 110.017	2.1 2.4 (2.2)	1.9 2.0 (1.7)
Waal – Nieuwe Maas	934.000 – 1001.000	6.6	4.5
China, free flowing rivers (upper bottom width)		3.0) *6.8*	
China, restricted channels (upper bottom width, ratio for broadest vessels only		*3.8 (two-way only)*	
China, canals (ratio for broadest vessels only)		*5.3 (two-way only)*	

There are still some open points!

Structure of the report

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5.1 General remarks and guide notes how to use the recommendations in chapter 5
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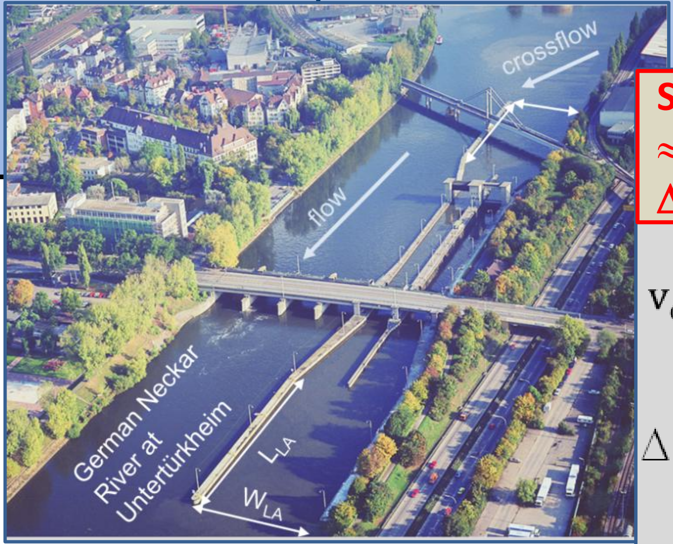
5.5 Length and widths of lock approaches

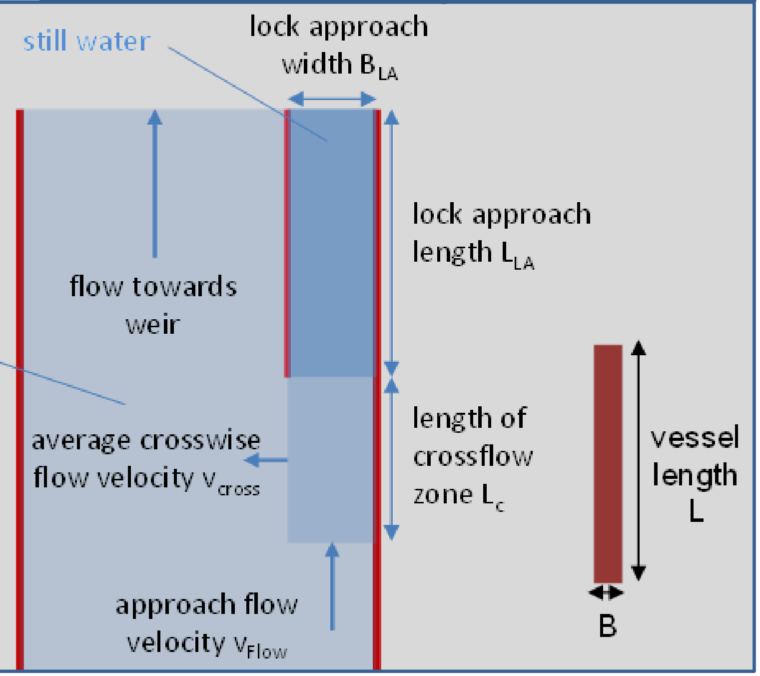


Special feature:
Extended (by influence of v_{Flow}) Concept Design as a starting point for Detailed Design

Sailing fast ($v_{Flow}/v_{SW} \approx 0.3$) $\rightarrow$ $B_{LA} = 2 \cdot B + \Delta b_c \approx 2.6\,B$

$$v_{cross} \approx v_{Flow} \frac{B_{LA}}{L_c}$$

$$\Delta F_{cf} \approx L_c \cdot v_{cross} / v_{ag}$$



General recommendation for a detailed study:
„Who can pay a lock, can also pay a detailed study!“

Structure of the report

5 RECOMMENDATI... ...IGN ASPECTS

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5.3 Fairway widths in ri...

5.4 Width and headroo...

5.5 Length and widths ...

5.6 Junctions

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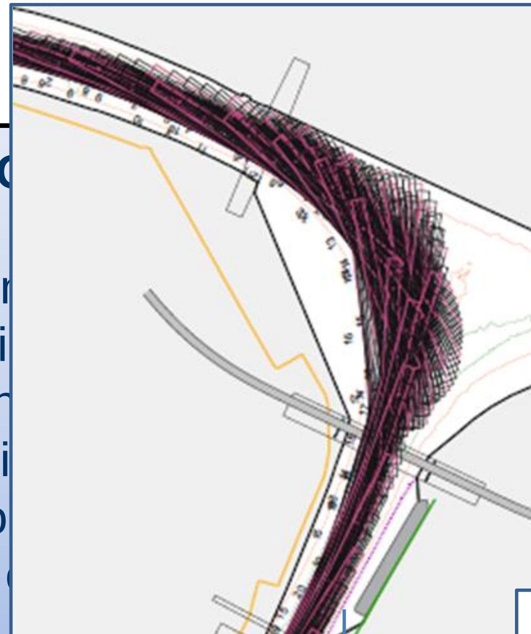

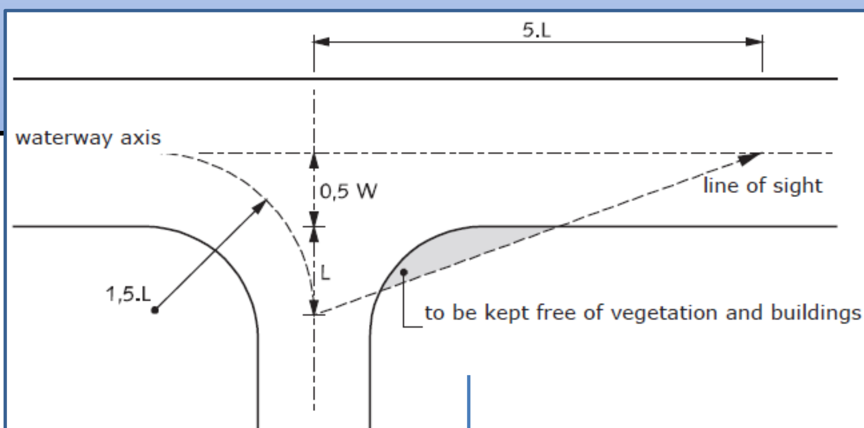

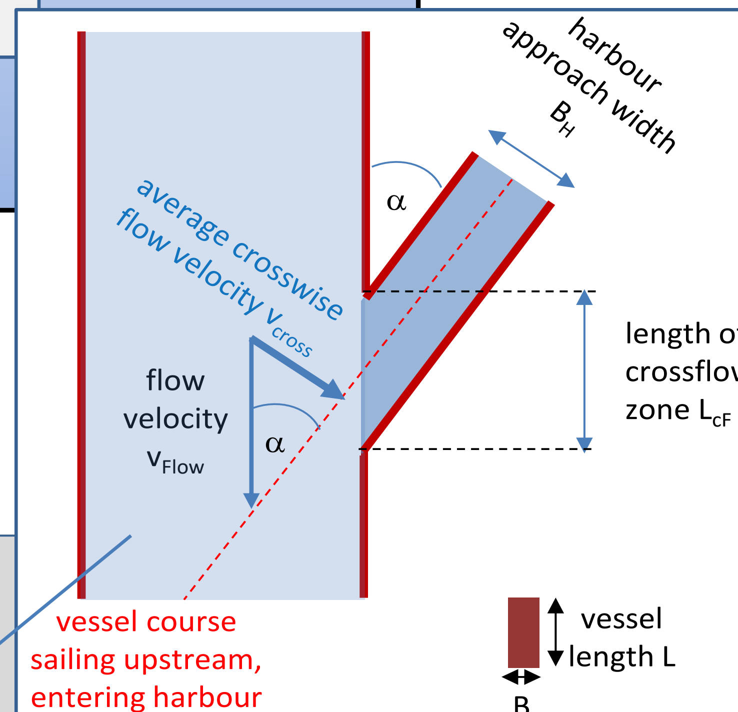

- **Junctions in canals according to Dutch Guidelines**
- **General recommendation to perform a Detailed Study, e.g. for narrow conditions or rivers**
- **Again: Extended Concept Design as a first attempt**

Structure of the report

5 RECOMMENDATIONS FOR SPECIAL DESIGN ASPECTS

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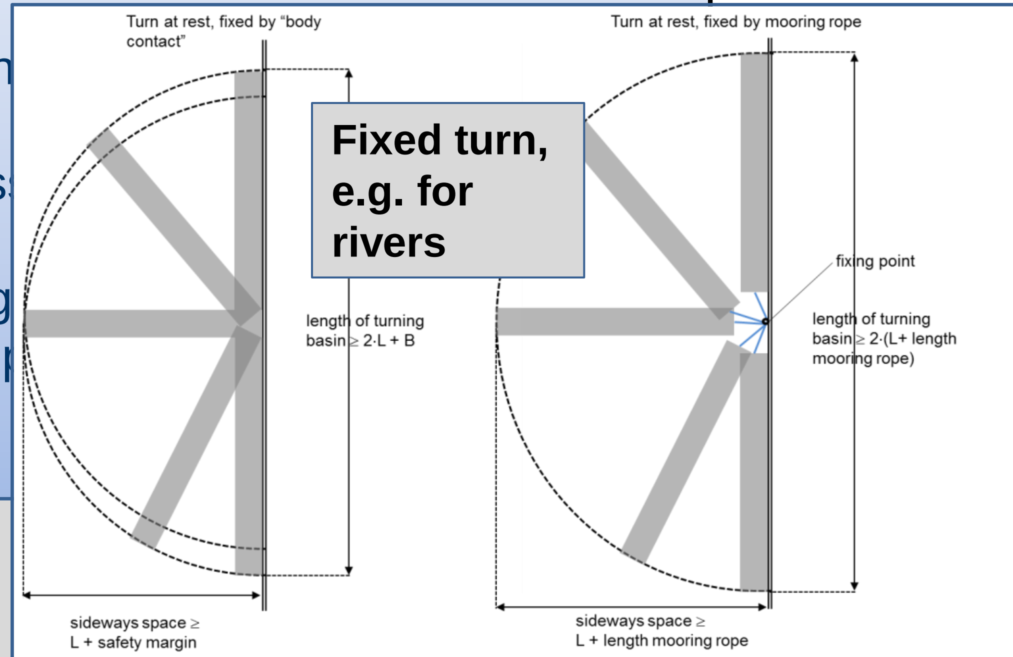
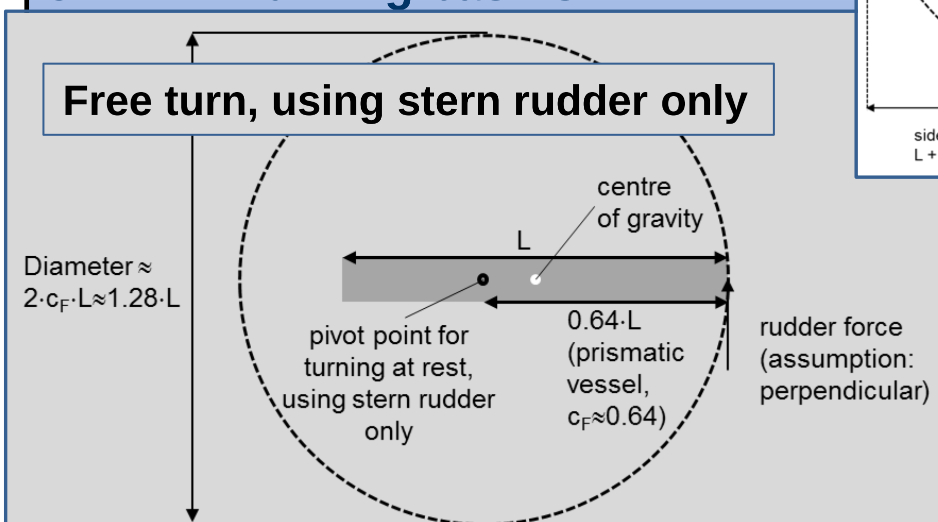
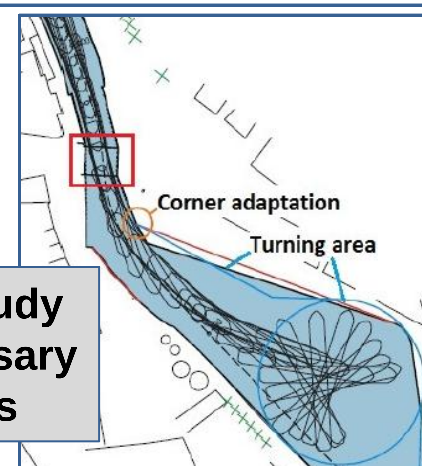




"Rule of thumb" in case of significant flow velocities:
$\Delta L_{drift}[m] \approx C_{\Delta l,drift}\, L[m] \cdot v_{Flow}[m/s]$



A Detailed Study will be necessary in many cases

Structure of the report

5 RECOMMENDATIONS FOR SPECIAL DESIGN ASPECTS

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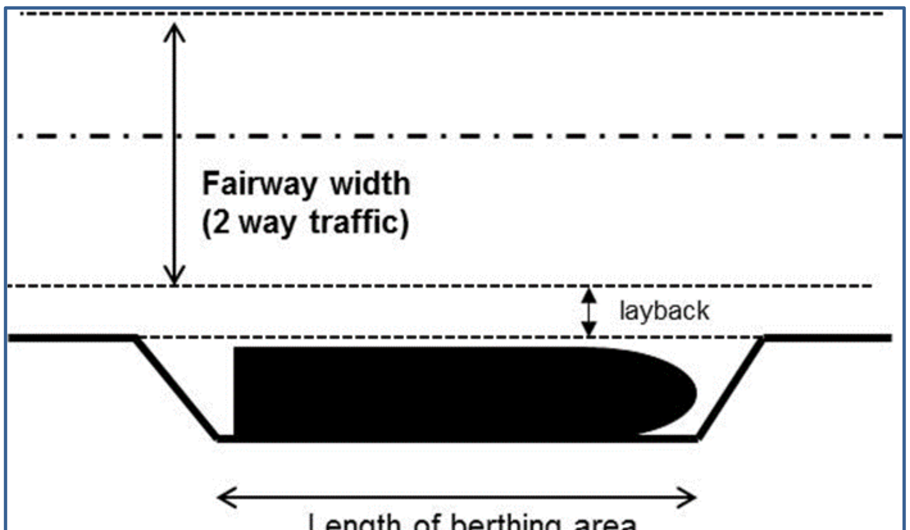
5.3 Fairway widths i
5.4 Width and head
5.5 Length and widt
5.6 Junctions
5.7 Turning basins
5.8 Berthing places and waiting areas

Dimensions of berthing places as a factor of L & B

	Length	Width	Layback	Quality of driving
Dutch	1.2 L	> B	0.5 B	A-B
Germany	-	> B	0.3 B	C
US	-	1.2 B		A
PIANC	1.1	> B + fender	0.3 B	C
PIANC	1.2	> B + fender	0.5 B	A



As always:

- **No recommendation, *whether* berthing or waiting places are necessary,**
- **but if "yes", take the recommended numbers ("PIANC")**

Structure of the report

5 CONCLUSIONS

Not finished yet. Maybe summarizing the "Absolutely essential fundamentals of WG 141 report" of the Antwerp-meeting 2016.

General:

- **Understandable and rational design (choice of methods, quantification)**
  → 3-steps-approach with rational decisions + quantified s&e-approach
  → Process recommendation instead of giving numbers for complicated design
- **Use reasonable design cases only → Accept nautical restrictions for seldom cases**
- **Consider the target group of the report**
  → Decision makers who don't know what is really important, which data are needed, which approach is the best and feasible …
  → Clients of navigational studies who have to know how expensive navigational studies for waterway design purposes may be
  → Layman receive comprehensive background information (Appendixes)

Methods:

- **Concept Design (huge number of influencing parameters and different guidelines):**
  → s&e approach replaces partly adding of increments (as in MARCOM 49)
  → hints on using alternative methods if application limits are reached
- **Practice (partly strongly varying and inaccurate data):**
  → Use it with care because local boundary conditions may dominate design

Structure of the report

5 CONCLUSIONS

- **Detailed Design (how to account for method-specific inaccuracies and random effects?):**
  - → Consider all possibly relevant variants (e.g. by aid of Concept Design) with less effort (e.g. one simulation only) with less effort and restrict simulations to decisive design cases
  - → Apply the principle of comparative variant analyses
    - → Transfer of knowledge from reference cases with good experiences and accepted s&e quality to design case
  - → Use objective results (time series of relevant data) to *quantify* s&e
  - → Use the “averaging principle” for decisive design cases to reduce random effects (several drives instead of one or average of drives with comparable boundary conditions) to end up with a comprehensive score
  - → Focus on *differences* between reference and design case, not absolute values
  - → Use all available information, also absolute values, expert rating …
  - → Interpret the results properly, considering that even the best approach used is not able to eliminate all inaccuracies (e.g. in case of narrow cross sections, T/h close to 1, unsteady turbulence and 3D-flow effects as those from secondary currents)
- **The report provides assistance to all a.m. aspects, clearly together with other codes of practice, e.g. concerning SHSs usage (not yet involved)**

Structure of the report

Class [m]	Headroom	Two way width normal	Two way width reduced	One way width normal	One way width reduced
IV	5.25	45	36	30	24
V	7.0	45	36	30	24

Very narrow! Not only bridge openings!

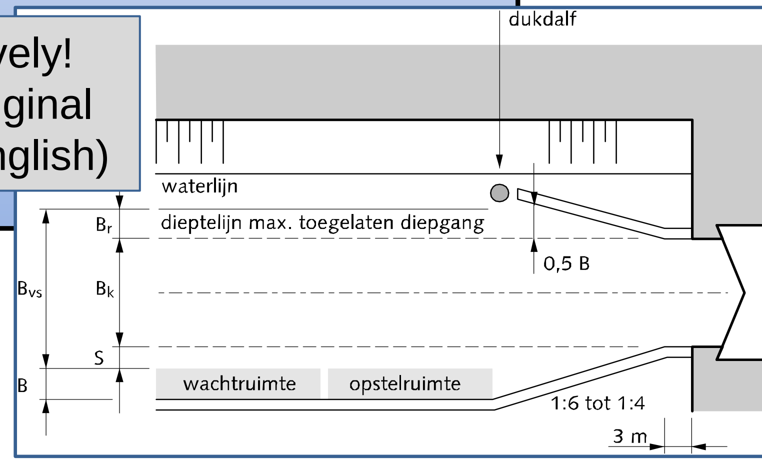
APPENDIX I: SUMMARY OF EXISTING GUIDELINES

- I.1 Preliminary remarks to existing guidelines
- I.2 Belgium Guidelines
- I.3 Chinese Guidelines
- I.4 Dutch Guidelines
- I.5 French Guidelines
- I.6 German Guidelines
- I.7 Russian Guidelines
- I.8 US Guidelines

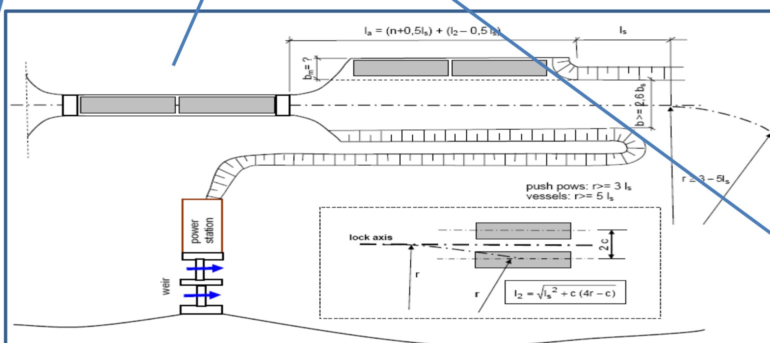
Canals only, extensions to the Dutch guidelines concerning minimum fairway dimensions.

$$F = \sum_{DU} \left(B_{DU} + L_{DU} \sin\beta + s_{DU} \right) + p$$

Unique design formulae



Very comprehensively!
→ Reference to original guidelines (in English)



Deals with e.g. locks ion rivers!

Very small fairways, s ≠ f(B,L), slow speed!

B [m]	F [m] Single-lane	F [m] Two-way
15.2	39.6	57.9
21.3	45.7	70.1
32.0	56.4	91.5
Widths < 39.6 m not recomm..		

$$\Delta w_R = 2\sqrt{(R+B)^2 + (C_f \cdot L)^2} - R - B$$

Canals only! Unique curve increments

Structure of the report

Example Chinese Guidelines

I.3.1 Classification and Design Vessel

I.3.2 Dimensions for Channels and Canals (Fairway Dimensions)

I.3.3 Increments and Clearance

I.3.4 Bridge Openings

I.3.5 Lock Approaches

I.3.6 *Turning Basins* and Junctions

I.3.7 Berthing Places **(no recommendation)**

Table 1: Chinese channel dimensions in rivers

classes of navigable waterways	Convoy general characteristics [m]			Channel dimension rivers [m]			Bend Radius	Bridge clearance [m]		
	length	beam	draught	depth	width single	width double		width single	width double	height
I	406	64.8	3.5	3.5~4.0	125	250	1200	200	400	7
	316	48.6	3.5		100	195	950	160	320	7
	223	32.4	3.							8
II	270	48.6	2.							6
	186	32.4	2.							8
	182	16.2	2.							6
III	238	21.6	2.							6
	167	21.6	2.							6
	160	10.8	2.							6
IV	167	21.6	1.							4
	112	21.6	1.6	1.6~1.9	40	80	340	60	120	4
	111	10.8	1.6		30	50	330	45	90	5
	67.5	10.8	1.6							
V	94	18.4	1.3	1.3~1.6	35	70	280	55	110	4.5
	91	9.2	1.3		22	40	270	40	80	5.5
	55	8.6	1.3							3.5
VI	188	7.0	1.0	1.0~1.2	15	30	180	25	40	3.4
	45	5.5	1.0							4.0
VII	145	5.5	0.7	0.7~0.9	12	24	130	20	32	2.8
	32.5	5.5	0.7							

Inverse classification system to CEMT

Bank increment s for single-lane traffic:

- 0.25~0.30 times swept path for barge
- 0.34~0.40 times swept path for convoys.

These numbers are included in the tables with "basic widths"!

Extra width due to cross flow

Classification	Downbound deviation [m]	additional clearance one way navigation [m]						
	cross current [m/s]							
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8
I	10	25	40	30	60	90	115	140
	10	20	35	25	45	65	90	115
	10	20	30	20	35	55	70	90
II								95
								80
								70
III								80
								70
								65

Generally very generous dimensions because of vessel types, pilot skills …

Some open (yellow marked) points in this table (state February 2017)

Unique recommendations concerning currents:

"For the place where the current effect is great, the width of the turning basin (perpendicular to the current direction) is 1.5 - 2.0 L, the length (along the current direction) is 2.5 - 3.0 L."

Structure of the report

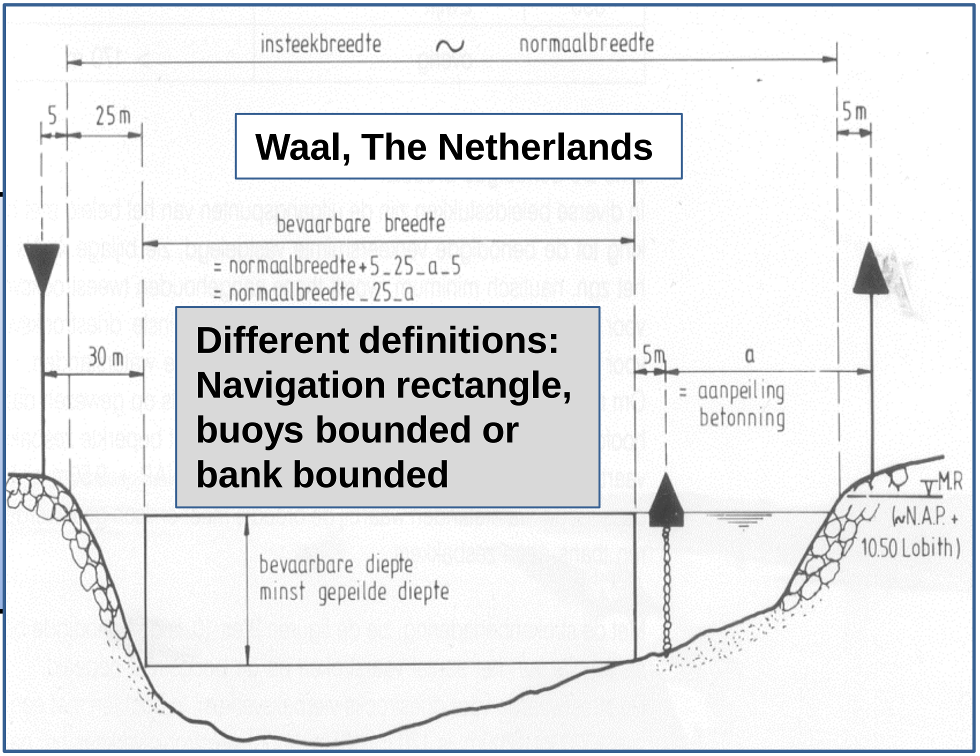
APPENDIX II: DIMENSIONS OF EXISTING GUIDELINES - PRACTICE

II.1 Introduction

II.2 Fairway widths in rivers

II.3 Lock approach lengths and widths

II.4 Bridge openings



Extremely varying

- **bridge opening ratios and**
- **lock approach widths and lengths**

Practice data must be interpreted with care!

*/**Bu = usable width, B = beam ship, u = upstream, d = downstream

River	Section [km]	Bu/B (u)*	Bu/B (d)**
Rhine	424.430 – 595.630	3.3	2.2
Neckar	9.746 – 110.017	2.1	1.9
Waal – Nieuwe Maas	934.000 – 1001.000	6.6	4.5
Average ratio		4.0	2.9

River	Bh/B (u)	Bh/B (l)	Lh/L (u)	Lh/L (l)
Main	2.8d, 1.8s	2.8d, 2.4s	~ 2.5	
Neckar	8.3t, 2.6d, 2.3s	4.2t, 2.5d, 2.0s	0.7 – 1.4	1.0 – 2.1
Nederrijn/Lek	2.9s	3.3s	6.3s	4.0s
Maas	8.2t, 4.9d, 9.4s	6.9t, 4.6d, 3.2s	4.3t, 3.3 d, 4.6s	4.2t, 2.5d, 3.9s
Mosel (Apach lock)	3 (s)	3s	1.26-1.76s	1s
France (CEMT/ITF class Va)	>2.15s	>2.15s	>0.86s	>0.86s
Average ratio	8.3t, 3.4d, 3.6s	5.6t, 3.3d, 2.7s		

B(L)h = beam (Length) harbour – B(L)s = beam (Length) berthed ship(s), u = upper harbour, l = lower harbour, d = double lock, s = single lock, t = triple lock

Structure of the report

APPENDIX III: APPROPRIATE ASSESSMENT OF SAFETY AND EASE QUALITY AND ITS USAGE FOR DESIGN

III.1 How to use the approach
III.2 Simplified safety and ease approach
III.3 Detailed safety and ease approach
III.4 Further examples of applying the safety and ease approach

Comprehensive information on the ideas and numbers behind the s&e approach and recommendations how it should be applied!

Detailed information on how to "design" the detailed s&e approach: E.g. parameters for making distances dimensionless

Table 62: Assignation of ease of navigation categories to the vessel speed over ground

designation of vessel speed	speed over ground	in order to achieve:	ease score
no restrictions	≥ 13 km/h	avoiding severe damage and danger of life and limb in case of accidents	A
adapted speed	ca. 9 – 10 km/h	reduced interaction forces in case of meetings	A, B
small canal speed	ca. 7 km/h	reduced wave heights, e.g. to avoid conflicts with pleasure boats	B
reduced speed	ca. 5 km/h	reduced bank forces	B, C
strongly reduced speed	ca. 3 km/h	no significant interaction forces	C
creep speed	< 2 km/h	no significant damage in case of accidents	C

E.g. background of ship speed criteria

Table 67: Scaling parameters, physical causes and order of magnitude of safety distances s* in terms of ship beams B [VBW, 2016], which can be used as length scales L_c for making characteristic values from simulations dimensionless

Scaling parameter			Physical cause and order of magnitude of approximate ship-to-ship or ship-to-bank safety distances s* for vertical banks
Width	Ship speed	Traffic situation	
Wide river	High cruising speed	One-way traffic, encounters and overtaking	Significant deformation of the primary wave field close to the ship and at the bank when sailing close to the bank ***(s* ≈ B)***
"	Moderate cruising speed	"	Limited deformation because the ship speed is lower ***(s* ≈ approx. 2/3 B)***
Narrow river, canal	"	"	Smaller deformation of the primary wave field because the relative eccentricity of the ship's course is smaller than in wider channels ***(s* ≈ 1/3 B)***
"	Cautious speed	One-way traffic and encounters	Further reduced wave heights because the ship speed is lower (corresponding to German guidelines for standard canal cross sections: ***s* ≈ 2 m or 1/6 B ship-to-ship, 4 m or 1/3 B ship-to-bank)***
"	Very slow speed	"	Bank forces are not relevant. Shipmasters must be able to find their way nevertheless, therefore reduction up to visibility distance ***(s* ≈ 2 m or 1/6 B)***

Structure of the report

Comprehensive information (as in specialist book) on the usage of simulation techniques!

APPENDIX IV: DETAILED OR CASE-BY-CASE-DESIGN – USING SIMULATION TECHNIQUES OR FIELD INVESTIGATIONS

IV.1 Preliminary remarks and definition

IV.2 General remarks for using simulation techniques

IV.3 Influence of human factor in using ship handling simulators

IV.4 General approach in using fast time and full bridge simulators for designing waterways

- **Introducing the NASA TLX (Task Load Index) Test for assessing the "work load" in steering the vessel.**
- **The index can be compared between the ease reference case "erc" and design case ("dc") to consider the human factor aspects *quantitatively*!**

Name of pilot:	Task (driving situation) / variant:	Date / time	
Work load aspect / Corresponding question	Assess-ment of a score between 0 and 1	Weight (from table below)	Weigh-ted score
Mental demand / How mentally demanding was the task?: very low = 0, very high = 1			
Physical demand / How physically demanding was the task?: very low = 0, very high = 1			
Temporal Demand / How hurried or rushed was the pace of the task?: very low = 0, very high = 1			
Performance / How successful were you in accomplishing what you were asked to do?: perfect = 0, failure = 1			
Effort / How hard did you have to work to accomplish your level of performance?: very low = 0, very high = 1			
Frustration / How insecure, discouraged, irritated, stressed and annoyed were you?: very low = 0, very high = 1			
		Average score	

Structure of the report

APPENDIX IV: DETAILED TECHNIQU

IV.1 Preliminary remarks

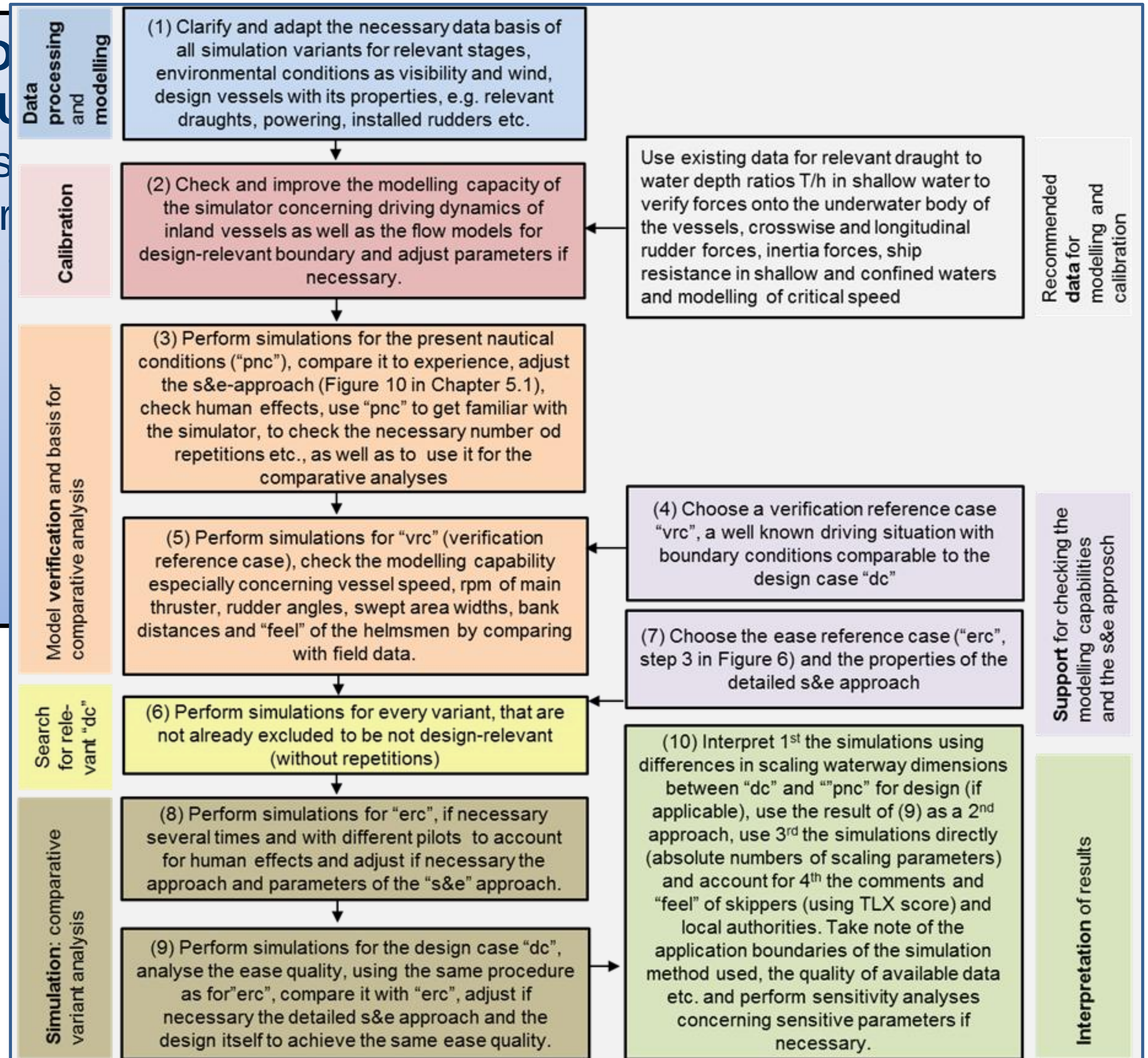
IV.2 General remarks for

IV.3 Influence of human

IV.4 General approach in using fast time and full bridge simulators for designing waterways

Detailed description of the "ideal approach" in using SHSs for waterway design purposes!

Use existing recommendations additionally!



Structure of the report

Comprehensive version of Chapters 2.3.X

APPENDIX V: EXTENDED CONCEPT DESIGN – ACCOUNT FOR EXTRA WIDTHS

V.1 How to account for extra widths

V.2 Understanding of s

V.2.1 Ship-induced wave

V.2.2 Sinusoidal ship cou

V.2.3 Navigating bends

V.2.4 Influence of longitu

V.2.5 Influence of cross c

V.2.6 Driving close to gro

V.2.7 Wind effects

Formulation and recommended approach	Remarks
Extra width ΔF_C in curves (one vessel, one driving direction)	
Approximation for applying the Concept Design within its R/L-ranges (R/L ≥ 5) • $\Delta F_C = c_C L^2/R \leq L$, c_C according to the chosen T or T/h, the driving direction, the longitudinal flow velocity as well as the way of driving from , Chapter 2.3.8 or Appendix 5 • More precisely and generally for R/L<5, use the Pythagoras-approach in with $c_F := (2 \cdot c_C)^{1/2}$ for $c_C \leq 0.5$ and $c_F = c_C + 0.5$ for $c_C > 0.5$ or c_F from Appendix 5 (recommended for rivers)	Note that ΔF_C is very much higher for shallow draft or high longitudinal flow velocities in case of a downstream drive than for deep draught vessels or ships sailing upstream, see Chapter 2.3.8. This holds true for a normal (easy) way of driving (s&e-qualities A, B). In case of sailing not very much faster than the flow velocity and using all navigational means, measurements show that c_C may be reduced to 0.25 for loaded and 0.5 for empty vessels, but not further (s&e-quality C or lower). In case of R/L<2 and high flow velocities, a detailed study will be recommended.

Example extra widths in curves c_c for Class Va vessels

Vessel	Flow velocities / Waterway				
	Canal $v_{Flow} \leq 0.5$ m/s, always acting in driving direction v≈9 km/h, v_{ag}≈10.8 km/h *(italic letters: v_{Flow}=0.0 m/s)*	$v_{Flow} \leq 1.0$ m/s ≈ **impounded river** $v_{Flow}/v = 0.4$ $v_{ag} \approx 5.4$ km/h upwards and 12.6 km/h downwards		$v_{Flow} \leq 1.5$ m/s ≈ **free flowing river**, $v_{Flow}/v = 0.4$ upstream and 0.5 downstream, $v_{ag} \approx 8.1$ km/h upwards and 16.2 km/h downwards	
		Downstream drive	Upstream drive	Downstream drive	Upstream drive
GMS (110x11.4, Class Va)	empty 0.6 *(0.4)* (0.5 Dutch guidelines) loaded 0.3 *(0.25)*	empty 0.8 loaded 0.4	empty 0.4 loaded 0.25	empty 0.9 loaded 0.4	empty 0.4 loaded 0.25

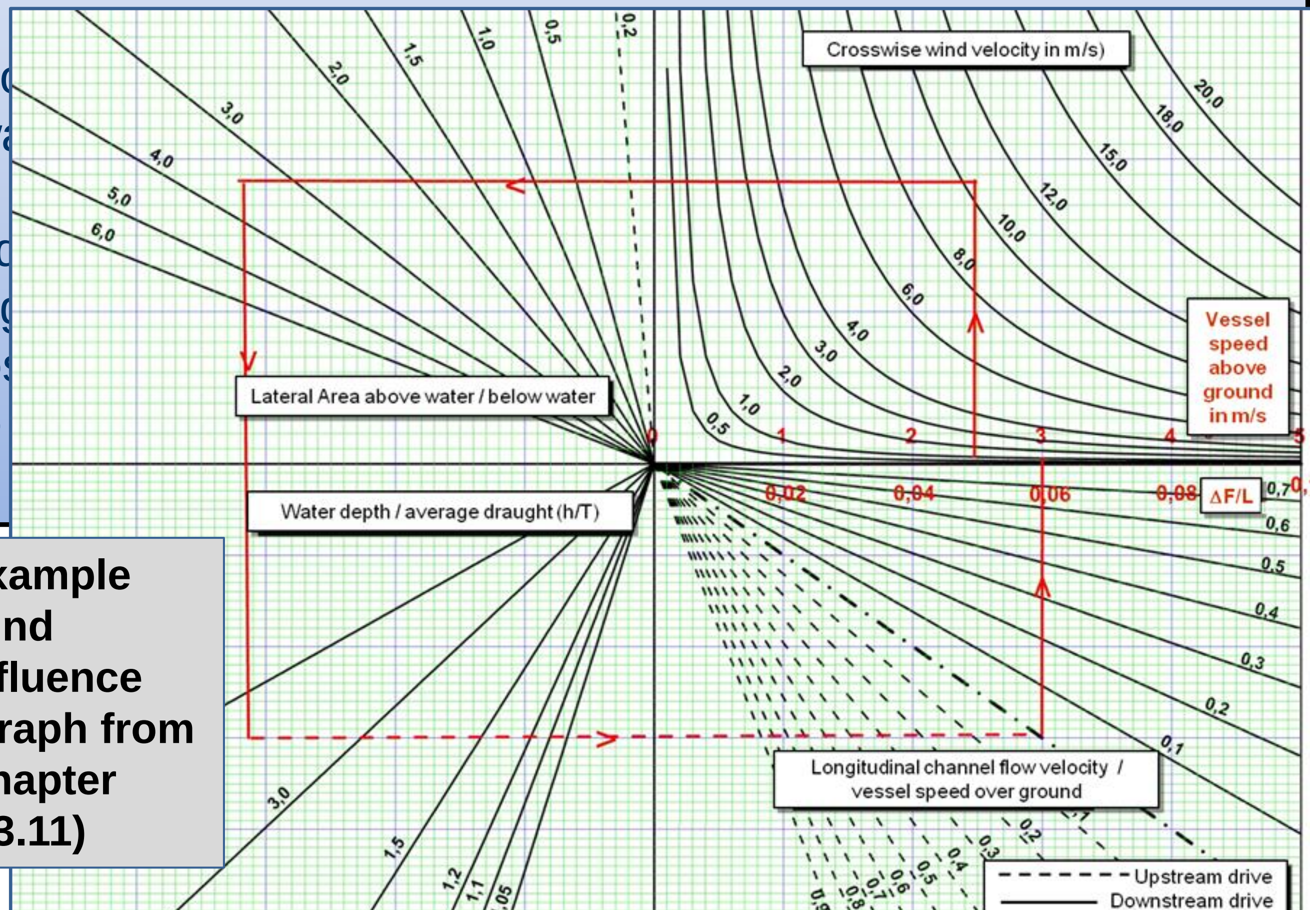
Providing approximation formulae for all relevant extra widths, together with necessary parameters for relevant scenarios and thresholds ($c_C \leq 0.25/0.5$ loaded/empty).

Structure of the report

APPENDIX V: EXTENDED CONCEPT DESIGN – ACCOUNT FOR EXTRA WIDTHS

V.1 How to account for extra widths

V.2 Understanding c
V.2.1 Ship-induced wa
V.2.2 Sinusoidal ship
V.2.3 Navigating bend
V.2.4 Influence of long
V.2.5 Influence of cros
V.2.6 Driving close to
V.2.7 Wind effects



Making it as simple as possible for users!

Example wind influence (graph from Chapter 2.3.11)

Structure of the report

INVESTIGATION OF SAFETY AND EASE OF TRAFFIC ON THE RIVER DANUBE BY REAL TIME SIMULATIONS

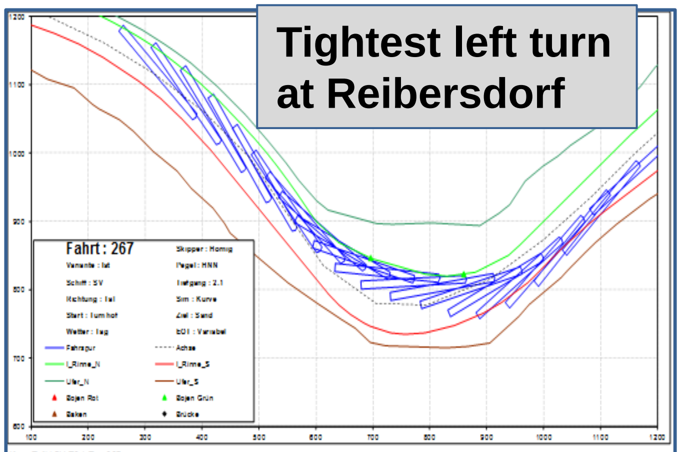
APPENDIX VI: APPLICATION OF THE DETAILED DESIGN APPROACH BY AN EXAMPLE (Danube downstream Straubing)

+ REFERENCES

Narrow Bogenberg Bridge

Class Vb sailing downstream

Tightest left turn at Reibersdorf



- Strictly applying the principles of
  - comparative variant analyses and ,
  - a quantified s&e approach (using weighted averages of different “reserves”), as well as
  - the averaging principle!
- Reference case = present nautical conditions
- Design case = Danube River improvement using river training, same vessels, almost the same fairway, but deeper draught, other flow field

Table 86: Performance of the SV in a specific area

	Final assessment for curve km 2314			
	SV	RNW	MW	HNN
“erc”	Actual	60.7%	56.2%	53.9%
“dc”	Planned	61.7%	59.3%	53.9%

The s&e in terms of reserves is almost the same or better!

Plan to finish the report – state 2nd February 2017

- **Version for reviewers from INCOM: Middle of March**
- **Meeting together with reviewers: Middle of April**
- **Final editing including references: Up to June 2017**