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The sustainable development of the Elbe estuary - an option for Hamburg to cope with climate change -

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Hamburg is situated about 140 km from the North Sea upstream of the of the Elbe estuary. The Hamburg metropoli-tan region comprehends about 4.2 mio. residents and its seaport is of major importance for Germany's foreign trade. The barrier-free connection of this Metropolis to the North Sea via the Elbe Estuary has promoted maritime traffic, but also provides a permanent threat of storm surges.

Both, the repeated adaptations of the shipping channels to the increasing needs for width and drafts of seagoing ves-sels and dike realignments and land reclamations have, among others, led to considerable changes in the tidal dy-namics of the Elbe estuary, namely an increase of the tidal hub in Hamburg by 1.20 m during the last 60 years. As the distance between the Elbe mouth and Hamburg nearly complies with half the period of the tidal wave, high water in Cuxhaven and low water in Hamburg occur nearly at the same time. Therefore, especially the continuing slump of low tides since 1950 of about 80 cm in Hamburg causes a water level gradient between the river mouth and Hamburg inducing high flood current velocities. Thus sediments from the Elbe mouth are eroded and transported upstream. Ebb currents are not strong enough to flush the sediments back to the same extent so that this "tidal pumping" effect causes a significant residual sediment transport upstream. The results are considerable problems and high costs for the maintenance of waterways and the sediment management. In order to minimise the dredging amounts in the fu-ture the Hamburg Port Authority and the Federal Administration for Waterways and Navigation have developed a "concept for a sustainable development of the Tidal Elbe River as an artery of the metropolitan region Hamburg and beyond" in 2006 which is currently updated.
The milestones of the future action plan are:
1. Attenuation of the incoming tidal energy by hydraulic engineering measures,
2. Dissipation of tidal energy by the establishment of shallow water (flooding) areas on the way to Hamburg,
3. Optimisation of the sediment management considering the whole system.

The two milestones of river engineering measures aiming at the sustainable development of the Elbe estuary also provide serious options to cope with climate change in respect to two main aspects:

a) Conservation of the ecological status of the Elbe estuary and control of the sediment regime:

Meanwhile a considerable mean sea level rise and respective regional effects on the North Sea and its adjacent es-tuaries are beyond doubt, only its magnitude and timescale are under vivid scientific discussion. Hydronumeric mod-elling of the North Sea shows that the whole tidal dynamics of the Elbe estuary will be changed by a sea level rise in the North Sea. Tidal high-waters will rise and the tidal hub will increase significantly in the estuary, thus aggravating the above mentioned "tidal pumping" effect.

By implementing hydraulic engineering measures the tidal energy entering the system can be dissipated. The recrea-tion of shallow water areas upstream the Elbe estuary has a verified positive effect on the mean low water and mean high water level in Hamburg reducing the tidal range significantly. This will then also influence the upstream transpor-tation of sediments in a positive way. Without these measures the estuary system will silt up even more and impede the maintenance of shipping channels, threatening the accessibility of the Hamburg port and the economic develop-ment of the metropolitan region. Not only does the concept for a sustainable

development of the Tidal Elbe River af-fect the dredging activities but also the ecological functions of these valuable ecosystems will be sustained and a de-crease of the number and variety of species can be avoided by giving the Elbe estuary more room to dissipate tidal energy.

b) Mitigation of storm surge risks:

The climate change induced increase in number and intensity of storms and storm surges endangers coastal regions and tidal estuaries. The above mentioned attenuation of tidal energy in the Elbe estuary will also mitigate the risk of storm surges. Furthermore, the newly created shallow water areas offer the opportunity to be transformed into storm flood release polders. By providing these areas with locking devices storm surge crests can be cut significantly. Thus a proactive management of the estuaries can add to the conservative approach of reinforcing dikes.

So this concept can accomplish a win-win-situation both for economy and ecology also under the boundary conditions of sea level rise and should be the basis for a future management of the Elbe estuary.

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