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

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)

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

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

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)
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
1.7 Definitions and designations

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.
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

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!
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

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!
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

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

2.1 Classification of commercial vessels for waterway design

<table>
<thead>
<tr>
<th>Class</th>
<th>Height</th>
<th>Typical vessel [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Length</td>
</tr>
<tr>
<td>I</td>
<td>&gt; 11.8</td>
<td>135</td>
</tr>
<tr>
<td>II</td>
<td>11.8 - 9.0</td>
<td>128.6</td>
</tr>
<tr>
<td>III</td>
<td>9.0</td>
<td>79.9</td>
</tr>
<tr>
<td>IV</td>
<td>9.0 - 6.5</td>
<td>63.1</td>
</tr>
<tr>
<td>V</td>
<td>6.5</td>
<td>55</td>
</tr>
<tr>
<td>VI</td>
<td>3.05</td>
<td>44</td>
</tr>
<tr>
<td>VII</td>
<td>3.05 – 1.25</td>
<td>35</td>
</tr>
</tbody>
</table>

Classification according to different countries / guidelines!

Example: Russian Classification

<table>
<thead>
<tr>
<th>CEMT/ITF class</th>
<th>beam (m)</th>
<th>length (m)</th>
<th>draught (m)</th>
<th>height above waterline (m)</th>
<th>cargo capacity (tonne)</th>
<th>engine power (kW)</th>
<th>bow thruster (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>5.05</td>
<td>38.5</td>
<td>2.5</td>
<td>1.2</td>
<td>3.5</td>
<td>365</td>
<td>175</td>
</tr>
<tr>
<td>II</td>
<td>6.6</td>
<td>50 - 55</td>
<td>2.6</td>
<td>1.4</td>
<td>5.25</td>
<td>535 - 615</td>
<td>240 - 300</td>
</tr>
<tr>
<td>III</td>
<td>8.2</td>
<td>67 - 85</td>
<td>2.7</td>
<td>1.5</td>
<td>5.35</td>
<td>910 - 1250</td>
<td>490 - 640</td>
</tr>
<tr>
<td>IV</td>
<td>9.5</td>
<td>80 - 105</td>
<td>3.0</td>
<td>1.6</td>
<td>5.55</td>
<td>1370 - 2040</td>
<td>750 - 1070</td>
</tr>
<tr>
<td>Va</td>
<td>11.4</td>
<td>110 - 135</td>
<td>3.5</td>
<td>1.8</td>
<td>6.40</td>
<td>2900 - 3735</td>
<td>1375 - 1750</td>
</tr>
<tr>
<td>Vla</td>
<td>17.0</td>
<td>135</td>
<td>4.0</td>
<td>2.0</td>
<td>8.75</td>
<td>6000</td>
<td>2400</td>
</tr>
</tbody>
</table>

Table 6: Characteristics of reference motor cargo vessels

Extended classification, e.g. concerning powering

Adapted from the Dutch guidelines
## 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

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, groyne, wind)
2.4 Definition and data needed

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

### 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, groynes, wind)

#### 2.4 Definition and clarification of design case and data needed

---

**Example:**

Class Va vessel passes a groyne head

Groyne field in the Upper Rhine River at average low water level. A Class Va tanker has just passed the groyne head

Vessel-affected cross flow towards the vessel at the position of the largest drawdown

---

Reference to VBW publication (free download under: [www.vbw-ev.de](http://www.vbw-ev.de) & [www.baw.de](http://www.baw.de))

---

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

2.4 Definition and clarification of design case and data needed

The report provides checklists to support the reader in finding relevant design cases.

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

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

<table>
<thead>
<tr>
<th>Waterway properties</th>
<th>Environmental conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>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?</td>
<td>Where there accidents due to unfavourable environmental conditions in the past, how often did they happen and what were the consequences?</td>
</tr>
<tr>
<td>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?</td>
<td>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?</td>
</tr>
<tr>
<td>How large are relevant water level fluctuations from surges, water management etc.?</td>
<td>Can an efficient wind protection e.g. from vegetation be assumed or ensured with acceptable effort?</td>
</tr>
<tr>
<td>What about existing headroom at bridges, stability demands of bridge constructions and corresponding minimum head clearances and thus number of permitted container layers?</td>
<td>What about relevant sight conditions (fog, sailing at night etc.)?</td>
</tr>
<tr>
<td>How large is the distance between existing places where special manoeuvres as overtaking are possible or can be foreseen with acceptable expenses?</td>
<td>Are there relevant (probability with respect to other influences) flow velocities (rule of thumb &gt; 0.5 m/s) in the canal, e.g. from lock or power plant operation?</td>
</tr>
</tbody>
</table>
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

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

<table>
<thead>
<tr>
<th>Lock Approach</th>
<th>BLA/B</th>
<th>LLA/L</th>
<th>Quality of driving</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>3.5 - 4.5 (s)</td>
<td>3.5 - 4.0</td>
<td>A - B</td>
</tr>
<tr>
<td></td>
<td>7.0 (d)</td>
<td>3.0 - 3.5*</td>
<td></td>
</tr>
<tr>
<td>Dutch</td>
<td>2.2 (s)</td>
<td>1.0 - 1.2</td>
<td>B - C</td>
</tr>
<tr>
<td>French</td>
<td>2.9 (s)</td>
<td>0.5*</td>
<td>C</td>
</tr>
<tr>
<td>Germany</td>
<td>3.0 - 4.0 (s)</td>
<td>2.8</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>4.5 - 6.0 (d)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Structure of the report

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

- 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?

Collection of design criteria determining the
- existing (analysis case) or
- necessary (design case) s&e quality

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!

Driving situation & traffic
one-way, meeting, overtaking, weak or strong traffic

- Fairway conditions
  - straight section, curve, low and strong longitudinal, cross and secondary currents, turbulence, regular or irregular banks, training measures, wide or narrow channel

- Helmsman
  - experience, skills, stress, distraction, deadline pressure, concentration, attention, tiredness

- Hydrology, weather
  - visibility, wind, rising or falling stage, low or high water

- Load and speed
  - deep draught, empty / ballasted vessels, cargo type, fast or moderate ship speed

- Vessel
  - with/without bow thruster, single or twin rudders, weak or strongly powered, one or two-wheeler

- Information systems
  - Radar, GPS, ECDIS, AIS, autopiloting
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!
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

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

<table>
<thead>
<tr>
<th>Class</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Nearly unrestricted drive</td>
</tr>
<tr>
<td>B</td>
<td>Moderate to strongly restricted drive</td>
</tr>
<tr>
<td>C</td>
<td>Strongly restricted drive</td>
</tr>
</tbody>
</table>
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 safety and ease

3.2.2 Example

- 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

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

- 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

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Arguments speaking for a higher necessary ease score for design</th>
<th>Cases where a lower ease quality may be acceptable for design</th>
<th>Score</th>
<th>1st factor</th>
<th>2nd factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Depth exploitation of waterway and type of lead</td>
<td>Deep draught vessels, especially with dangerous goods in very shallow water</td>
<td>Empty or ballasted vessels, no dangerous goods, sufficient water depth</td>
<td>0</td>
<td>1/7</td>
</tr>
<tr>
<td>2</td>
<td>Level of training, personal skills and</td>
<td>Poorly trained pilots, low knowledge on waterway features and</td>
<td>Optimally qualified and experienced helmsman</td>
<td>0*</td>
<td>1/7</td>
</tr>
<tr>
<td>3</td>
<td>Attitude and willingness to cooperate</td>
<td>Objecting to cooperation</td>
<td>Inexperienced or unwilling</td>
<td>-1</td>
<td>1/7</td>
</tr>
<tr>
<td>4</td>
<td>Waterway equipment</td>
<td>Safe navigation equipment or way condition</td>
<td>Inadequate navigation equipment or way condition</td>
<td>+1*</td>
<td>1/7</td>
</tr>
<tr>
<td>5</td>
<td>Traffic situation, ship-ship and ship-ship interaction</td>
<td>One-way traffic, many manoeuvres as overtaking</td>
<td>2 or more navigational lines, accepted interaction forces</td>
<td>+1</td>
<td>1/7</td>
</tr>
<tr>
<td>6</td>
<td>Vessel equipment and instrumentation</td>
<td>Main rudders only or weakly powered bow thrusters, no engine power, no information systems</td>
<td>Strongly powered bow thruster or passive bow rudder, high engine power, dual propellers, optimal information systems</td>
<td>-1*</td>
<td>1/7</td>
</tr>
<tr>
<td>7</td>
<td>Striven vessel speed over ground, individual drive</td>
<td>≥ 13 km/h (1)</td>
<td>10 – 12 km/h (0.5)</td>
<td>5 – 9 km/h (0)</td>
<td>&lt; 4 km/h (1)</td>
</tr>
<tr>
<td>8</td>
<td>Feasible speed range relative to water between Vmini and minimum speed to ensure sterility</td>
<td>≤ 2 km/h (+1)</td>
<td>3 – 4 km/h (+0.5)</td>
<td>4 – 5 km/h (-0.5)</td>
<td>&gt; 6 km/h (-1)</td>
</tr>
<tr>
<td>9</td>
<td>Hindrance due to recreational boating, especially human powered as rowing boats</td>
<td>Strong negative effect especially on possible average speed (+1)</td>
<td>Average hindrance of commercial navigation (0)</td>
<td>No significant influence on speed of freight vessels (-1)</td>
<td>+1</td>
</tr>
<tr>
<td>10</td>
<td>Hindrance of necessary speed reduction in case of high traffic density of commercial navigation</td>
<td>≥ 30,000 vessels per year (+1)</td>
<td>15,000 – 30,000 vessels per year (+0.5)</td>
<td>5,000 – 15,000 vessels per year (-0.5)</td>
<td>&lt; 5,000 vessels per year (-1)</td>
</tr>
</tbody>
</table>

Total score: Sum of single scores (second last column), multiplied by the weighting factor (last column) = + 0.075
3 APPROPRIATE ASSESSMENT OF SAFETY AND EASE QUALITY AND ITS USAGE FOR DESIGN

3.1 Introduction
3.2 Simplified safety and ease approach
  3.2.1 Parameters influencing waterway design
  3.2.2 Example
3.3 Detailed safety and ease approach supporting detailed design

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!

**Specifications in APPENDIX III**

Table 66: Some examples of the approach proposed by 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

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

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

- **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**.

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

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

- **Use national guidelines if available and applicable**

- **Use international guidelines if applicable and accepted instead**

- **Compare results from national and international guidelines as well as practice**

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

- **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”
Fairways in rivers - conclusions from practice data

<table>
<thead>
<tr>
<th>Waterway</th>
<th>Fairway width for alternate single-lane (basic width)</th>
<th>Fairway width for two-way (basic width)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ease quality</td>
<td>Remarks</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>B</td>
</tr>
<tr>
<td>min W_f (straight sections) 1)</td>
<td>3.0 B</td>
<td>2)</td>
</tr>
<tr>
<td>min D (over entire fairway width)</td>
<td>1.2 d</td>
<td>1.3</td>
</tr>
<tr>
<td>min R (ΔF needed for R ≠ ∞) 3)</td>
<td>2 L</td>
<td>3 L</td>
</tr>
</tbody>
</table>

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
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

Existing fairway widths in rivers and from Guidelines (width in draught depth), interpreted as to be limited by buoys, related to vessel beam for two-way traffic.

- 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
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

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

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

- **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
Structure of the report

Recommened Steps in Waterway Design

1. Prepare and check data basis
2. Check modelling capacity
3. Simulate the verification reference case “vrc” and compare it with field data
4. Choose the verification reference case “vrc” (may be identical to “pnc”)
5. Simulate the verification reference case “vrc” and compare it with field data
6. Simulate “dc” for possible variants (maybe only 1 time)
7. Simulate “erc” and adjust if necessary the “s&e” approach
8. Simulate the design case “dc”, analyse the ease quality, compare it with “erc” and adjust “dc” if necessary
9. Interpret results properly!
10. Interpret 1st the simulations, using differences between “dc” and "pnc", use the result of (8) as a 2nd approach, use 3rd the simulations directly (absolute values) and account for 4th experiences

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!
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.

\[
\begin{align*}
\text{Single-lane:} & \\
\text{necessary } W_{F,T_{\text{Min}}} & = \text{basic width + sum}^{1)} \text{ (extra widths for vessel with } T_{\text{Min}}) \\
& \geq \min W_{F,T_{\text{Max}}} + 2 \cdot m_{G} \cdot \Delta T \\
\text{necessary } W_{F,T_{\text{Max}}} & = \text{basic width + sum}^{1)} \text{ (extra widths for vessel with } T_{\text{Max}}) \\
\text{Two-way (standard encounters: both vessels } T_{\text{Min}}, \text{ or one } T_{\text{Max}}, \text{ the other } T_{\text{Min})} & \\
\text{necessary } W_{F,T_{\text{Min}}} & = \text{basic width + sum}^{1)} \text{ (extra widths for the one vessel with } T_{\text{Min}} \text{ and the other with } T_{\text{Max}}) + m_{G} \cdot \Delta T \\
& \geq \min W_{F,T_{\text{Max}}} + 2 \cdot m_{G} \cdot \Delta T \\
\text{necessary } W_{F,T_{\text{Max}}} & = \text{basic width} + \text{sum (increments for vessels both with with } T_{\text{Max})} \\
^{1)} \text{ the sum may be arithmetically (deterministic increments) or statistically (root of the sum of squares)}
\end{align*}
\]
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

- Water surface width
- Fairway width
- Ship beam
- Bank clearance
- Bottom width
- Depth
- Draught
- Dynamic draught
- Bank clearance
## 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

### Summary of considered guidelines!

---

<table>
<thead>
<tr>
<th>Ship (B x L x T)</th>
<th>Two-way (bank slope 3/1)</th>
<th>Single-lane</th>
<th>Driving quality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wf/B</td>
<td>h/T</td>
<td>n</td>
</tr>
<tr>
<td><strong>China Canal</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average (Class II – V)</td>
<td>4.4</td>
<td>1.3</td>
<td>4.4</td>
</tr>
<tr>
<td><strong>China Channel</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average (Class II – VII)</td>
<td>4.4</td>
<td>1.4</td>
<td>6-7</td>
</tr>
<tr>
<td><strong>China River</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average (Class I – VII)</td>
<td>4.4</td>
<td>1.2</td>
<td>-</td>
</tr>
<tr>
<td><strong>Dutch normal</strong></td>
<td>11.45 x 185 x 3.5</td>
<td>4.0</td>
<td>1.4</td>
</tr>
<tr>
<td><strong>Dutch narrow</strong></td>
<td>11.45 x 185 x 2.8</td>
<td>3.0</td>
<td>1.3</td>
</tr>
<tr>
<td><strong>France</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.40 x 180 x 3</td>
<td>3.77</td>
<td>1.5</td>
<td>6.25</td>
</tr>
<tr>
<td><strong>Germany</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.45 x 185 x 2.8</td>
<td>3.3</td>
<td>1.4</td>
<td>5.6</td>
</tr>
<tr>
<td><strong>Russia</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16.5 x 135 x 3.5</td>
<td>2.6</td>
<td>1.3</td>
<td>-</td>
</tr>
<tr>
<td><strong>US River</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.7 x 59.5 x 2.7</td>
<td>~3.3</td>
<td>~1.3</td>
<td>~4.9</td>
</tr>
</tbody>
</table>

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.
RECOMMENDATIONS FOR SPECIAL DESIGN ASPECTS

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

5.1 Introduction for canals

5.2 Canal fairway width

5.2.1 Concept Design for canals

5.2.2 Practice approach for canals

5.2.3 Detailed design for canals

Structure of the report

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

Recommended “basic” waterway dimensions

<table>
<thead>
<tr>
<th>Waterway</th>
<th>For alternate single-lane</th>
<th>For two-way</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease quality</td>
<td>Remarks</td>
<td>Ease quality</td>
</tr>
<tr>
<td>C</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>min ( W_F ) (straight canal sections)</td>
<td>2-B(^1)</td>
<td>For security reasons</td>
</tr>
<tr>
<td>min ( n )</td>
<td>2.5</td>
<td>3.5</td>
</tr>
<tr>
<td>min ( D ) (over bottom width)</td>
<td>1.3 d</td>
<td>Because of squat &amp; efficiency of bow thrusters</td>
</tr>
<tr>
<td>min ( R ) (( \Delta F ) needed for ( R \neq \infty ))</td>
<td>4 L</td>
<td>7 L</td>
</tr>
<tr>
<td>max ( v_{flow} ) (longitudinal)</td>
<td>0.5 m/s</td>
<td></td>
</tr>
<tr>
<td>max ( v_{cross} ) (averaged over ( L ), ( \Delta F ) needed for ( v_{cross} \neq 0 ))</td>
<td>0.5 m/s</td>
<td></td>
</tr>
<tr>
<td>design ( v_W ) (inland) (( \Delta F ) needed for empty/ballasted or container vessels at ( v_W \neq 0 ))</td>
<td>5-6 BF (8.0 – 13.9 m/s; 10.5 m/s according to Dutch Guidelines)</td>
<td></td>
</tr>
<tr>
<td>design ( v_W ) (costal) (( \Delta F ) needed for empty/ballasted or container vessels at ( v_W \neq 0 ))</td>
<td>6-7 BF (10.8 – 17.2 m/s; 13.5 m/s according to Dutch Guidelines)</td>
<td></td>
</tr>
</tbody>
</table>
5 RECOMMENDATIONS FOR SPECIAL DESIGN ASPECTS

5.1 General remarks and guide notes how to use the recommendations

5.2 Canal fairway width

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

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 $v/v_{\text{crit}}$ 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 $v/v_{\text{crit}}$ according to Table 9, the basic width may be increased accordingly if higher $v/v_{\text{crit}}$ should be enabled, see example in Chapter 2.3.1. This would e.g. lead to an increase of $2(0.35 - 0.3)B = 0.1B$ concerning the safety distances to banks and gives $2.1B$ for the basic width. This number may be assigned to a s&é quality tending more to A than B. If, on the other hand, the extra widths concerning instabilities of about $0.4B$, which are included in $2B$ according to the remarks in Table 20, could be reduced to $0.3B$, 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 $1.9B$, which may tend to a s&é 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&é-quality between A and B of about $4B$, 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 $0.25B$ 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 $(2 - \sqrt{2})0.4B \approx 0.25B$, leading to $0.5B$ more space, giving $4.5B$ 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 $\geq 2m$, according to $0.17B$ for Class Va or Vb vessels, this leads to $\sqrt{2}(0.3 - 0.17)B \approx 0.2B$ less necessary width and thus $2.8B$ for the entire basic width. This value is more than experiments made in DST, showing that encounters may technically be possible even with $2.5B$ 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 $2.1B$ for A or $1.9B$ for C for one-lane traffic
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

- 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 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

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)

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

Table 1: Minimum value bridge opening and safety margin (H = fixed height of the vessel above design water level) in canals, straight section

<table>
<thead>
<tr>
<th>Waterway</th>
<th>Bridge opening single-lane</th>
<th>Bridge opening two-way</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ease quality</td>
<td>Remarks</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>B</td>
</tr>
<tr>
<td>min ( W_F )</td>
<td>2 B</td>
<td></td>
</tr>
<tr>
<td>min ( H_a )</td>
<td>1.0 H + s</td>
<td>Add minimum safety margin 0.3 m</td>
</tr>
</tbody>
</table>

Recommended min. bridge opening dimensions

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

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

**Decision of INCOM to establish a new WG concerning “Headroom Clearances under Bridges”**
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 and waiting areas

### Table 1: Bridge opening ratio

<table>
<thead>
<tr>
<th>River</th>
<th>Section [km]</th>
<th>$W_u/B (u)^*$</th>
<th>$W_u/B (d)^{**}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rhine</td>
<td>424.430 – 595.630</td>
<td>3.3 (3.1)</td>
<td>2.2 (2.6)</td>
</tr>
<tr>
<td>Neckar</td>
<td>9.746 – 110.017</td>
<td>2.1 (2.2)</td>
<td>1.9 (1.7)</td>
</tr>
<tr>
<td>Waal – Nieuwe Maas</td>
<td>934.000 – 1001.000</td>
<td>6.6</td>
<td>4.5</td>
</tr>
<tr>
<td>China, free flowing</td>
<td>3.0</td>
<td>6.8</td>
<td></td>
</tr>
<tr>
<td>China, restricted</td>
<td>3.8 (two-way only)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>China, canals (ratio</td>
<td>5.3 (two-way only)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*There are still some open points!*
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

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

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

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

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

General recommendation for a detailed study: „Who can pay a lock, can also pay a detailed study!“
**Structure of the report**

- 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

---

### 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

#### 5.3 Fairway widths in rivers

#### 5.4 Width and headroom of bridge openings

#### 5.5 Length and width of lock approaches

#### 5.6 Junctions

---

**Diagram:**

- **flow velocity** $v_{flow}$
- length of crossflow zone $L_{CF}$
- vessel length $L$
- vessel course sailing upstream, entering harbour
- approach width $B_{H}$

---

**Flow Diagram:**

- waterway axis
- $1.5L$
- $0.5W$
- line of sight
- to be kept free of vegetation and buildings

---

**Table:**

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junctions in canals according to Dutch Guidelines</td>
<td></td>
</tr>
<tr>
<td>General recommendation to perform a Detailed Study, e.g. for narrow conditions or rivers</td>
<td></td>
</tr>
<tr>
<td>Again: Extended Concept Design as a first attempt</td>
<td></td>
</tr>
</tbody>
</table>
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

“Rule of thumb” in case of significant flow velocities:
\[ \Delta L_{\text{drift}} \approx C_{\Delta L_{\text{drift}}} L \cdot v_{\text{Flow}} \]

Fixed turn, e.g. for rivers

A Detailed Study will be necessary in many cases
### Structure of the report

#### 5 RECOMMENDATIONS FOR SPECIAL DESIGN ASPECTS

| 5.1 | General remarks and recommendations |
| 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 and waiting areas |

#### Dimensions of berthing places as a factor of L & B

<table>
<thead>
<tr>
<th></th>
<th>Length</th>
<th>Width</th>
<th>Layback</th>
<th>Quality of driving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dutch</td>
<td>1.2 L</td>
<td>&gt; B</td>
<td>0.5 B</td>
<td>A-B</td>
</tr>
<tr>
<td>Germany</td>
<td>-</td>
<td>&gt; B</td>
<td>0.3 B</td>
<td>C</td>
</tr>
<tr>
<td>US</td>
<td>-</td>
<td>1.2 B</td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>PIANC</td>
<td>1.1</td>
<td>&gt; B + fender</td>
<td>0.3 B</td>
<td>C</td>
</tr>
<tr>
<td>PIANC</td>
<td>1.2</td>
<td>&gt; B + fender</td>
<td>0.5 B</td>
<td>A</td>
</tr>
</tbody>
</table>

As always:
- No recommendation, whether berthing or waiting places are necessary,
- but if “yes”, take the recommended numbers (“PIANC”)

---

PIANC WG 141: Design Guidelines for Inland Waterways; Status-information for INCOM, Brussels, February 1st, 2017, Bernhard Söhngen
5 CONCLUSIONS

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
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

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 narrow! Not only bridge openings!

Canals only, Unique curve increments

Very comprehensive!

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

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

Deals with e.g. locks ion rivers!

<table>
<thead>
<tr>
<th>Class</th>
<th>Headroom [m]</th>
<th>Two way width</th>
<th>One way width</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>normal</td>
<td>reduced</td>
<td>normal</td>
</tr>
<tr>
<td>IV</td>
<td>5.25</td>
<td>45</td>
<td>36</td>
</tr>
<tr>
<td>V</td>
<td>7.0</td>
<td>45</td>
<td>36</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class</th>
<th>Headroom [m]</th>
<th>Two way width</th>
<th>One way width</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>normal</td>
<td>reduced</td>
<td>normal</td>
</tr>
<tr>
<td>IV</td>
<td>5.25</td>
<td>45</td>
<td>36</td>
</tr>
<tr>
<td>V</td>
<td>7.0</td>
<td>45</td>
<td>36</td>
</tr>
</tbody>
</table>

\[ B_{VS} = B_k + 0.5 B \]

\[ B_k = 2 \frac{f + s}{\sin \beta} \]

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

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

Very narrow! Not only bridge openings!

Canals only, Unique curve increments

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

Deals with e.g. locks ion rivers!

<table>
<thead>
<tr>
<th>B [m]</th>
<th>F [m]</th>
<th>Single-lane</th>
<th>Two-way</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.2</td>
<td>39.6</td>
<td>57.9</td>
<td></td>
</tr>
<tr>
<td>21.3</td>
<td>45.7</td>
<td>70.1</td>
<td></td>
</tr>
<tr>
<td>32.0</td>
<td>56.4</td>
<td>91.5</td>
<td></td>
</tr>
</tbody>
</table>

Widths < 39.6 m not recommended.
Table 1: Chinese channel dimensions in rivers

<table>
<thead>
<tr>
<th>Classes of navigable waterways</th>
<th>Convoy general characteristics [m]</th>
<th>Channel dimensions rivers [m]</th>
<th>Bend Radius [m]</th>
<th>Bridge clearance [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>length</td>
<td>draft</td>
<td>width single</td>
<td>width double</td>
</tr>
<tr>
<td>I</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VII</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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”!

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.”

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)
## 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!

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

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

Different definitions:
- Navigation rectangle, buoys bounded or bank bounded

![Waal, The Netherlands](image)
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

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

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

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

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

<table>
<thead>
<tr>
<th>Scaling parameter</th>
<th>Physical cause and order of magnitude of approximate ship-to-ship or ship-to-bank safety distances $s^*$ for vertical banks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width</td>
<td>Traffic situation</td>
</tr>
<tr>
<td>Wide river</td>
<td>High cruising speed, One-way traffic, encounters and overtaking</td>
</tr>
<tr>
<td>&quot;</td>
<td>Moderate cruising speed</td>
</tr>
<tr>
<td>Narrow river, canal</td>
<td>&quot;</td>
</tr>
<tr>
<td></td>
<td>Cautious speed, One-way traffic and encounters</td>
</tr>
<tr>
<td></td>
<td>Very slow speed</td>
</tr>
</tbody>
</table>

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

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

Average score
### APPENDIX IV: DETAILED DESIGN TECHNIQUES

#### IV.1 Preliminary remarks

#### IV.2 General remarks for using simulation techniques

#### IV.3 Influence of human factor in using ship handling simulators for designing waterways

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

<table>
<thead>
<tr>
<th>Structure of the report</th>
</tr>
</thead>
</table>

**Detailed description of the “ideal approach” in using SHSs for waterway design purposes!**

**Use existing recommendations additionally!**
APPENDIX V: EXTENDED CONCEPT DESIGN – ACCOUNT FOR EXTRA WIDTHS

V.1 How to account for extra widths

V.2 Understanding of safety distances

V.2.1 Ship-induced waves

V.2.2 Sinusoidal ship course

V.2.3 Navigating bends

V.2.4 Influence of longitudinal currents

V.2.5 Influence of cross currents

V.2.6 Driving close to groynes

V.2.7 Wind effects

Structure of the report

Comprehensive version of Chapters 2.3.X

Formulation and recommended approach

Remarks

Extra width $\Delta F_c$ in curves (one vessel, one driving direction)

Approximation for applying the Concept Design within its R/L-ranges ($R/L \geq 5$)

- $\Delta F_c = c_c \frac{L^2}{R} \leq L$, $c_c$ 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 $c_c = (2-c_C) \frac{1}{2}$ 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 $\Delta F_c$ 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-qualities 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

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Canal</th>
<th>V\text{Flow} $\leq$ 0.5 m/s, always acting in driving direction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$v_{\text{Flow}} = 0.5$ m/s, always acting in driving direction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$v_{\text{ag}} \approx 9$ km/h, $v_{\text{ag}} \approx 10.8$ km/h</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(italic letters: $v_{\text{Flow}} = 0.0$ m/s)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Canal</th>
<th>$v_{\text{Flow}} \leq$ 1.0 m/s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$v_{\text{Flow}} = 0.4$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$v_{\text{ag}} \approx 5.4$ km/h upwards and 12.6 km/h downwards</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Canal</th>
<th>$v_{\text{Flow}} \leq$ 1.5 m/s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$v_{\text{Flow}} = 0.4$ upstream and 0.5 downstream,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$v_{\text{ag}} \approx 8.1$ km/h upwards and 16.2 km/h downwards</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Canal</th>
<th>Downstream drive</th>
<th>Upstream drive</th>
</tr>
</thead>
<tbody>
<tr>
<td>GMS (110x11.4, Class Va)</td>
<td>empty 0.6 (0.4) (0.5 Dutch guidelines) loaded 0.3 (0.25)</td>
<td>empty 0.8 loaded 0.4</td>
<td>empty 0.4 loaded 0.25</td>
</tr>
<tr>
<td></td>
<td>Downstream drive</td>
<td>Upstream drive</td>
<td></td>
</tr>
<tr>
<td></td>
<td>empty 0.9 loaded 0.4</td>
<td>empty 0.4 loaded 0.25</td>
<td></td>
</tr>
</tbody>
</table>

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).
APPENDIX V: EXTENDED CONCEPT DESIGN – ACCOUNT FOR EXTRA WIDTHS

V.1  How to account for extra widths

V.2  Understanding of safety distances
  V.2.1 Ship-induced waves with its drawbacks to safety distances
  V.2.2 Sinusoidal ship course and effect of human factor
  V.2.3 Navigating bends
  V.2.4 Influence of longitudinal currents
  V.2.5 Influence of cross currents
  V.2.6 Driving close to groynes
  V.2.7 Wind effects

Example wind influence (graph from Chapter 2.3.11)

Making it as simple as possible for users!

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

- 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

<table>
<thead>
<tr>
<th>Final assessment for curve km 2314</th>
</tr>
</thead>
<tbody>
<tr>
<td>SV</td>
</tr>
<tr>
<td>-----</td>
</tr>
<tr>
<td>Actual</td>
</tr>
<tr>
<td>Planned</td>
</tr>
</tbody>
</table>

“erc”

“dc”

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