Theory and Experimentation

Sections : Introduction, Definitions, Background, Validation, Experiments, Motivation

Intro

We most likely come back and finish this section from Tuesday, as its most relevant for the presentation. Check the motivation section for a kinda intro.

first plants
modern day changes is accelerated morphological evolution
bio and geo diversity is inherently important in itself (references)
this river is one of the last left,

Definitions

Channel Type - Depends on stream gradient, riparian vegetation and sediment supply.

See "Sorting out river channel patterns (2010) Progress in Physical Geography – M. Kleinhans" for a decent overview.

Anastomosed – Often confused with braided. A type of river with multiple, interconnected, coexisting channel belts on alluvial plains. They distinguish themselves by a dense network of belts of variable width and length which by turns split and join.

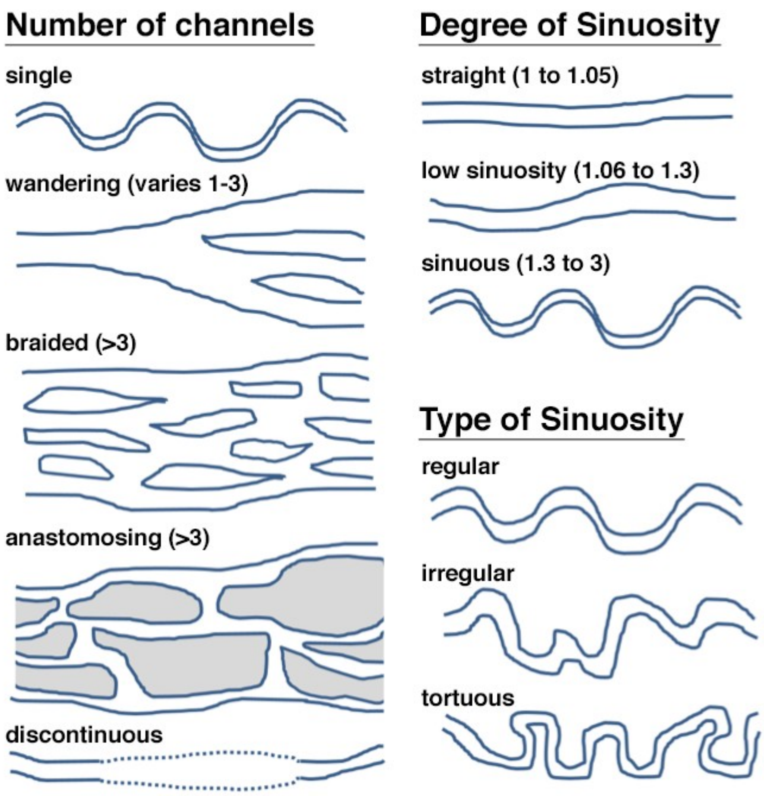
Fig. 11. Examples of modern anastomosing rivers with cohesive vegetated banks, carrying muddy suspended and a mixed sand-mud load at high water stages. The aerial photographs (from Google Earth). **A.** The Marmaris River in SW Turkey. **B.** The Mississippi River near Keithburg in Illinois, USA. **C.** The Six Mile Creek in Alaska, USA.

See -Anastomising rivers: a review of their classification, origin and sedimentary products (2000) Makaske. - for a comprehensive review. Would recommend at least one of you have a flick through this one … Although a lot of it is covered in the Background section below.

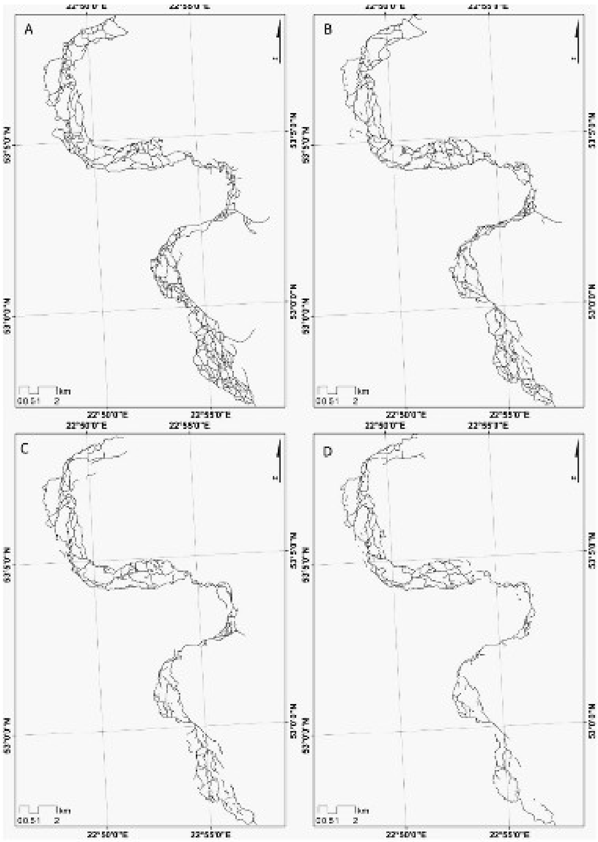
Braided river – Characterised as having lots of relatively small channels that frequently diverge and reconnect. Channels are shallow and migrate laterally relatively rapidly, and the ***slope*** is generally quite ***high***. Larger sedimentary load than the discharge of the river.

Meandering river – Only emerged once land plants evolved complex root systems that were able to stabilise soils. Usually occur at the low-gradient plain towards the end of the system. The situation is very different in a non, or poorly vegetated environment. Here, the river can rapidly erode away its river banks so it is very easy for the river to spread horizontally, frequently forming new channels and migrating laterally over time.

Straight (single channel) – Very few found in nature. (1) On the two banks there are materials with higher stability such as outcrop of rock, clay sediments and dense vegetation and so on which will confine the channel lateral migration. The straight channel planform under these conditions maintains chronically (***Like our first experiment)*** (2) Temporarily formed straight channel during the development of meandering river. This straight channel has some stability and its planform may change or disappear during the channel migration. (3) In river delta areas there are straight channel planforms which have higher stability because thick clay sediments in banks confine channel lateral migration. - ***Qain N, 1985. On the classification and causes of formation of different channel patterns. Aeta Geographica Sinica, 40(1): 1-10. (in Chinese) Qian N, Zhang 1L Zhou Z, 1987. Channel Bed Evolution. Beijing: Science Press, 584.***
- Straight river: its formation and speciality : Wang and Ni (2002)



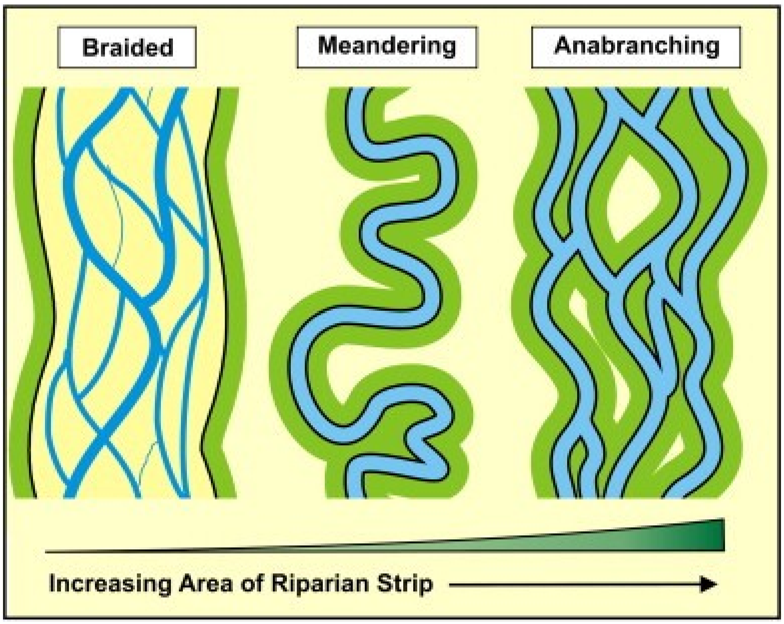
River Narew - The hydrological regime of the River Narew manifested itself by long lasting flooding and additional intensive inundation by shallow groundwater. The Narew is a lowland low-energy river in northeastern Poland (Fig. 1). It drains an area of 75,000 km2, partly located in Belarus, and is a right-hand tributary of the largest river in Poland, the Vistula. The catchment is located in a temperate climatic zone with moderately warm summers (mean temperature in July 18°C), cool winters (mean temperature in January -2ºC), and an annual average precipitation total of ca. 600 mm.- ***Marcinkowski et al (2018) Where might the hands-off***

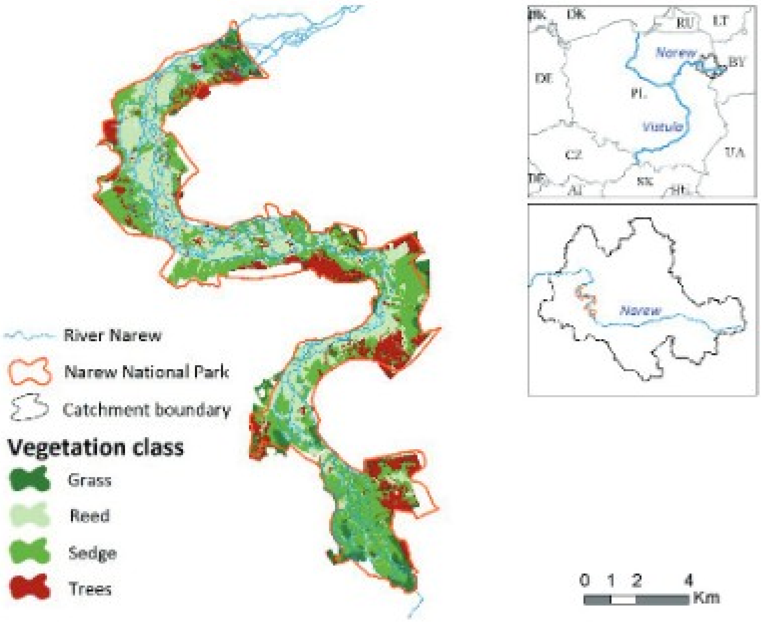


Last 100 years of change. See for higher resolution - ***Controls on anastomosis in lowland river systems: Towards process-based solutions to habitat conservation (2017) – Marcinkowski et al.***

Fig. 2. Changes in the channel network of the River Narew in the Narew National Park over time: (A) 1900, (B) 1966, (C) 1997, and (D) 2012.

Riparian zone/area – The interface (transitional area) between land and the river. Usually aquatic plants or on the banks of the stream. These zones dissipate stream energy. Meanders combined with vegetation and root systems, **slow the flow** of water, **reducing soil erosion and flood damage.**





Notice how the trees cause the overall rivers shape to meander! -from the hands- off paper *Marcinkowski et al (2018)*

Fig. 7. Map of the riparian corridor vegetation in the NNP.

Sediment Supply – We haven't thought about this much but this could have a big effect !! Easily modeled with higher sedimentation rates. Overloading a river with more sediment than transport capacity may result in braiding whereas reduced load may result in meandering. (Church, M. 2006: Bed material transport and the morphology of alluvial river channels. Annual Review of Earth and Planetary Sciences 34, 325–54).

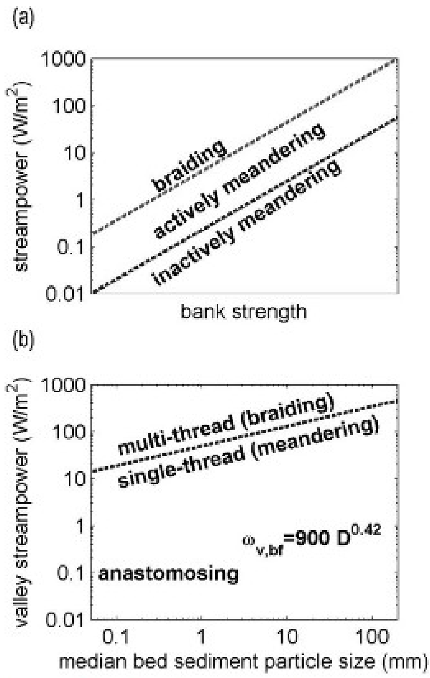


Figure 6. (a) Relation between channel pattern, flow strength (unit streampower) and bank strength. (b) Relation between channel pattern, streampower based on valley slope and bankfull discharge, and channel bed sediment size.
Source: (a) After Figure 6.4c in Ferguson (1987); (b) van den Berg (1995)

Humans and Settlements -

- Hunter-gatherer: minimal effect
- Early Civ-
- Medieval – Water used as defense, extensive managed forestry, agriculture in floodplains, fords and bridges, milling, building, canalisation,
- Industrialisation

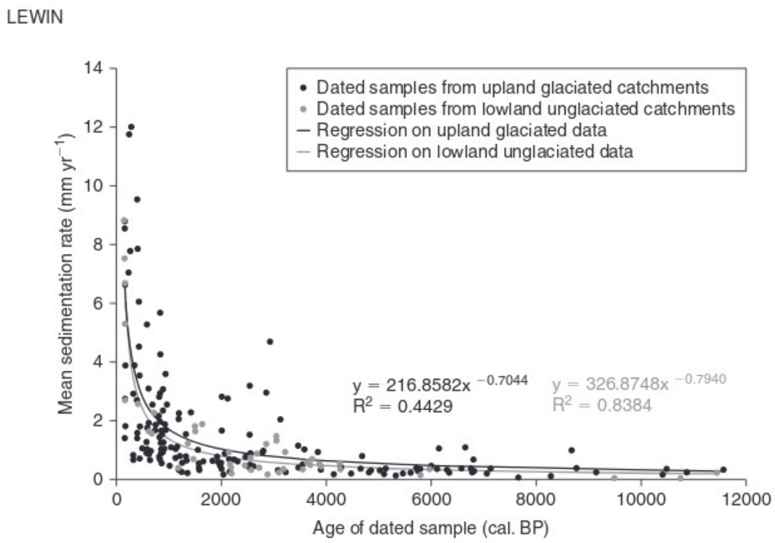


Figure 8. Mean sedimentation rates based on [14]C-dated overbank sediment depth (modified from Macklin, Jones, & Lewin, 2010).

SEDIMENTATION RATE GETS HIGHER OVER HISTORY EXPONENTIALLY
exponential/power law

Background

Anastomosing rivers are interesting dynamic system created as a result of interaction between constructive and destructive processes. Anastomosing systems are formed in middle part of river system. Slope on these area is very small — approximately 10cm per 1km. Flow rate is also very small, river do not erode terrain. Organic and non-organic materials carried by river are mostly transported through this part of river and deposited later in lower reaches. Waters rich of nutrients penetrate soil in surrounding banks. Fertile areas near river channels are characterized by a significant increase in vegetation. Products of plant decay deposit on this area as peat (approximately 1-1.5 mm/year Gradzinski et al. (2003)). Peat accumulation lasting for thousands years may produce a peat bog with a depth of several meters. - ***Network_Systems_Modelled_by_Complex_Cellular_Automata_Paradigm - Pawel***

“Anastomosing rivers were historically common around the world before agricultural and industrial development in river valleys.” (LEWIN J. Medieval environmental impacts and feedbacks: The lowland floodplains of England and Wales. Geoarchaeology-an Int. J. 25, 267, 2010)

“Since the vast majority of anastomosing rivers are morphologically quite similar, they can be considered as an example of an equifinal system, i.e., different combinations of processes or causes produce a similar form” (MAKASKE B. Anastomosing pattern. Encyclopedia of Planetary Landforms, 1, 2014)

“Schumm (1985) put more focus to the channel lateral stability and categorized both braided and meandering rivers as laterally unstable and bedload-dominated. It was also pointed out earlier by Schumm (1968) that the use of the terms ‘braided or braiding’ and ‘anastomosed or ‘anastomosing’ as synonyms is incorrect, because these channel patterns represent different types of river behaviour. Smith and Smith(1980) defined an anastomosing river as ‘an interconnected network of low-gradient, relatively deep and narrow, straight to sinuous channels with stable banks of fine-grained sediment and vegetation’. Nanson and Knighton (1996) had similarly classified anastomosing rivers as a specific variety of a broader category of anabranching rivers, characterized by laterally stable multiple channels irrespective of their sinuosity. It is now also widely recognized that an anastomosing river system requires cohesive and/or densely vegetated, relatively stable channel banks (e.g., Rust, 1981; McCarthyet al., 1991; Gibling et al., 1998; Gradziñskiet al.,2000; Gruszka and Zieliñski, 2008; Grosset al., 2011). - ***Widera, M., Kowalska, E. & Fortuna, M., 2017. A Miocene anastomosing river system in the area of Konin Lignite Mine, central Poland.Annales Societatis Geologorum Poloniae, 87: 157–168***

Validation

We could (conceptually/theoretically) validate our model by replicating the conditions that create the types of river structure known (i.e. meandering rivers need plant structure, human river control stops braided rivers, etc …)

From Least Comprehensive to Most

- Anastomosation of any kind (already acheived)
- River Narew’s general structure (partially (fully?) achieved)
- Show that the model can recreate other river types (such as single channel, meandering, braided rivers, etc.) when parameters are altered to model different scenarios
    - A very steep terrain may create a single channel?
    - High water flow from source node floods system or single channel?
    - ***The major problem here is that this model was only designed to replicate anastomosing rivers and therefore does NOT explicitly consider “sinuosity” or erosion. However, if you have a look at the definitions of these river types and implement them I reckon it might actually work. Turns out single channel only really occurs in part or where there are outcrops of high stability either side.***
- Further validation starts to blur the line between hypothesis and experiment so will be covered in those sections.

Table 2. Characteristics of the present condition of NNP anastomosing system.

Characteristics	Condition according to HF	NNP state	Fulfillment	Remarks
Low gradient	<0.005	0.0002	YES	-
Vegetation - early growth, sedges, reed	required	reed communities (41%), grass (26%) sedge communities (22%)	YES	-
Organic soils (peat)	required	Whole valley bottoms filled with peat deposits from the Holocene	YES	-
Low stream energy	<10 W m^{-2}	2-3 W m^{-2}	YES	-
Low sediment potential	<0.1 (tons ha^{-1} $year^{-1}$)	0.03 (tons ha^{-1} $year^{-1}$)	YES	Based on PESERA model
Seasonal floodings	required	Mean annual number of days with flooding - 37	YES	Calculated for period 1951 – 2012 based on Q observations from Suraż gauging station
Steep, resistant to erosion banks	required	Present in the whole river system	YES	-
Low W/D ratio	<10	2 - 4	YES	-

-From hands off paper again , this is at PRESENT in the river narew, - ***Marcinkowski et al (2018)***

***river*-width/*river*-depth *ratio* (W/D)**

Table III. Representative measures for present-day channel characteristics.

	W/D Ratio	Gradient/Specific Streampower	Bed Material	Dominant Features (see Figure 3)
A. Braided	>20	>5m km^{-1}, >100 W m^2	gravel	Ia, b, c, d, IIc, IIIb, c
B. Active meandering	5–20	>2m km^{-1}, 10–100 W m^2	sand/gravel	Ia, b, c, IIc , IIIa, c
C. Stable meandering	<15	<3m km^{-1}, <50 W m^2	sand/gravel	Ia, IIa, b, IIIa, d
D. Anastomosing	<15	<2.5m km^{-1}, <20 W m^2	sand/gravel	Ib, d, IIb, IIIc, d

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from medieval environmental impacts paper – Lewin (2010)

Experiments

My memory is a bit shit, so if you can remember any experiments we have talked about (especially with Rick) add them here. I remember him talking about adding drains, settlements, how many river branches exit the screen (increase water flow or another parameter, measure this and graph it), finding emergent properties (and the phase transitions that create them). The most essential way our model is related to complexity, will be via control/order parameters and the macroscopic behaviours they induce. At some point in these experiments, river behaviour should shift into a different dynamic or cause new structures, showing phase transitions/new macroscopic properties with increasing complexity of the model sort of thing.

1. The First Plant(s)

- We could use the terrain height as a proxy for carboniferous growth.
- Super growth peat (after enough has built over a long enough period?)
- Once, plants starting to grow in the peat, it holds together the terrain better, so that the waters path is more restricted, hopefully causing meandering, see 5 (seasonal mowing) to see the reverse effect. If this is found to be the case this should be our **CORE** experiments, and already pretty satisfactory in terms of experimentation.

2. Effects of Settlements

- We could use terrain as a proxy for urban settlement or river protection (i.e. industrial areas cannot have water displaced to them) we can then analyse how urban development affects river flow. Settlements should drain water quicker. To model this, perhaps add cells that are sinks to the surrounding area , they should also be “flood proof”, water should not be allowed to pass onto these areas.

3. Ice Ages

- self similar – branching process with stotrms – sandpile model- rainfall and storms winter melts
- Let the model run until it gets stuck (or turn off water supply mid way through a simulation, then simulate a surge of lots of water (probably accelerating), the hope is that this causes the “reservoirs/lakes” / pools of water that have formed at the bottom of the river to behave like the original cell, i.e. anabranching behaviour starts from these pools of water, i.e. self-similar, fractal, sandpile kinda thing.

4. Exponential growth in sedimentation deposit rate over human history

- Human waste / environmental modification (building bridges / mining) has lead to an exponential increase in the rate of sedimentary deposition over time

LEWIN

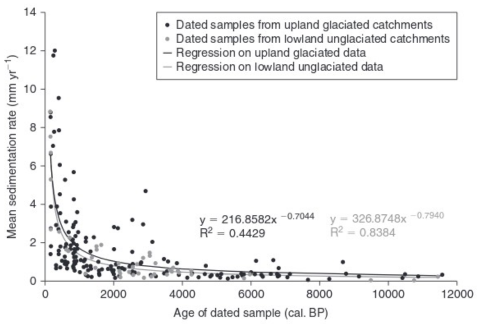

Figure 8. Mean sedimentation rates based on [14]C-dated overbank sediment depth (modified from Macklin, Jones, & Lewin, 2010).

5. Last 100 years of River Narew

- “The results show that 110 km of anabranches have been lost from the Narew National Park (6810 ha), a 42% reduction in total anabranch length since 1900. The cessation of localized water level and channel management (fishing dams, water mills and timber rafting), the loss of traditional floodplain activities (seasonal mowing) and infrastructure construction (embanked roads and an up-stream dam) are contributing to low water levels and flows, the deposition of sediment at anabranch inlets, the encroachment of common reed (Phragmites australis), and the eventual loss of anabranches. construction of a large reservoir in the upper catchment in the late 20th century.” - Marcinkowski Controls on anastomosis in lowland river systems (2017).
- **Timber Rafting –** Historically timber rafting (floating timber on rafts down a river) was common, this ended in WW2, it is hypothesised has a positive influence on anastomosis. Often timber rafters would deepen the anabranch inlets using hand tools. To model this, deepen the branch channels, i.e. dig away the peat/terrain underneath. This probably has to be done on a static model, then allowed to evolve again, compare to a benchmark and see if it keeps the anabranching.
- **Dam Fishing –** Around 1930, the practice of dam fishing was discontinued, it is thought to have a positive impact. The fishers, dam up a small branch of the river, with a small hole. Makes spring flooding last longer. To model this, block or restrict the water flow of a branch in several places. To be honest, I’m not really sure this will work with our model.
- **Seasonal Mowing –** This one should work well. This stopped in the 1980’s. This just means cutting down the shrubs and forests that start to encroach on the floodplain. Works well with our introduction of plants, simply model the removal/shortening of the height of plants/trees, should counter the effect of plants in our model, that hopefully will cause their to be less anabranching. Therefore, showing this practice kept the integrity of the rivers structure.
- **Channel realignment –** This consists of changing the multi-channel planform into a single channel to expand the area of agricultural usage on the floodplain. This obvious has a negative impact on the anastomisis. To model, “stop” simulation midway and change some section of the river to be straight and see how this effects it downstream.

Motivation: *Motivate the work* - *understand why the simulation/experiments are of interest*

modern day changes is accelerated morphological evolution
bio and geo diversity is inherently important in itself (references)
this river is one of the last left,

- Variable rainfalls, snow melts, disordered weather patterns, dam removal, dam creation, nitrogen flux, city/town planning (sustainability), climate/ecological change,

- Methodologically applies to several cutting edge poorly understood phenomena (e.g. angiogenesis, plant root formation).

- Very similar patterns are found in lava flows, outflow channels (Found on Mars and Venus)

- "However, a small number of studies reported worldwide until nowadays and studies evidencing their extinction [13-14] might lead to the conclusion that only several anastomosing systems remain worldwide and a special focus on their investigation is highly required" – Hands off paper

- Anastomising rivers are SENSITIVE to climatic or tectonic forcing - frequent channel avulsions due to the increased frequency of floods, rise of base level, and/or sediment overloading - ***Electrical resistivity imaging of anastomosing river subsurface stratigraphy***