Cite as: Västilä, K. et al. 2023. Two-stage channels for nature-based agricultural water management: Northern European experiences. In Verberk et al. (eds.). Towards 2048: The next 25 years of river studies: NCR DAYS 2023 Proceedings. Netherlands Centre for River Studies publication 51-2023

Two-stage channels for nature-based agricultural water management: Northern European experiences

Authors:
Kaisa Västilä[a,b], Tom Jilbert[c], Krister Karttunen[b], Kaisa-Leena Huttunen[b], Jari Koskiaho[b], Jani Wikström[c], Pasi Valkama[b], Jukka Aroviita[b]

Highlights

- We report preliminary results on two-stage channels compared to conventional dredging
- Floodplains improved riparian diversity and moderately trapped particulate substances
- Partial mowing improves the conveyance and likely the water quality benefits

Overview

Conventional dredging of agricultural streams and small rivers to support drainage and flood management substantially degrades the ecosystem and the natural channel processes (e.g. Västilä et al., 2021). The objective of this contribution is to investigate an alternative, nature-based two-stage (compound) channel design (Figure 1) aiming to improve the flow conveyance, water quality and biodiversity in small agricultural catchments. The analyzed two-stage channels (TSCs) located in Finland were constructed by excavating a 1-5 m wide floodplain on one or both sides of the low-flow channel.

The TSCs have provided well-functioning drainage since their establishment ~5-15 years ago. To mitigate the increase in flow resistance generated by natural vegetation succession, partial mowing of the floodplain is recommended instead of maintenance dredging. For instance, mowing in 40% of the two-stage reach length improved the conveyance capacity at autumn flood flows by ~25%. Regarding water quality, TSC construction increased suspended sediment (SS) and phosphorus (P) loads when the newly excavated floodplain was unvegetated, but the loads returned to the pre-excavation values in ~1 year. Deposition on the floodplains significantly increased with increasing floodplain inundation frequency, i.e., decreasing elevation of floodplain above channel bed (H_{FP}), from ~10 kg SS/m^2 and 7.3 g P/m^2 for H_{FP}=0.6 m to 0.6 kg SS/m^2 and 0.6 g P/m^2 for H_{FP}=0.92 m. The water quality performance of TSCs can likely be improved by selective vegetation maintenance (Figure 1; see also Västilä et al., 2016).

The TSC design could benefit riparian biodiversity, as indicated by results on beetles. In addition, the five examined TSCs had 10-50% higher number of plant species on the riparian areas (floodplain and channel banks) and low-flow channel compared to conventionally dredged reference reaches. The TSC design seemed not to provide much improvement to physical habitat quality in the main channel, in contrast to DeZiel et al. (2019) who found improved fish diversity.

There are currently few tens of kilometers of two-stage channels in Finland, but since 2023 TSCs are integrated into the new European Union agri-environmental subsidy scheme (CAP-AES), which is expected to aid in mainstreaming them (see also Västilä et al., 2021). The two-stage channel design is considered widely applicable under Boreal and Continental climates, with cost-efficiency gained by applying it instead of conventional re-dredging when flow conveyance needs improvement.

Affiliations

[a] *Aalto University School of Engineering, P.O.Box 15200, 00076 Aalto, Finland*
[b] *Finnish Environment Institute, Latokartanonkaari 11, 00790 Helsinki, Finland*
[c] *Department of Geosciences and Geography, University of Helsinki, PO Box 64, 00014 University of Helsinki, Finland*

References

DeZiel, B., Krider, L., Hansen, B., Magner, J., Wilson, B., Kramer, G., Nieber, J. 2019 Habitat improvements and fish community response associated with an agricultural two-stage ditch in Mower County, Minnesota. J. Am. Water Resour. Assoc., 55, 154–188.

EA International. (2020) Råån, Helsingborg Municipality - Field evaluation of two-stage channels impact on local biodiversity and nutrient retention potential. Report Number: 2020:06. ISBN 978-91-7675-185-5. Hörby, Sweden.

Trentman, M.T., Tank, J.L., Jones, S.E., McMillan, S.K., Royer, T.V. (2020) Seasonal evaluation of biotic and abiotic factors suggests phosphorus retention in constructed floodplains in three agricultural streams. Sci. Total Environ. 2020, 729, 138744.

Västilä, K., Järvelä, J., Koivusalo, H. (2016) Flow–vegetation–sediment interaction in a cohesive compound channel. J. Hydraul. Eng., 142, 04015034

Västilä, K., Väisänen, S., Koskiaho, J., Lehtoranta, V., Karttunen, K., Kuussaari, M., Järvelä, J., Koikkalainen, K. (2021) Agricultural water management using two-stage channels: performance and policy recommendations based on Northern European experiences. Sustainability, 13, 9349. https://doi.org/10.3390/su13169349

Introduction

Two-stage channels are applied for agricultural drainage particularly in Midwest US while pilot sites and field investigations in Europe are sparse (Västilä et al., 2016; EA International, 2020). According to the limited evidence available, agricultural two-stage channels likely improve water quality by retaining suspended sediments and nutrients on the floodplain and potentially enhance plant and fish biodiversity (e.g. Trentman et al., 2020; Västilä et al., 2021). This study addresses some of the remaining knowledge gaps, including the optimal design and maintenance of TSCs to maximize their benefits.

Method

We conducted field investigations in six agricultural channels where a two-stage channel design was applied 3-15 years ago, and in conventionally dredged reference reaches. The influence of the elevation of the floodplain above the main channel bed and of the partial mowing of the floodplain vegetation (Figure 1) on the retention of suspended sediment (SS) and sedimentary phosphorus (P) was measured at two sites by grass mats 0.09 m^2 in area, water levels by pressure sensors, transported SS and P loads by in-situ calibrated sensors (as in Västilä et al., 2016), and biodiversity based on abundance and richness of diatoms, invertebrates, riparian beetles and plants. Sedimentary phosphorus was analyzed using ICP-OES and sequential extraction.

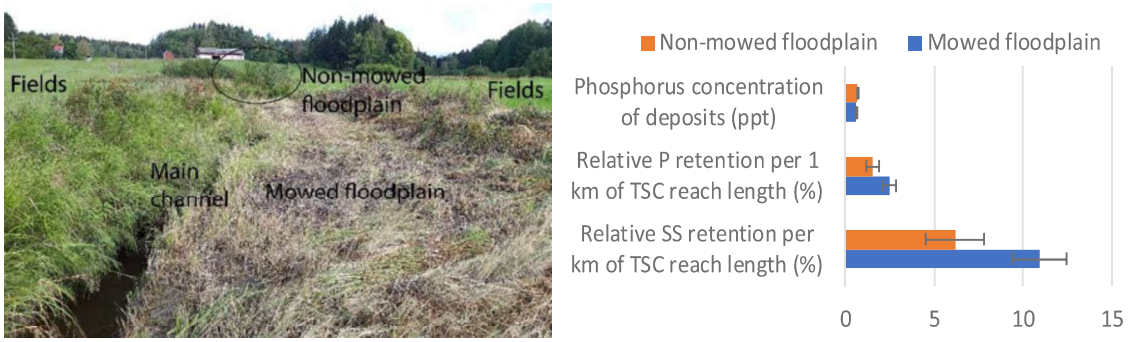

Figure 1. A studied agricultural two-stage channel (Ritobäcken Brook, Finland) consisting of a narrow main (low-flow) channel and a vegetated floodplain (left). The influence of the mowing of the floodplain vegetation on the suspended sediment and phosphorus deposition was compared to a non-mowed control reach (right).

Results and discussion

At the longest monitored site, SS deposition on the floodplains was around two-fold in the first few years after the two-stage channel construction compared to a decade later when the very dense vegetation likely limited the supply of SS from the main channel to the floodplain (see also Västilä et al., 2016). The trapping increased by 77% for SS and 60% for P when the > 1 m high floodplain vegetation was mowed to the height of ~10 cm (Figure 1). The total P retention is larger through additional uptake in plant biomass (e.g. Trentman et al., 2020). At the two investigated sites, over half of the total P was formed of iron-bound fraction, which can become bioavailable under reducing conditions.

Regarding biodiversity, the TSCs had, in general, slightly lower diatom richness and no difference in invertebrate diversity compared to the conventional dredging, although there was high variation in responses among the study systems. TSCs had higher riparian beetle diversity and more unique beetle species compared to the conventionally dredged or natural-like reference sections. As TSCs exhibited unique species, also for pollinators (Västilä et al., 2021), the modification of part of the conventionally dredged channel network to two-stage channels could enhance the catchment-scale biodiversity.

Climate change increases the need for efficient drainage, flow conveyance and such new methods for decreasing the transport of fine sediment and nutrients to downstream water bodies. Further investigations at TSC study sites of varying drainage designs and maintenance practices are needed to understand the variables controlling the SS and nutrient retention under Boreal conditions, while the mass balance for suspended sediment and nutrients in two-stage channels and conventionally dredged reaches should be compared taking into account the processes in the low-flow channel.

Acknowledgements

We acknowledge funding from Ministries of the Environment and Agriculture and Forestry, Academy of Finland, Maa- ja vesitekniikan tuki ry, and Salaojituksen tukisäätiö sr. We thank laboratory technician Antti Louhio at Aalto University for help in constructing equipment for the field investigations.