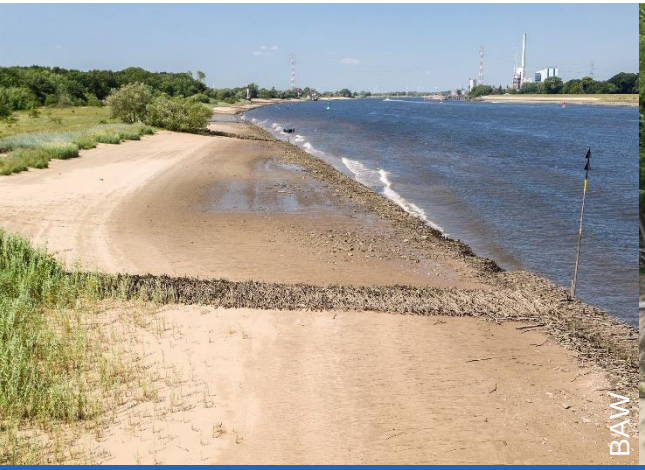


Isabel Schreiber (BAW)
Kathrin Schmitt, Dr Maike Heuner (BfG)

Living shoreline techniques for bank protection along estuarine waterways

Collection of measures in tidal areas

25. April 2022
Version: 3

Hamburg, 25.04.2022

Contents

Beach protection with brushwood training wall Warflether Sand

- **Km 23.50-24.90** left bank Weser
- **Implementation period**: n/a
- **Contact**: Branch office Farge: sven.wennekamp@wsv.bund.de
- **Construction design**: Brushwood training wall (longitudinal structure consisting of tied fascines) made of hardwood fascines to protect the beach
- Maintenance of the training wall is carried out on a section by section basis

Brushwood training wall and brushwood groynes acting as beach protection.

Beach protection with groynes Warflether Sand

- **Km 23.50-24.90** left bank Weser
- **Implementation period**: n/a
- **Contact**: Branch office Farge: sven.wennekamp@wsv.bund.de
- **Construction design**: Brushwood groynes made of hardwood fascines tied to stakes
- Groynes are patched as necessary (every 2-4 years)

BAW

Brushwood groynes protecting the beach, combined with a complementary brushwood training wall.

Beach protection with training wall Juliusplate

- **Km 25.00-25.50** left bank Weser
- **Implementation period**: n/a
- **Contact**: Branch office Farge: sven.wennekamp@wsv.bund.de
- **Construction design**: Brushwood training wall made of hardwood to protect the beach
- Reinstatement works are carried out as necessary

Branch office Farge

Brushwood training wall made of hardwood acting as beach protection.

Beach protection with groynes Juliusplate

- **Km 25.00-25.50** left bank Weser
- **Implementation period**: n/a
- **Contact**: Branch office Farge: sven.wennekamp@wsv.bund.de
- **Construction design**: Brushwood groyne made of hardwood fascines tied to stakes to protect the beach
- Refilling of the groynes is carried out as necessary

BAW

Reinstatement of the brushwood groynes acting as beach protection (March 2020).

Creek damping Bunkerbucht

- **Km 27.850** right bank Weser
- **Implementation period:** 2020
- **Contact**: Branch office Farge: sven.wennekamp@wsv.bund.de
- **Construction design**: Brushwood box to damp a creek running along the revetment

Branch office Farge

Damping of a creek running between the revetment and a vegetation field. Photo taken shortly after completion of the measure (2020).

Beach protection with groynes Elsflether Sand

- **Km 28.50-31.40** left bank Weser
- **Implementation period**: n/a
- **Contact**: Branch office Farge: sven.wennekamp@wsv.bund.de
- **Construction design**: Brushwood groyne made of hardwood fascines tied to stakes acting as beach protection
- Refilling of the groynes is carried out as necessary

BAW

Brushwood groynes protecting the beach.

Beach protection with brush mattress Elsflether Sand

- **Km 28.50-31.40** left bank Weser
- **Implementation period**: From 2016-2017
- **Contact**: Branch office Farge: sven.wennekamp@wsv.bund.de
- **Construction design**: Willow brush mattresses made of hardwood fascines tied to stakes acting as bank protection
- Refilling of the mattresses is carried out as necessary

Branch office Farge

Longitudinal brush mattress structure installed landward from the groynes.

Beach protection with brush mattress Elsfleth marina

- **Km 32.75** left bank Weser
- **Implementation period**: From 2015
- **Contact**: Branch office Farge: sven.wennekamp@wsv.bund.de
- **Construction design**: Dead wood brush mattresses made of hardwood fascines tied to stakes to protect the bank and trap sand at the lock entrance
- Refilling of the mattresses is carried out as necessary

Branch office Farge

Brush mattresses acting as bank protection and sand trap.

Beach protection with groynes

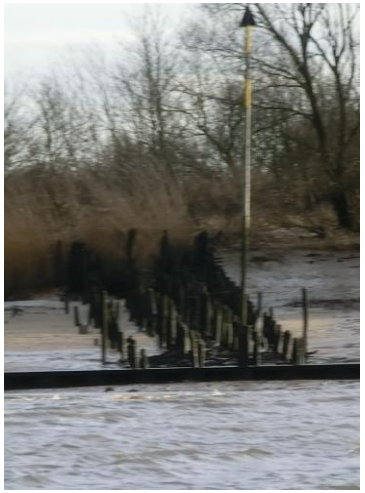
- **Km 33.10-33.25** left bank Weser
- **Implementation period**: n/a
- **Contact**: Branch office Farge: sven.wennekamp@wsv.bund.de
- **Construction design**: Brushwood groyne made of hardwood fascines tied to stakes acting as beach protection
- Refilling of the groynes is carried out as necessary

Branch office Farge

Brushwood groynes directly adjacent to the Weser dike to protect the beach.

Groyne maintenance Harriersand

- **Km 33.30-34.25** right bank Weser
- **Implementation period**: n/a
- **Contact**: Branch office Farge: sven.wennekamp@wsv.bund.de
- **Construction design**: Brushwood groynes made of hardwood fascines tied to stakes acting as beach protection
- The groynes have been in place for several decades and are refilled as necessary



Branch office Farge

Brushwood groynes near Harriersand.

Training wall Käseburger Siel

- **Km 36.50-36.60** left bank Weser
- **Implementation period**: n/a
- **Contact**: Branch office Farge: sven.wennekamp@wsv.bund.de
- **Construction design**: Brushwood training wall made of hardwood fascines tied to stakes acting as beach protection
- Refilling of the training wall is carried out as necessary

Branch office Farge

Training wall made of tied fascines.

Training wall Schierlohstrand

- **Km 38.10-38.20** left bank Weser
- **Implementation period:** 2013
- **Contact**: Branch office Farge: sven.wennekamp@wsv.bund.de
- **Construction design**: Brushwood training wall made of hardwood fascines tied to stakes acting as beach protection
- Refilling of the training wall is carried out as necessary

Branch office Farge

Brushwood training wall on the Schierlohstrand.

Brushwood training wall Harriersand

- **Km 39.875-40.62** right bank lower Weser
- **Implementation period**: ~2000
- **Contact**: WSA Weser-Jade-Nordsee: Rainer.hauerken@wsv.bund.de
- **Construction design**: Brushwood training wall made of 4 tied pile rows adjacent to the sheet pile wall of the WSA's office in Bremen.
- Water motion has been reduced and the site has silted-up since (2018).

WSA Weser-Jade-Nordsee

Brushwood training wall made of 4 tied pile rows adjacent to the sheet pile wall of the WSA's office in Bremen.

Creek damping lower Weser

- **Km 42.400** right bank lower Weser
- **Implementation period**: ~2008
- **Contact**: WSA Weser-Jade-Nordsee: Rainer.hauerken@wsv.bund.de
- **Construction design**: Brushwood box (2 tied pile rows) acting as creek damping to protect the bank and reduce water motion
- Water motion has effectively slowed down. On the landward side of the damping, reeds have developed; rushes are colonising in front of the brushwood box.
- As soon as a complete vegetation cover has established the measure will be deemed to be effective with maintenance being suspended.

WSA Weser-Jade-Nordsee

Longitudinal brushwood box structure acting as a creek damping to reduce water motion. Riparian vegetation has colonised the site around the structure: reeds on the landward side and rushes on the seaward side.

Northern tip Harriersand island

- **Km 43.125-44.050** right bank lower Weser
- **Implementation period:** ~1987 (tip of the island); ~1994 (brushwood groynes)
- **Contact**: WSA Weser-Jade-Nordsee: Rainer.hauerken@wsv.bund.de
- **Construction design**: Transverse fascine structures consisting of heavily silted brushwood groynes (4 tied pile rows) acting as silt traps to reduce local dredging volumes
- 1/3 of the structure is covered by vegetation with the remainder of the site consisting of tidal flats

WSA Weser-Jade-Nordsee

Fascine structure acting as a silt trap on the northern tip of the Harriersand island.

Bank stabilisation lower Weser (Niedersachsenkai)

- **Km 43.300-44.125** left bank lower Weser
- **Implementation period**: ~1995
- **Contact**: WSA Weser-Jade-Nordsee: Rainer.hauerken@wsv.bund.de
- **Construction design**: Brushwood training wall made of 4 tied pile rows to stabilise the bank and encourage tidal flat sedimentation.
- Split into a northern and southern section. The medium section has been dredged away to make way for the “Niedersachsenkai” pier.

WSA Weser-Jade-Nordsee

Brushwood training wall made of 4 tied dead wood pile rows.

Brushwood training wall Sandstedt

- **Km 43.100-44.100** right bank lower Weser
- **Implementation period**: ~1950
- **Contact**: WSA Weser-Jade-Nordsee: Rainer.hauerken@wsv.bund.de
- **Construction design**: Brushwood training wall to ensure and control sluice drainage
- Smooth operation, maintenance carried out in 5-year intervals

WSA Weser-Jade-Nordsee

Brushwood training wall ensuring and controlling sluice drainage in Sandstedt on the lower Weser.

Pile and brushwood groynes Sandstedt

- **Km 44.250-44.500** right bank lower Weser
- **Implementation period:** ~1985 (pure brushwood groynes); from ~1993 (pile groynes)
- **Contact**: WSA Weser-Jade-Nordsee: Rainer.hauerken@wsv.bund.de
- **Construction design**: 2 brushwood groynes and 6 pile groynes with a brushwood head
- Pile groynes made of pine/larch poles
- Brushwood groynes in the beach area suffered from premature rot
- → danger to beach visitors, prompting replacement by single-row pile groynes

WSA Weser-Jade-Nordsee

Single-row pile groynes with a brushwood head to protect the bank at Sandstedt beach.

Brushwood training wall for water supply to the Upper Schweiburg

- **Km 44.500-44.800** left bank lower Weser
- **Implementation period**: ~1990-2000
- **Contact**: WSA Weser-Jade-Nordsee: Rainer.hauerken@wsv.bund.de
- **Construction design**: Brushwood training wall made of 4 tied pile rows to support water supply to the Upper Schweiburg, bank stabilisation and tidal flat sedimentation.
- The brushwood training wall has been constructed twice: the first structure was situated 50m further west (landward) and rapidly silted up, albeit without completely meeting the intended purpose.
- The second structure was built at today's position, again to supply more water to the Schweiburg, but proved to be only partially effective for this purpose. Tidal flats have stabilised.

WSA Weser-Jade-Nordsee

Brushwood training wall made of 4 tied pile rows to supply more water to the Schweiburg and stabilise the bank and tidal flats.

Brushwood box for groyne protection in Rechtenfleth

- **Km 46.625** right bank lower Weser
- **Implementation period**: ~2000-2005
- **Contact**: WSA Weser-Jade-Nordsee: Rainer.hauerken@wsv.bund.de
- Preliminary inspections carried out by the WSA Bremerhaven and BAW
- **Construction design**: Brushwood box system to protect the groyne root from permanent exposure to scouring and damaging effects.
- Since an armour stone extension of the groyne towards the embankment has not sufficiently reduced the level of hydrodynamics, the brushwood box was built to contain water motion.

WSA Weser-Jade-Nordsee/WSA Bremerhaven

Brushwood box system protecting the groyne root.

Reduction of water motion Königsbalje

- **Km 47.58-47.875** right bank lower Weser
- **Implementation period**: ~1994
- **Contact**: WSA Weser-Jade-Nordsee: Rainer.hauerken@wsv.bund.de
- **Construction design**: Combined armour stone/dead wood structure: brushwood training wall (2 tied pile rows) with a riprap toe protection to slow down water motion.
- The structure has been installed at a distance of 5m from the bank and is aligned to the bank's natural shape.

WSA Weser-Jade-Nordsee

Combined structure aligned to the natural shape of the river bank to reduce hydrodynamics.

Creek damping lower Weser

- **Km 48.150** right bank lower Weser
- **Implementation period**: ~2008
- **Contact**: WSA Weser-Jade-Nordsee: Rainer.hauerken@wsv.bund.de
- **Construction design**: Groyne protection consisting of a brushwood mattress made of 4 tied pile rows acting as a deflector for creek damping.
- Water motion has effectively slowed down; maintenance will cease after 2019 since the mission has been accomplished.

WSA Weser-Jade-Nordsee

Four tied pile rows acting as groyne protection.

Brushwood training wall Strohauser Plate

- **Km 48.500-50.380** left bank lower Weser
- **Implementation period**: ~2010-2018
- **Contact**: WSA Weser-Jade-Nordsee: Rainer.hauerken@wsv.bund.de
- **Construction design**: Brushwood training wall made of 4 tied pile rows (built in 6 construction phases) to stabilise tidal flats.

WSA Weser-Jade-Nordsee

Brushwood training wall made of 4 tied pile rows stabilising the bank and tidal flats.

Tidal flat and reed area development lower Weser

- **Km 49.125-50.07** right bank lower Weser
- **Implementation period:** 1992-1998
- **Contact**: WSA Jade-Weser-Nordsee Rainer.hauerken@wsv.bund.de
- **Construction design**: Combined armour stone (iron silicate slag)/dead wood structure.
- 2 tied pile rows with a riprap toe protection (brushwood box). Steep erosion edges before works started. (Previously built with barges.) The site has flourished requiring only intermittent maintenance.

WSA Weser-Jade-Nordsee

Combined armour stone/dead wood structure: 2 tied pile rows with a riprap toe protection.

Tip of the Strohauser Plate island

- **Km 50.380-51.640** left bank lower Weser
- **Implementation period:** ~1987 (tip of the island); ~1995 (brushwood groynes)
- **Contact**: WSA Weser-Jade-Nordsee: Rainer.hauerken@wsv.bund.de
- **Construction design**: Training wall spanning the complete stretch combined with adjacent transverse fascine structures (brushwood groynes) at km 50.700, km 51.000 east and west, km 51.200 east and west, km 51.400.
- The fascine training wall has been overbuilt with iron silicate slag.
- As intended, the area around the tip of the island has become heavily silted up, reducing local dredging volumes.

WSA Weser-Jade-Nordsee

Heavily silted up transverse fascine structures made of 4 tied pile rows forming a training wall that is overbuilt with slag.

Creek damping lower Weser

- **Km 50.380** left bank lower Weser
- **Implementation period**: ~1993
- **Contact**: WSA Weser-Jade-Nordsee: Rainer.hauerken@wsv.bund.de
- **Construction design**: Longitudinal brushwood mattress structure acting as a creek damping to protect the bank and groyne and support reed growth and tidal flat sedimentation.
- Tidal flats and reed vegetation behind the structure have stabilised. Groyne protection and creek deflection are operating effectively.

WSA Weser-Jade-Nordsee

Longitudinal fascine structure protecting the banks and groyne and supporting tidal flat and reed development.

Creek damping lower Weser

- **Km 52.350** left bank lower Weser
- **Implementation period**: ~1999
- **Contact**: WSA Weser-Jade-Nordsee: Rainer.hauerken@wsv.bund.de
- **Construction design**: Creek damping made of brushwood boxes to stabilise the banks and groyne and to support tidal flat sedimentation and reed growth.
- Reed vegetation behind the brushwood box has recovered well; full groyne protection is operating effectively.
- One more maintenance session scheduled for 2021.

WSA Weser-Jade-Nordsee

Brushwood box for creek damping.

Bank protection former ferry pier Kleinensiel

- **Km 53.500** left bank lower Weser
- **Implementation period**: ~1991
- **Contact**: WSA Weser-Jade-Nordsee: Rainer.hauerken@wsv.bund.de
- **Construction design**: Solid bank protection made of brushwood boxes with riprap cover.
- Goes back to times of ferry operations exposing the bank to heavy hydraulic loads → bank protection was a must.
- The bank has stabilised, is largely silted up and covered by vegetation, making maintenance superfluous.

WSA Weser-Jade-Nordsee

Anti-scour brushwood box with riprap cover at the ferry pier.

Brushwood box Kleinensieler Plate

- **Km 54.600-54.850** left bank lower Weser
- **Implementation period:** 2018; two more similar construction phases (some 100m long) further north scheduled in 2019 and 2020.
- **Contact**: WSA Weser-Jade-Nordsee Rainer.hauerken@wsv.bund.de
- **Background**: During the implementation of the compensation scheme “Kleinensieler Plate” backfilling created a steep bank entirely left to nature after completion in 2000. Repeated cases of erosion edges have been observed at the elevation; the crest of the backfill is colonised by shrubs that tumble into the water from time to time due to storms or erosion effects, which impedes transport safety.
- **Construction design**: Parts of the erosion edge are protected by a longitudinal brushwood box structure. Brushwood is set to be refilled in 2020 with no maintenance needs expected afterwards.

WSA Weser-Jade-Nordsee

Brushwood box protecting an erosion edge and the vegetation established on the bank.

Indirect ecological upgrading of the bank in Großensiel

- **Km 56.100-56.500** left bank lower Weser
- **Implementation period**: ~1990
- **Contact**: WSA Weser-Jade-Nordsee: Rainer.hauerken@wsv.bund.de
- **Construction design**: Longitudinal riprap structure
- Indirect technical-biological bank protection solution: technical structure, albeit aimed at supporting the development of reed and ruderal areas

WSA Weser-Jade-Nordsee

Technical longitudinal structure serving biological objectives: bank protection as well as reed and ruderal area development.

Bank protection Luneplate

- **Km 58.400-58.875** right bank lower Weser
- **Implementation period**: ~2003
- **Contact**: WSA Weser-Jade-Nordsee: Rainer.hauerken@wsv.bund.de
- **Construction design**: Combined armour stone/dead wood structure: brushwood box (2 tied pile rows) and a riprap layer, both completely covered in silt.

WSA Weser-Jade-Nordsee

Combined structure made of two tied dead wood pile rows and a riprap layer.

Reinstatement works on the Delme

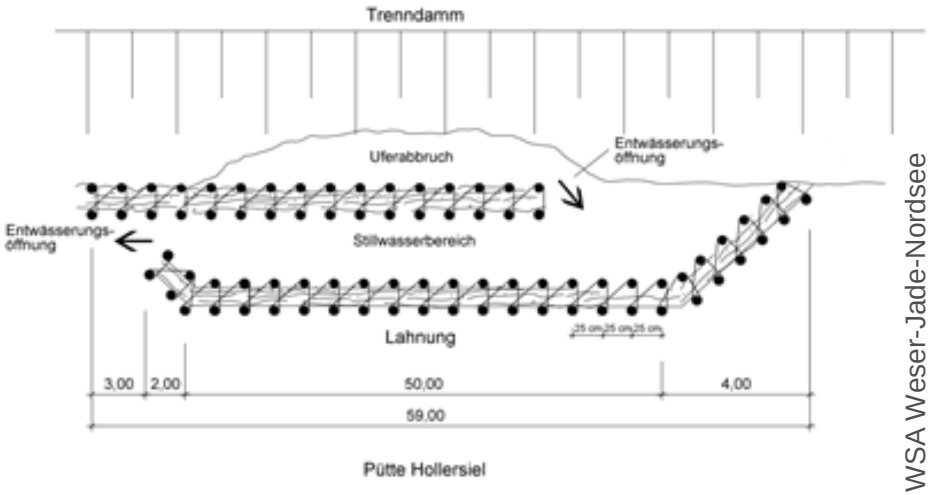
- **Km 0-0.5** both Delme banks (near km 20.750 of the Ochtum where it is joined by the Delme)
- **Implementation period:** As necessary
- **Contact**: WSA Weser-Jade-Nordsee, branch office Habenhausen: friedrich.hauptmann@wsv.bund.de
- **Construction design**: Embankment protection of a dike without foreland (*Schardeich*) by means of a riprap toe protection capped with willow brush mattresses made of willow cuttings
- Willow rods were available from willow trees growing at the slope crest and were immediately used as live material
- Maintenance obligations go back to the 8m expansion of the Weser (watercourses outside the WSV's scope of responsibility)

Bremen branch office 1

Longitudinal structure acting as embankment protection. The revetment is made of a riprap toe protection and a transverse armour stone structure capped with a willow brush mattress with willow cuttings.

Compensation scheme Hunte expansion Hollersiel

- **Km 11.9-12.0** right bank Hunte
- **Implementation period:** 2018
- **Contact**: WSA Weser-Jade-Nordsee: Dieter.hoeffmann@wsv.bund.de
- **Construction design**: A longitudinal brushwood box structure made of 2 tied pile rows was placed immediately in front of the vulnerable bank. The boxes were filled with straw serving as a filter and capped with fascines.
- A secondary armour stone protection structure was installed in front to absorb wave action. Previous plans envisaged a 2nd pile structure, but appropriate ground fixing proved to be impossible, which gave way to the alternative armour stone solution.
- Since the structure was installed in 2018 only, final conclusions on its impacts would be premature. It is placed on the far side of the navigation channel behind a former land protection dike, where tidal influence is muted.



WSA Weser-Jade-Nordsee

Compensation measure comprised of longitudinal structures made of double pile rows and riprap.

Erosion protection in a bend

- **Km 5.15-5.20** right bank Wümme
- **Implementation period:** 2014-2015 winter season
- **Contact**: Branch office Farge: sven.wennekamp@wsv.bund.de
- **Construction design**: Brushwood box training wall made of hardwood fascines securing a breach in a bend to prevent further abrasion and maintain the natural river course

Branch office Farge

Protection of a breach in the area around a Wümme bend to preserve the natural river course.

Test track 1 Lesum/Wümme confluence

- **Km 17.31-17.39** left bank Wümme
- **Implementation period:** 2013-2014 winter season
- **Contact**: Branch office Farge: sven.wennekamp@wsv.bund.de
- Test track 1 under the maintenance plan for the Lesum/Wümme mouth
- **Construction design**: Combined structure of brushwood box (hardwood fascines) and brush mattresses tied to stakes
- Backfilling up to the level of the reed behind the brushwood box plus minor initial planting of reeds
- Purpose: embankment toe and bank protection, scour repair

BAW

Test track 1 on the Wümme: combined structure comprised of a brushwood box, a tied brush mattress placed in front and rearward backfilling up to the level of the reed (photos taken in 2020).

Test track 2 Lesum/Wümme confluence

- **Km 17.00-17.08** right bank Wümme
- **Implementation period:** 2013-2014 winter season
- **Contact**: Branch office Farge: sven.wennekamp@wsv.bund.de
- Test track 2 under the maintenance plan for the Lesum/Wümme mouth
- **Construction design**: Brush mattress made of hardwood fascines tied to stakes acting as embankment toe and bank protection on the outer bank

BAW

Test track 2 on the Wümme: dead wood brush mattress protecting the embankment.

Test track 3 Lesum/Wümme confluence

- **Km 16.18-16.24** right bank Wümme
- **Implementation period:** 2013-2014 winter season
- **Contact**: Branch office Farge: sven.wennekamp@wsv.bund.de
- Test track 3 under the maintenance plan for the Lesum/Wümme mouth
  Purpose: embankment toe and bank protection, scour repair
- **Construction design**: Brushwood box made of hardwood fascines and pile wall made of timber poles. Backfilling up to the level of the reed behind the brushwood box plus minor initial planting of reeds
- Intended effect not achieved → structure was unstable in parts and required reworking

Branch office Farge

BAW

Test track 3 on the Wümme: brushwood box behind a pile wall (2014) and status of the adapted measure as of 2020 (right).

Contents

Lowering of revetment Juelssand/Hetlingen

BAW

- **Km 650.600-651.200** right bank Elbe
- **Implementation period:** 6 weeks in 2012
- **Contact**: WSA Elbe-Nordsee, Elbe Habitat Foundation, Integrierte Station Unterelbe
- **Total cost**: ~ €43,000
- **Construction design**: 5 sections of the revetment (total revetment length: 600m) were truncated by 60-80cm to 10m each to allow for overtopping into the hinterland
- Bottom and face of the cut-outs shielded with river mattresses
- 500mt of armour stones have been moved

Local lowering of the revetment and installation of river mattresses to enable vegetation establishment. → Measure FR 4.5 HH/SH under the *Integrated Management Plan (IBP) Weser* (“Restoring banks to a more natural state”)

Lowering of revetment Juelssand/Hetlingen

- **Km 650.600** right bank Elbe
- **Implementation period:** 2004
- **Contact**: WSA Elbe-Nordsee, branch office Wedel
- **Construction design**: Lowering one section of the revetment to create improved conditions for the development of estuarine bank dynamics and a natural vegetation zoning in the transition zone between water and land
- Today, a tidal creek with a near-natural bank structure, including sandy tidal flats, reeds and tall forb vegetation, can be found behind the revetment

BAW

Tidal creek development enabled by a truncated revetment at km 650.600 of the right Elbe bank.

Redesign of the Hanskalbsand bank: combined measure

- **Km 642.300-642.700** (main navigation channel) left bank Elbe
- **Implementation period:** 2005-2008; 2015-2019 (continuous)
- **Contact**: Branch office Wedel: john.appel@wsv.bund.de
- **Construction design**: Combination of live material engineering, dead wood and a technical training wall. Willow brush mattresses acting as beach protection, transverse brushwood box structures acting as sediment trap

BAW

Combined measure comprised of willow brush mattresses, brushwood groynes and a riprap training wall.

Redesign of the Hanskalbsand bank: combined measure

- **Km 6.700-6.900** Hahnöfer Nebenelbe
- **Implementation period:** 6-8 weeks in every spring season from ~2005
- **Contact**: Branch office Wedel: john.appel@wsv.bund.de
- **Construction design**: Combined measure comprised of willow brush mattresses and willow brushwood rolls protecting a tidal creek and other erosive banks

BAW

Willow population established from willow brush mattresses (top right) acting as tidal creek protection and brushwood rolls shielding the bank (bottom).

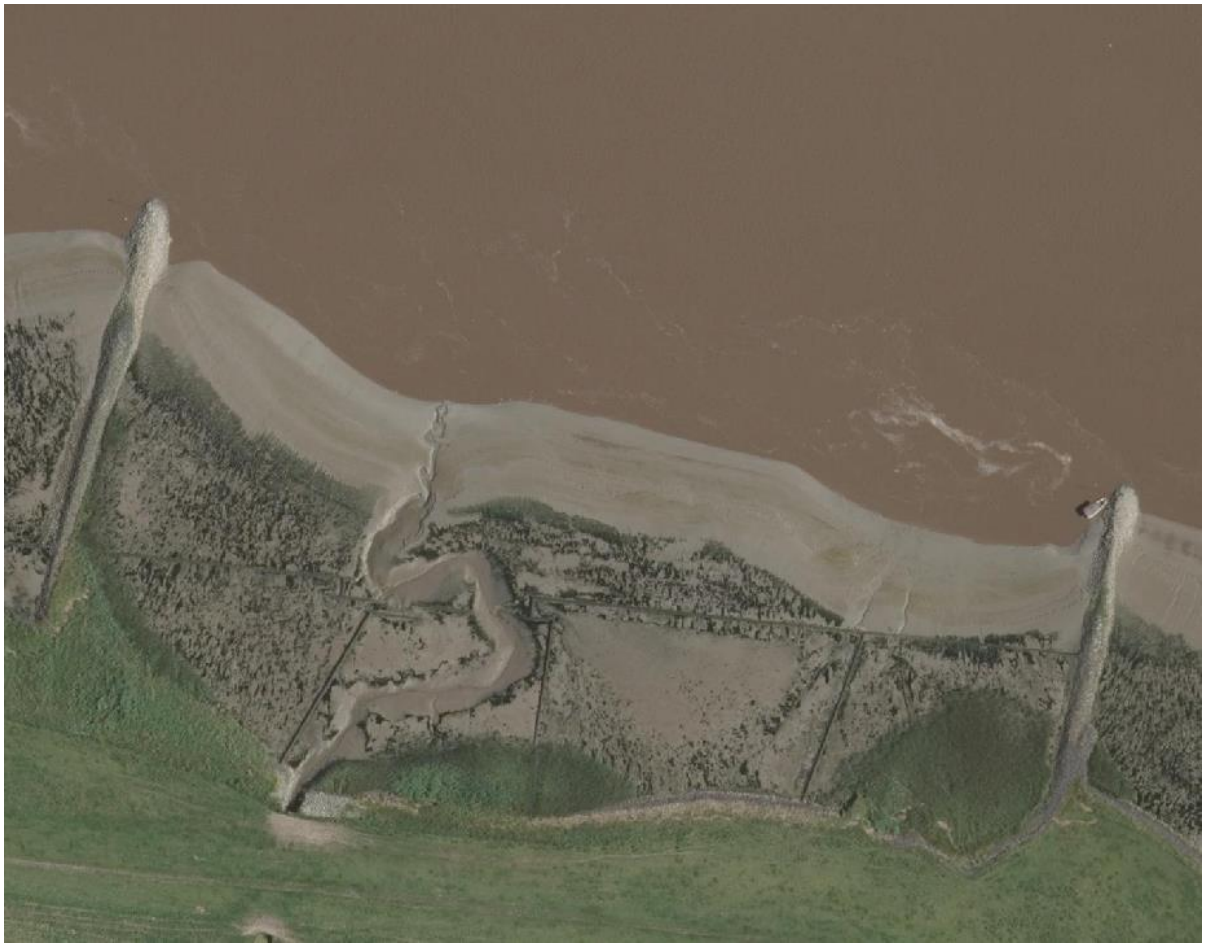
Brushwood box structure at the Hullen

- **Km 703.150-703.770** left bank Elbe
- **Implementation period:** 2003 (with parts being completed in 2014 only), continuous refurbishment from 2013
- **Contact**: WSA Cuxhaven: peter.scholz@wsv.bund.de
- **Construction design**: Brushwood box scheme acting as bank protection
- Bank protection under maintenance agreement, structure partly transferred from the Land of Lower Saxony
- Outlets raised with fascines or coir fascines, replacement of missing piles, restocking of rocks

BAW

Brushwood boxes acting as bank protection (photos taken in 2020).

Brushwood box construction between groynes in Belum



- **Km 73.140-73.375** left bank Oste
- **Implementation period:** From September 2011 (continuous maintenance)
- **Contact**: WSA Cuxhaven: peter.scholz@wsv.bund.de
- **Construction design**: Brushwood box scheme acting as bank protection between Belum's groynes no. 9 and no. 11.
- In certain sections missing fascines were replaced by coir fascines. Some fascines go lost in the area every year due to storm tides and floating ice.

Aerial photograph of the brushwood boxes built between groynes no. 9 and 11.

Brushwood box construction between groynes in Belum

- **Km 73.375-73.610** left bank Oste
- **Implementation period:** From June 2013 (continuous maintenance)
- **Contact**: WSA Cuxhaven: peter.scholz@wsv.bund.de
- **Construction design**: Brushwood box scheme acting as bank protection between Belum's groynes no. 7 and no. 9.
- In certain sections missing fascines were replaced by coir fascines. Some fascines go lost in the area every year due to storm tides and floating ice.

Aerial photograph of the brushwood boxes built between groynes no. 7 and 9.

Rearward groyne protection Otterndorfer Stack a

- **Km 709.780-709.800** left bank Elbe
- **Implementation period:** February 2011-August 2018
- **Contact**: WSA Cuxhaven: peter.scholz@wsv.bund.de
- **Construction design**: Protection of the groyne root with brushwood boxes
- Brushwood boxes were reinforced with a riprap toe protection during stage 2 and completely overbuilt with riprap during stage 3.

Branch office Cuxhaven: Peter Scholz

Protection of the groyne root with measures ranging from brushwood boxes built in 2011 (top) to a complete riprap superstructure (bottom).

Groyne root protection Medem Stack 3

- **Km 712.460-712.580** left bank Elbe
- **Implementation:** Continuously from spring 2017
- **Contact**: WSA Cuxhaven: peter.scholz@wsv.bund.de
- **Construction design**: Rearward protection of the groyne root with brushwood boxes and fascine work (brushwood mattresses)
- Construction phase I with vegetation coir rolls failed: no vegetal cover developed, 75% of fill material got lost

Branch office Cuxhaven: Peter Scholz

Brushwood boxes (left) and brushwood mattresses (right) acting as rearward protection of the groyne root.

Protection of dikes without foreland on the Pinnau

- **Km 6.750-7.000** left bank Pinnau
- **Implementation period:** 29 May - 4 July 2018
- **Contact**: WSA Elbe-Nordsee: caroline.feldmann@wsv.bund.de; external contractor: BSD
- **Construction design**: Bank maintenance of dikes without foreland (*Schardeiche*) with brushwood mattresses made of willow fascines from the preceding pruning season, arranged in a cross pattern.
- Cross profiles are measured on an annual basis for documentation purposes.

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Brushwood mattresses supporting bank maintenance of dikes without foreland at the time of installation (left) and 4 weeks later (right).

Fascine boxes with natural stone filling Pinnau

- **Km 7.340-7.500** left bank Pinnau
- **Implementation period:** May to June 2020
- **Contact**: WSA Elbe-Nordsee: caroline.feldmann@wsv.bund.de
- **Construction design**: Position stability of the revetment is ensured by fascine enclosure, rapid silting and growth of the new reed vegetation, rooting encouraged by coir mesh matting
- Measure initiated for embankment protection purposes

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Profiling works on the Pinnau

- **Km 7.500-8.080** right bank Pinnau
- **Implementation period:** Calendar week 7, 2019
- **Contact**: WSA Elbe-Nordsee: caroline.feldmann@wsv.bund.de
- **Construction design**: In order to rectify scour damage and bank collapses at dikes without foreland (*Schardeiche*), digging works were carried out under a pilot scheme to have the soil (cohesive, densely rooted) that had slipped into the Pinnau aligned the to the surrounding embankment and to examine the position stability of the dumped soil on the new embankment profile. Reed vegetation recolonised quickly.
- Continued severe flooding in the winter of 2019-2020, however, caused the cohesive material to become sodden and slump again before the new plants' root penetration provided sufficient protection.

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Reprofiling of the slumped cohesive soil on the Pinnau.

Vegetation and stone mattresses on the Lühe dike

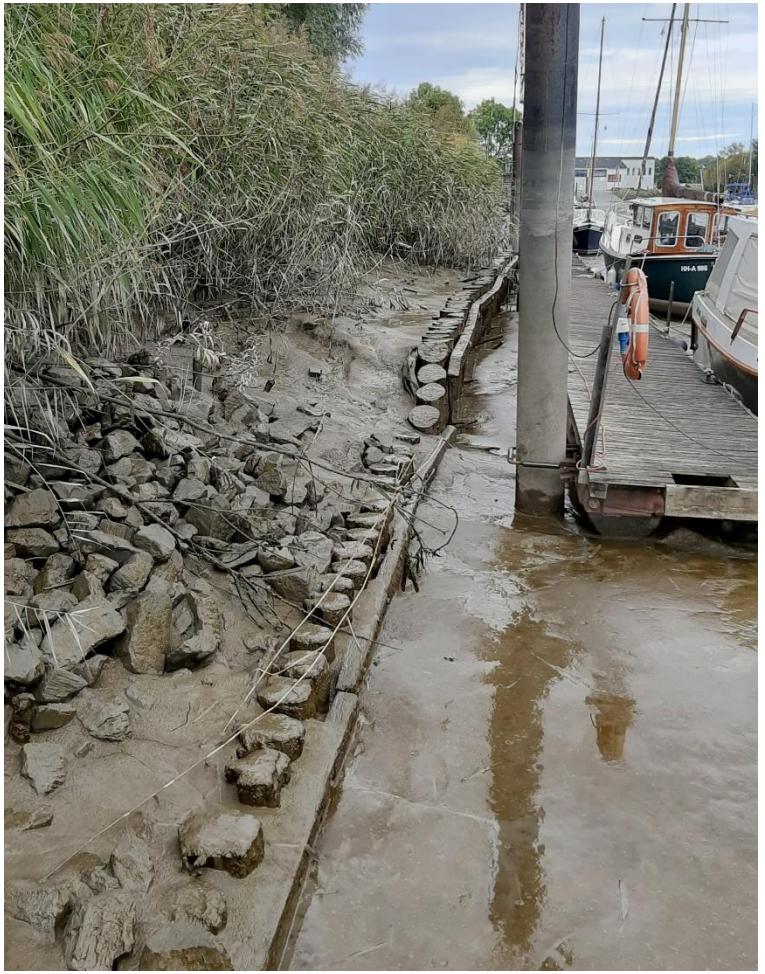
- **Km 8.345-8.7** on a 300m stretch along the Lühe dike between the harbour and the road bridge in Steinkirchen
- **Implementation period:** Spring 2012
- **Contact**: Branch office Stade: caroline.feldmann@wsv.bund.de
- **Construction design**: In the winter of 2010-2011, severe longitudinal cracks in the embankment and subsidences along the embankment toe were discovered. As a response, a combined technical-biological bank protection scheme was put in place.
- In some sections pile walls (pine wood) were installed to protect the embankment toe.
- The steep embankment with a slope of 1:2 was shielded with stone mattresses, that have proven their worth.
- A strip of 1m in width situated above the stone mattresses is also exposed to hydraulic loads in times of flooding. Therefore, it was covered with pre-grown, natural fibre based grass mattresses reinforced with an additional armouring ("composite") (contractor: BGS Ingenieurbiologie und Ökologie GmbH). The use of grass mattresses requires a certain degree of predictability of the construction schedule since delays entail major maintenance efforts in terms of rolling out and irrigating the mats.

Top: Gätje und Feldmann (2012): WSV Nord's Annual Report 2012, bottom: BAW

Top: protective pile wall after installation (2012); bottom: status of the works as of October 2020

Pile wall toe protection with backfill Bützflether Süderelbe

- **Km 2.350-2.380** left bank Bützflether Süderelbe
- **Implementation period:** 25 days of work
- **Contact**: Branch office Stade: christopher.edler@wsv.bund.de
- **Construction design**: Toe protection consisting of a pile wall made of driven spruce piles plus soil backfill and reed cover
- Purpose of the measure: remediation of bank collapses caused by wash and wake



BAW

Condition of the pile wall toe protection during October 2020 on-site visit.

Pile wall toe protection with revetment Bützflether Süderelbe

- **Km 2.410-2.550** right bank Bützflether Süderelbe
- **Implementation period:** 100 days of work
- **Contact**: Branch office Stade: christopher.edler@wsv.bund.de
- **Construction design**: Toe protection consisting of a pile wall made of driven spruce piles plus stone mattresses
- Purpose of the measure: remediation of bank collapses caused by wash and wake

BAW

Pile wall toe protection and stone mattresses (on-site visit in October 2020).

Pile wall Este

- **Km 7.030-7.090** right bank Este
- **Implementation period:** 15 days of work
- **Contact**: Branch office Stade: christopher.edler@wsv.bund.de
- **Construction design**: Spruce revetment made of horizontal round timber piles plus soil backfill and natural vegetation
- Purpose of the measure: remediation of bank collapses caused by wash and wake

Photos to be handed in.

Bank protection Ruthenstrom

- **Km 5.220-5.350** left bank Ruthenstrom
- **Implementation period:** 15 days of work
- **Contact**: Branch office Stade: christopher.edler@wsv.bund.de
- **Construction design**: Brushwood box with willow fascines to protect bank from further collapse
- Purpose of the measure: remediation of bank collapses caused by wash and wake

BAW

Technical-biological bank protection solution on the Schwinge in October 2020: brushwood boxes and pile walls.

Pile wall toe protection with revetment and natural vegetation

- **Km 0.470-0.560** right bank Schwinge
- **Implementation period:** 25 days of work
- **Contact**: Branch office Stade: christopher.edler@wsv.bund.de
- **Construction design**: Toe protection consisting of a pile wall made of driven spruce piles plus riprap and natural vegetation
- Purpose of the measure: remediation of bank collapses caused by wash and wake

BAW

Pile wall toe protection on the Schwinge (on-site visit in October 2020).

Removal of revetment at Asseler Sand (Compensation measure)

- **Km 0,3-0,9** left Bank Schwarztonnensander Nebenelbe
- **Implementation period:** 2020
- **Contact:** Branch office Wedel: astrid.roeder@wsv.bund.de
- **Construction design**: Removal of about 640 m of revetment and four partially deteriorated groynes
- Shoreline flattening and removal of riprap bank protections to promote typical estuarine bank dynamics and shallow water areas, as well as the promotion of tidal flat and reed development.

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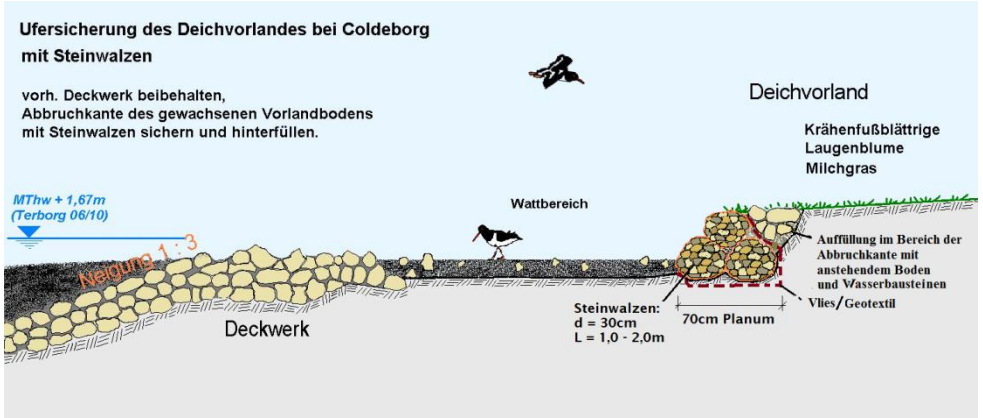
Compensation measure: Shoreline flattening, removal of riprap revetment and groynes as well as the building of a small riparian inlet.

Contents

Nature-based bank reinforcement with rock rolls near Coldeborg

- **Km 27.2-27.4** left bank Ems
- **Implementation period:** 9 days of work (7-15 August 2015)
- **Contact**: WSA Ems-Nordsee: Friedhelm.Roeloffzen@wsv.bund.de
- **Construction design**: Rock rolls at the revetment top occasioned by 2014 embankment inspection.



WSA Ems-Nordsee. Roeloffzen

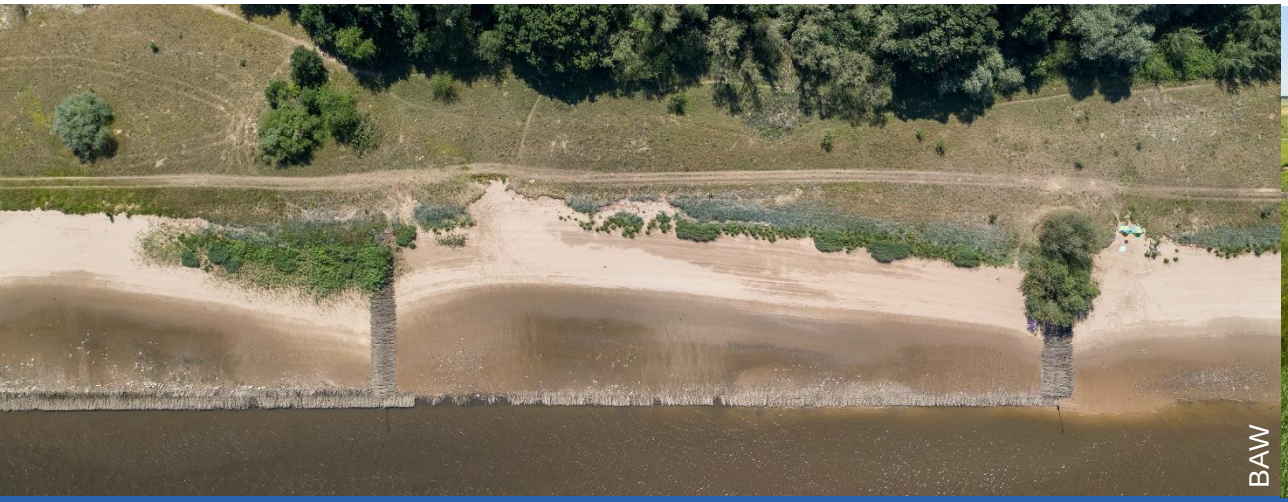
Protection of the erosion edge with rock rolls.

Brushwood boxes on the Dortmund-Ems Canal (DEC)

- **Km 218.3-219.8** right bank DEC
- **Implementation period:** 2010-2016
- **Contact**: WSA Ems-Nordsee: hans-hermann.schmitz@wsv.bund.de
- **Construction design**: Rectification of erosion damage at the slope crest of the revetment near the summer dike. Brushwood boxes were installed in several sections to protect the revetment.

WSA Ems-Nordsee

Sections with brushwood boxes acting as erosion protection on the Dortmund-Ems Canal.



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