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MATHEMATICAL MODELLING OF SEDIMENT DYNAMICS AND THEIR DEPOSITION IN LITHUANIAN RIVERS AND THEIR DELTAS (CASE STUDIES)

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Abstract. Mathematical modelling of sediment transport and deposition in the floodplains and canals of rivers is closely related to the hydrodynamics, as well as the design of engineering measures, of water pollution control and reduction.
The dynamics of flow velocities and water level in the urban section of the Nevėžis River at Kėdainiai were estimated by applying a hydraulic-mathematical model, DELTA. It was established that there were no conditions for undesirable riverbed siltation. During the dry season ($Q_{v.f}$ = m^3/s), flow velocity did not exceed 0.5 m/s in the study section. When the discharge affected the formation of the riverbed ($Q_{v.f}$ = 70 m^3/s), the flow velocity reached 1.2–1.3 m/s and accumulated bed sediments were washed away.
A two-meters high dam near Skongalis does not stimulate bed silting, as it is not high enough to have much influence on the bed formation processes or the reduction of riverside overgrowth. When the water level is low and the flow velocity is small (0.1 m/s), the water in the river is only slightly turbid (turbidity is 2–6 mg/l), so there is no scope to decrease sedimentation in this case. To improve the aesthetical view of the river, it is advisable to regulate the riverbed by reducing the river width to a 30 m maximum.
Floods in the Nemunas delta inundate the bright areas of the valley, where the significant amount of sediments brought by the water is deposited. This decreases the water pollution entering the Curonian Lagoon and the Baltic Sea. It is, therefore, desirable to find ways to intensify this deposition and to put them into practice.
The possibility of increasing the discharge of water flowing through the flood plane was investigated, applying the DELTA model. The influences of road banks built across the floodplain and the growth of bushes in the valley were tested. They cause increases in depth and decreases in flow velocity, which can alter the amount of sediment deposition.

Keywords: hydraulic modelling, riverbed process floodplains, sediment dynamics, regulation.

1. Introduction

Nearly all-major Lithuanian rivers perform the functions of a cleaned-sewage receiver. The waters of the largest Middle Lithuanian river, the Nevėžis, are polluted both by the waste from the industrial towns Panevėžys and Kėdainiai, and by biogenic materials washed out from the fertile land of agricultural fields – nitrogen (*N)* and phosphorus (*P)* – compounds (Aksomaitiene 2000; Bagdžiūnaitė-Litvinaitienė, Lukianas 2005; Šileika 1996; Šileika *et al*. 2000; Vaitiekūnienė 2006).

Wash products transport a large amount of biogenic materials and heavy metals (Deletic 2001; Ždankus, Sabas 2005). The key influence on the sedimentation of these materials is made by river flow dynamics and riverbed processes (Van Rijn 1993; Christiansen, Wiberg 1997; Pasche and Rouve 1984; Thornton *et al*. 1997).

In order to better investigate the flow dynamics of the urban Nevėžis through Kėdainiai town, and the influence of the existing bed layer on the sedimentation and silting processes, we chose a mathematical method for riverbed modelling by applying model DELTA (Vaikasas, Rimkus 2003). This method enabled us to reconstruct the influence of the spillway dam on the flow dynamics of the study section and evaluate the changes to its riverbed processes with sufficient detail.

The silting processes and sediment deposition are quite different in the floodplain of rivers. The floods inundating the floodplains of urban rivers leave significant amounts of sediments containing bioorganic matter and heavy metals in the flooded areas (Althaus *et al.* 2008). This reduces the contamination of the water getting into the seas. Naturally, it would be desirable to find ways to further increase sediment deposition (Van Rijn 1993). With the aim of estimating how these processes work in the Nemunas delta, field investigations were performed and sediment deposition processes were mathematically modelled using the DELTA model (Fig. 1).

The ability of grasses to entrap sediments has already been investigated and has been employed in the creation of vegetation strips which serve as barriers to retain sediments transported by runoff (Deletic 2001; Rimkus *et* *al.* 2004; 2007). The effect of water grasses on the sedimentation process has also investigated (Vaikasas, Rimkus 1996). However, the flow over grass-covered floodplains has not been studied sufficiently so further investigations are necessary.

Fig. 1. Floodplain of Nemunas delta

The way that road banks have been built across the floodplains generally causes the water discharge flowing trough the valley to decrease. Therefore, a trace design must be chosen that minimises this influence.

The research objective is to model the dynamics of flow velocities and water levels and to investigate the peculiarities of sediment deposition, silting and water purification, based on this modelling.

This paper discusses the results of the investigation into these issues and the factors affecting them.

2. Methods

A quasi two-dimensional mathematical model DELTA was used for the hydraulic modelling (Vaikasas, Rimkus 2003). To enable calculation of the distribution of flow velocities, the bed flow was divided into strips of equal discharge flow. Flow velocities in the strips were calculated using one-dimensional Saint Venant equations:

$$-\frac{dz}{dl} = \frac{v^2}{C^2 h} + \frac{d}{dl}\left(\frac{v^2}{2g}\right), \tag{1}$$

where: v – average flow velocity (in cross-section of calculation strip); h – average water depth (in cross-section of calculation strip); dl – length of calculation interval; $\frac{dz}{dl}$ – hydraulic (water surface) gradient.

Chezy roughness coefficient C in the formula (1) was calculated according to Manning's formula, best suited for riverbeds:

$$C = \frac{1}{n} R^{1/6}, \tag{2}$$

where $R = \frac{A}{\chi}$ – hydraulic radius; A – area of cross-section profile; χ – wetted perimeter; n – roughness coefficient, measured or selected from tables (depending on watercourse condition).

In this case it was established according to direct measurements of flow velocities and riverbed condition taken during winter-spring 2006 and was checked by verifying the model (n $\cong$ 0.030). Measurement results are described in depth in another article (Rimkus *et al.* 2007).

A dam, necessary for take up of water, has been constructed near Skongalis. Water levels and average flow velocities were calculated, representing the "before and after construction" scenarios, for various cross-sections in the modelled section of the Nevėžis, from the dam at Skongalis to the Panevėžys highway (Fig. 2).

Calculations were made for the minimal environmental discharge (80% of dry season probability) Q = 0.6 m^3/s, which has to be ensured when the river water is used for technical needs. Calculations were also made for relatively moderate but frequent flood discharge Q = 70 m^3/s when water starts to flow into the valley. Such discharge is known as bed forming discharge. In addition, calculations were made for long duration perennial minimal discharge Q = 3 m^3/s.

Model DELTA, originally created for the Nemunas delta, was employed for the investigation of sediment deposition in the floodplain (Vaikasas, Rimkus 2003). The known mathematical models could not be applied to our investigations as they are not adapted for calculating the sediment deposition in grass covered flooded areas (MIKE 21 1996; Cao, Carling 2002). This requires a special method of calculation. Formulae were created to estimate the ability of grass to entrap sediments (Vaikasas, Rimkus 1996, 2003). The velocities between the grasses are low, causing sediment particles to sink quickly, in the same way as in still water. Sediment deposition is then proportional to the fall velocity of the particles and the sediment concentration between the grasses, formed by the concentration at the flow bottom over the grass layer.

Consequently, sediment deposition into the unity of bottom area D can be expressed as follows:

$$D = k_{cor} w C_b, \tag{3}$$

where: w – fall velocity of sediment particles; C_b – sediment concentration at flow bottom, i.e. at the surface of grass layer; k_{cor} – correction coefficient depending on the state of grasses, which can be changed by water flow or after grass cutting.

Sediment concentration in the flow is commonly expressed by the average concentration $\overline{C}$ along the water depth, making it necessary to estimate the ratio $F = \overline{C} / C_b$. This changes formula (3) as follows:

$$D = k_{cor} w \overline{C} / F. \tag{4}$$

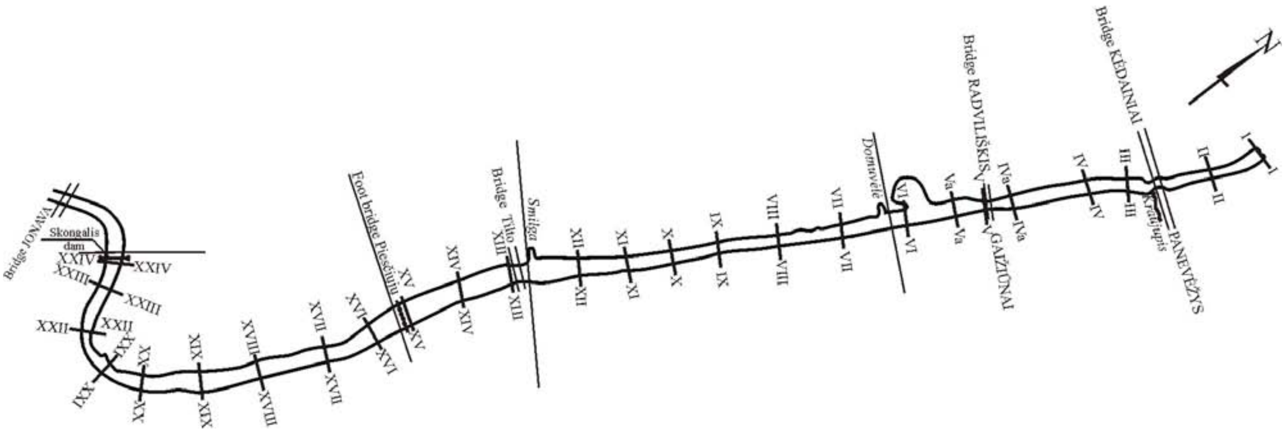

Fig. 2. Distribution scheme of cross-sections in modelled section of the Nevėžis River

The following formula was derived for the calculation of ratio F:

$$F = \left(\frac{a}{h-a} \right)^z \left[\int_a^h \left(\frac{h-y}{y} \right)^z v_y dy \right] \cdot \frac{1}{\int_a^h v_y dy},$$

$$z = \frac{w}{\beta k u_*}, \qquad (5)$$

where: h – water depth; y – distance from the bottom; v_y – water velocity at distance y from the bottom, $a = 0.3\,h_{gr}$; h_{gr} – thickness of grass layer; $k = 0.4$ – Van Karman number; z – Rouse number; β – ratio of sediment and water momentum diffusion coefficients; u_* – shear velocity.

These formulae were employed for our investigations.

3. Results and discussion

3.1. Flow dynamics in the Nevėžis River

The calculated water levels and flow velocities are presented in Figures 3 and 4.

At minor flow, i.e. environmental discharge of 0.6 m^3/s, water levels and longitudinal gradients depend largely on the relief of the riverbed bottom. There are several shallow sections (wades) along the riverbed where the bottom altitudes are high. Shallow water runs over them at velocities, which are no lower than floodwater velocities (Fig. 5).

As mentioned previously, the values for the roughness coefficient n in calculations were taken for the winter period, i.e. when there is relatively little overgrowth of the riverbed by water plants and grasses. The distribution of water velocities within the flow strips across the riverbed, when the discharge is Q = 3 m^3/s, is shown in Figures 6 and 7.

There are pools between them, which reach depths of between 1–2 m. The flow velocity in these pools is only 1–5 cm/s.

Following construction of the dam, the water level at the start of the dam pond rose by about 0.7 m and flow velocities in deeper parts of the pond decreased dramatically at environmental discharge, not even reaching 1 cm/s. The water level altitude at the end of pond changed by 0.7 cm, i.e. the water level became almost horizontal. Water velocities increased by only small amounts due to the potential energy accumulated in places under the bridge.

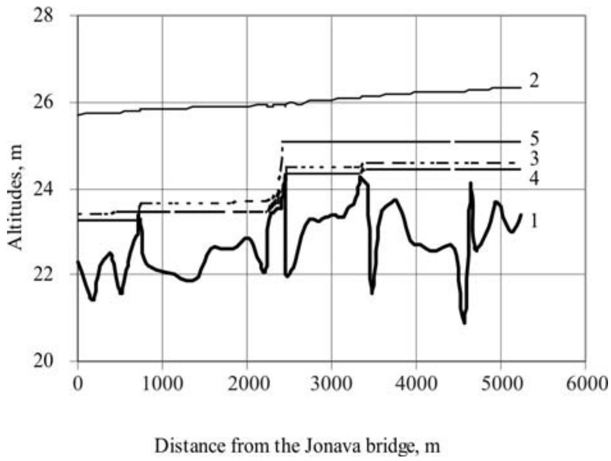

Fig. 3. Longitudinal profiles of water levels: 1 – river bed bottom in deepest cross-section in waterway; 2 – when flood discharge is 70 m^3/s; 3 – when Q = 3 m^3/s and no dam; 4 – when environmental discharge is Q = 0.6m^3/s and no dam; 5 – when Q = 0.6 m^3/s and dam in place

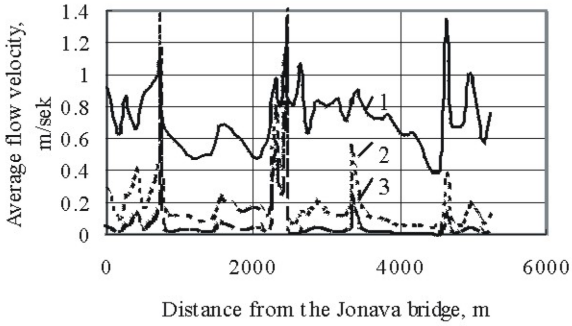

Fig. 4. Flow velocities: 1 – when flood discharge is 70 m^3/s; 2 – when discharge is a normal 3 m^3/s; 3 – when environmental discharge is 0.6 m^3/s

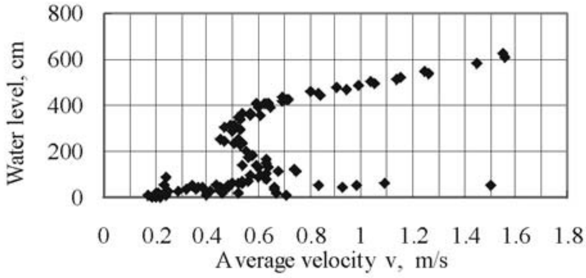

Fig. 5. Water velocity dependence on water levels and vegetation (measured in the Nevėžis riverbed at the Vilainiai gauging-station at cross-section III)

The calculations made without the spillway dam showed that once the dam was built the water discharge increased from 0.6 to 3.0 m^3/s due the use of the Kavarskas pump-house to increase the minimal Nevėžis discharges by pumping water from the Šventoji. Water levels also increased, but only by an average of 12 cm, as they were more affected by the rapid flow through the wades where water depths were shallow.

The levels changed even less in the pools, meaning that the discharge increased 5-fold from 0.6 to 3 m^3/s; flow velocities showed increases up to 4–4.5 times, i.e. roughly proportional to the discharges. Flow velocities below the dam were somewhat higher in comparison to the pond, as discharges were minimal and water depths in the pools were somewhat shallower. Taking water from the dam pond to supply the Lifosa chemical fertilizer plant (at up to 0.24 m^3/s) decreased the flow velocities below the dam, as the environmental discharge is reduced by approximately 40%, down to 0.36 m^3/s. Flow velocities are also reduced, becoming even lower than those above the dam.

These velocities remain unchanged as the water flows downstream to where the Obelys, a Nevėžis tributary which carries the discharge returned from the chemical plant, joins the river. Although the water quality here is almost unchanged, due to the decrease in flow velocity, the environmental conditions for aquatic fauna during the dry season can deteriorate below the Obelys entry point, as the wades become very shallow and divide the river bed into separate small basins (within the pools). As an example of this, on 29 August 1958, the Nevėžis discharge measured was only 0.4 m^3/s. In this case, almost all of the water was taken into the plant and sedimentation stopped in this section of the river. It would be worth considering the resumption of the use of the Kavarskas pump-house to increase the minimal Nevėžis discharges by pumping water from the Šventoji.

Reduced water velocities and the abundance of bioorganic materials allow more intense growth of water grasses (Van Rijn 1993; Gonzalez *et al.* 2008; Ždankus *et al.* 2008). These grasses grow beside the banks of the Nevėžis, squeezing the main channel flow and causing the flow velocities in the middle of the riverbed to increase to some extent. As can be seen in figure 5, there are some instances where water velocities increased by more than 1 m/s, due to narrowing of the main channel flow by grass overgrowth and shallow depth. Hence grass growth, though very intensive, did not adversely affect the flow hydraulic conditions.

The remains of the grass are removed after vegetative growth has ended and by flooding. However, intensely growing grasses change the appearance of the riverbed, which may be considered as unacceptable in the urbanized section of the Nevėžis. In this case, the grasses should be cut and removed from the riverbed.

To improve the riverside appearance and reduce growth of grasses, the left bank from the Smilga fall down to the footbridge (cross-sections XIII–XV) should be tidied up. The riverbed is wide through this section, so it should be narrowed and its embankments formed in line with architectural requirements. This would increase the flow depth and lessen the growth of water grasses.

The analysis of flow velocity distribution (when Q = 3 m^3/s, see Fig. 6–7) shows that most are regular and have no sharp maximum.

This distribution of average flow velocities in the plan is determined both by the regular shape of the Nevėžis flowing through Kėdainiai and by the relatively straight trace of the river section. Cross-section XXI is the only place where the position of the highest velocities moves towards the left bank, due to the centrifugal forces occurring at the bend. However, the absolute flow velocities reduce, due to the impact of the near spillway dam and its affluent significantly decreasing this centrifugal force (Fig. 7). A similarly even distribution of velocity vectors remains during higher floods in the Nevėžis.

3.2. The increase of sediment deposition in the Nemunas floodplain

It was found that the most efficient way to increase sediment deposition was to increase the water discharge overflowing into the valley, by deepening and widening places for water overflow. The amount of sediments getting into the valley and depositing there increases as well. The wash of floodwater increases also because of a feature, that in the strips of the riverbed existing below the places of water wash, the sediments brought by the river flow begin to fall, as the riverbed discharge and the flow velocities are decreased there. Those performed then silt up of the bed of the main river canal and raise the water level that increases the water overflow into the valley.

The overgrowth of grass in the river valley favours sediment deposition as sediment particles are trapped and retained by the grass. Provided that the grasses are not laid flat by a strong flow, sediment deposition is constant over the floodplain grassland areas, even when the sediment concentration is low or the flow velocity is quite high. Riverbeds with high flow velocities do not allow sediment deposition. A comparison of the amounts of sediment deposited in the valley, measured by field investigations, and the amounts calculated according to the formulae created for sediment-laden river flow, showed that sediment deposition in the grass-covered areas is several times greater than that calculated for rivers (Vaikasas, Rimkus 2003; Rimkus *et al.* 2004, 2007; Gonzalez *et al.* 2008 and Althaus *et al.* 2008). This can be explained by the fact that there is very little sediment deposition in floodplains that are covered by sand.

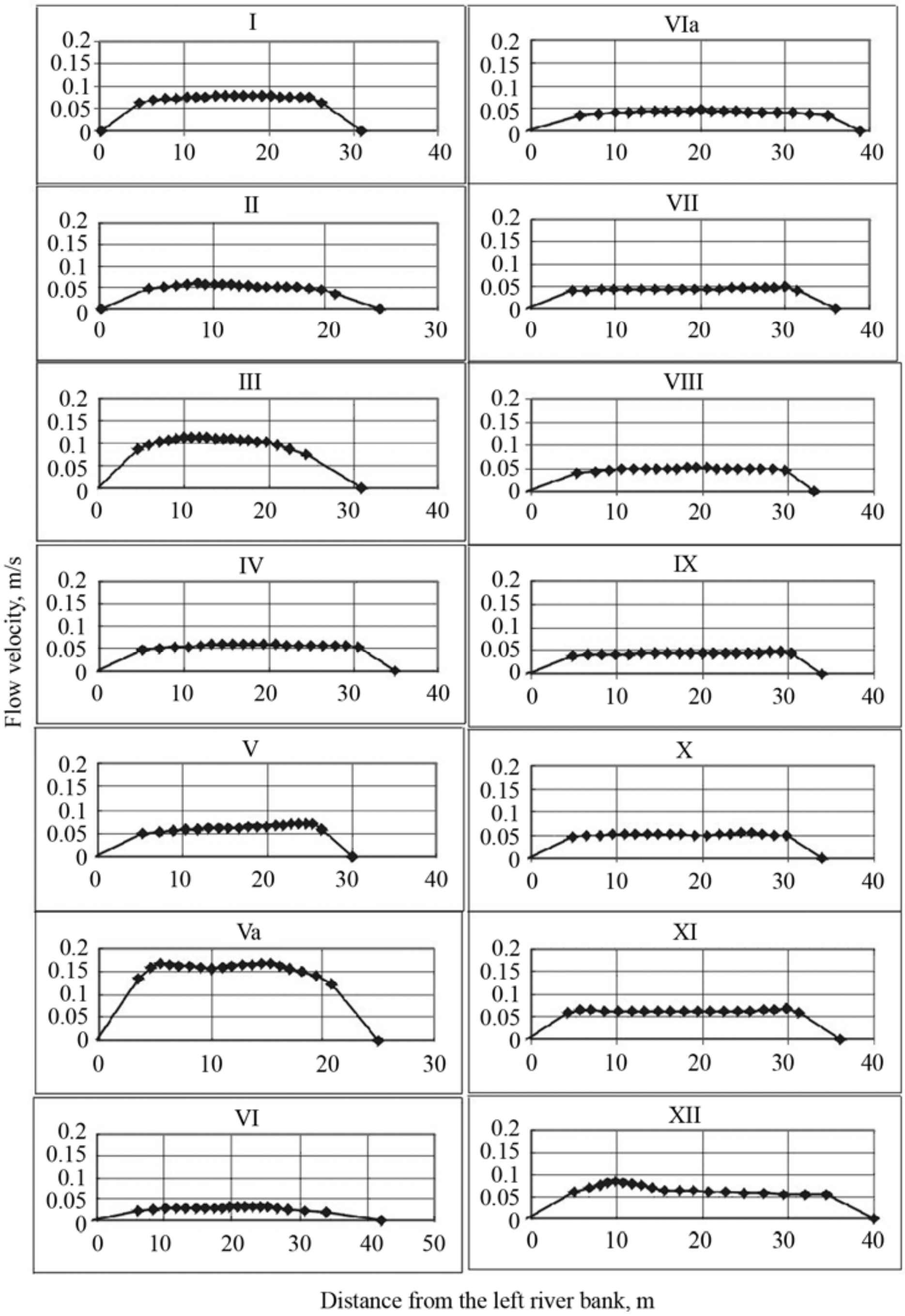

Fig. 6. Flow velocities m/s at cross-sections I–XII (in dam pond), when discharge is as usual (3 m^3/s)

A place for natural water overflow exists at the village of Panemunė, which could be widened and deepened to increase the water discharge overflowing in the upper part of the Nemunas delta. Increasing the conductivity of this overflow was modelled successfully, as water now flows further into Lake Užlenkė, from where it spreads into the whole valley. Attempts to increase the conductivity of other smaller overflows, for example at Malūnkalnis and at Maržiogis, were not successful. The overflowing water flows on further through narrow beds, which limits conductivity. Merely widening the inflow from the riverbed proved to be ineffective.

Deepening an 800 m wide overflow site below the railway bridge could also have increased sediment deposition in the valley. However, it was only the deepening of the overflow at Panemunė that appeared to be economically acceptable. During the investigations, attention was paid to selecting the optimal trace for a new road around the town of Tilžė, with regard to the possibility of digging a channel there. The ground for the road banks could be taken from this channel, which would need to be 120 m wide and 2 m deep to supply enough material. The channel would prevent the negative influence of the road and could increase the conductivity of the valley.

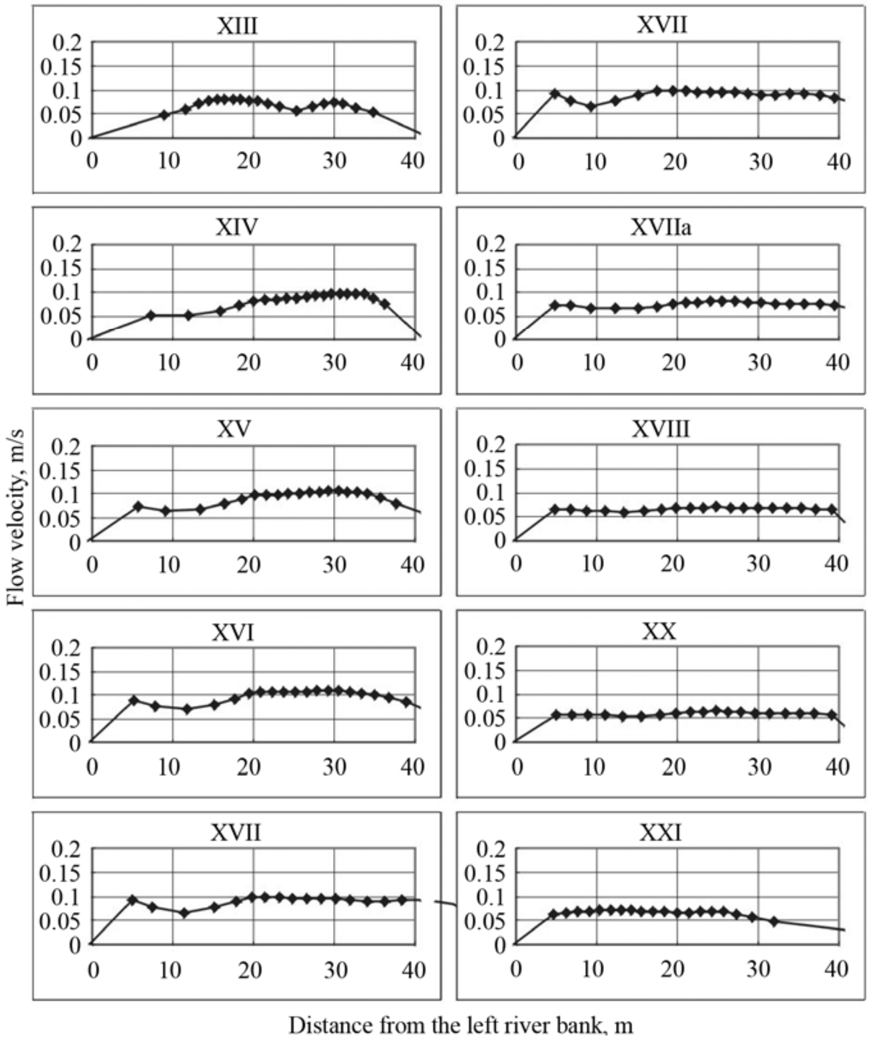

Fig. 7. Flow velocities at cross-sections XIII–XXI (in dam pond), when discharge is – 3 m^3/s

Several variations of channel depth and width were modelled, and the corresponding sediment deposition amounts were estimated. The results of the modelling are presented in Figure 8.

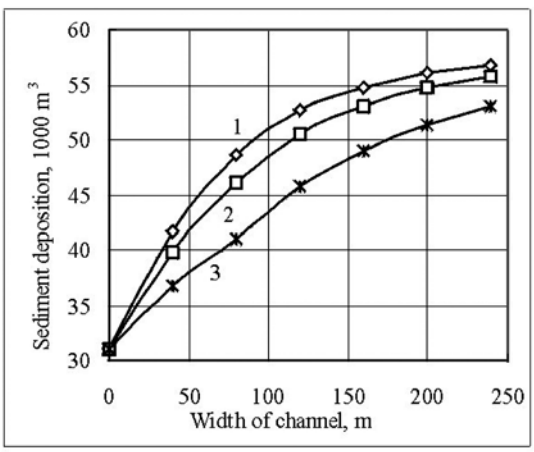

Fig. 8. Dependence of average amount of sediment, settled during one year, on the width of channel, when the depth of channel is: 1 – 3.0 m; 2 – 2.5 m; 3 – 2.0 m

The average sediment deposition in the valley during one year is proportional to the widening of channel, up to widths between 50–100 m; beyond 100 m the increase in sediment deposition slows. When the channel depth is 2 m and the width is 150 m, the increase of sediment deposition is 53%; after widening to 240 m the increase is 71%. When the channel depth is 2.5 m, the respective increases in sediment deposition are 70% and 85%. The increase is somewhat lower in a 3.0 m deep channel. However, the cross section of the channel increases more by increasing the depth compared with its widening, therefore, the deepening to 3.0 m ensures the desirable increase of sediment deposition with less volume of excavated ground.

Increasing sediment deposition by 50% (from 31000 to 46700 m^3 in Figure 8), when channel depths are 3.0 m, 2.5 m and 2.0 m, would require channel widths of 68 m, 85 m and 130 m respectively. The equivalent ground volumes to be excavated would be 212000 m^3, 298000 m^3 and 452000 m^3. Increasing sediment deposition by 70% would require respective channel widths of 114 m, 147 m and 237 m, and the equivalent ground volumes would be 312000 m^3, 441000 m^3 and 711000 m^3.

In both cases, the minimum volumes occur when the channel depth is 3.0 m, and volumes increase with lower channel depths. The dependencies are shown in Figure 9.

Shallow channels require the excavation of larger ground volumes, making them less acceptable. However, much deeper channels would be flooded more often during any summer and autumn floods, which is undesirable for the exploitation of the channel meadow.

Figure 10 shows the dependence of the desired increase in sediment deposition on the volume of ground to be excavated from the channel.

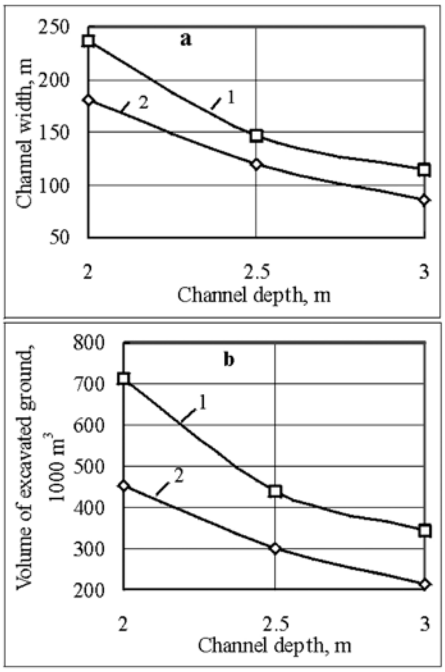

Fig. 9. Dependence of required channel width (graph a) and ground volumes for excavation from the channel (graph b) on channel depth, when the desired increase in sediment deposition in the valley, after building the channel, is: 1 – 70%, 2 – 50%

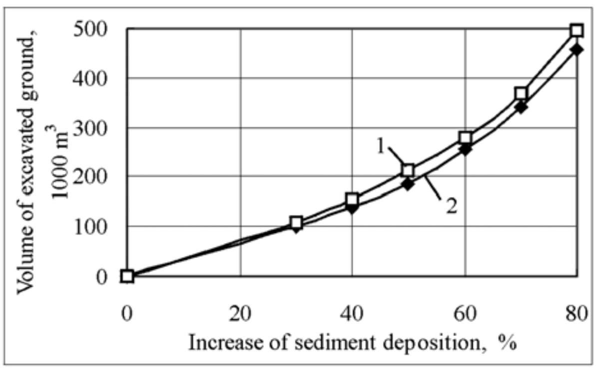

Fig. 10. Dependence of desired increase in sediment deposition on volume of ground to be excavated from the channel: 1 – channel depth 2.5 m; 2 – channel depth 3.0 m

These excavation volumes are seen to be greater as the desired sediment deposition increase reaches 70–80%. Consequently, the acceptable increase in sediment deposition may not actually be more than 50–70%. The availability of finance would determine the final choice of variant, along with potential requirements for the use of the excavated material, e.g. for building new roads or protective dykes. Direct expenses would then only be necessary for the arrangement of meadows to protect the channel bottom from erosion by the water flow.

Similar build projects may arise over a number of years, so the channel could initially be made slightly narrower and then widened as and when required.

Developing flow velocities in the excavated channel were calculated and their values are given in Figure 11.

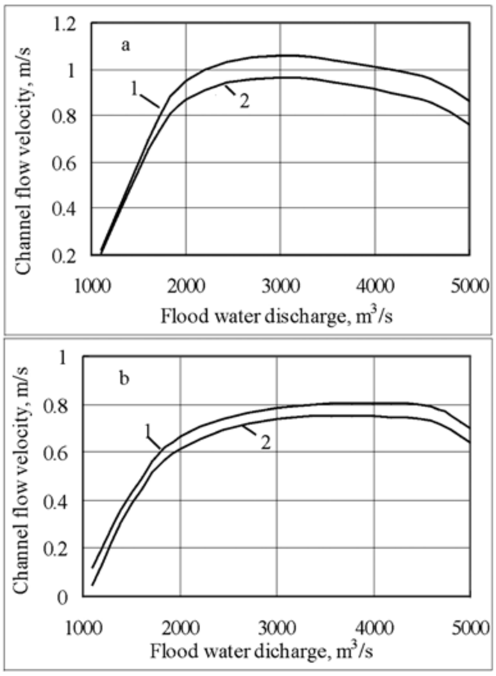

Fig. 11. Water velocities developing in the channel, when its depth is: 3 m (graph a), 2.5 m (graph b), and when the width of channel is: 1 – 100 m; 2 – 160 m

The velocities depend on the amount of floodwater discharge. During low floods they are correspondingly low and increase as flood levels increase. However, when water levels are high during heavy flooding, the channel flow is dammed and the flow velocities decrease slightly.

Maximum flow velocities approaching 1 m/s develop during floods where water discharge is between 2500–4000 m^3/s. In meadows the maximum permissible velocity is 1.5 m/s. In deep channels the developing velocities are greater but they decrease with increasing channel width.

As has been mentioned previously, the 800 m wide water overflow below the railway bridge could be deepened. According to our calculations, deepening this overflow to 1.0 m would only increase sediment deposition by about 10%, due to conditions being less favourable for further flow widening. The excavated ground volume would be twice that in Panemunė, making the deepening of this overflow much less acceptable economically. It could only sensibly be carried out after the deepening of the water overflow in Panemunė.

3.3. Influence of building road banks and growing trees in the Nemunas floodplain

Bushes and trees growing in the valley cause decreases in the riverbed flow velocities, which can increase deposition of suspended sediment. In the meadows of the floodplains, however, sediment deposition does not increase with decreasing flow velocities, as the velocities in flooded valleys are low enough and grasses are not flattened by the flow. This means that grasses can entrap sediments, unaffected by small changes of flow velocities, as the grass state does not change in these conditions.

Where thick bushes cause too great an increase in water level, they can pond the water inflow in the valley and decrease sediment deposition there. This is shown by the calculation data presented in Figure 12.

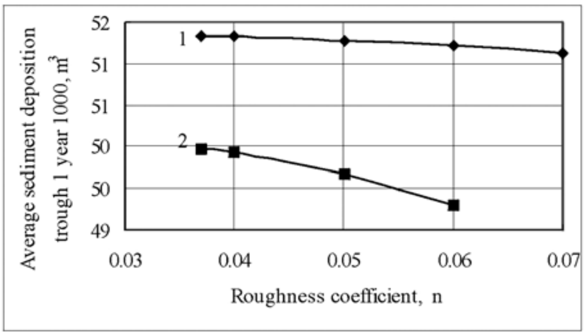

Fig. 12. The influence of the transverse road bank existence and the growing of bushes or tree strips in the valley on sediment deposition in the valley, when: 1 – the transverse road bank is absent; 2 – the bank exists

The influence of the hydraulic roughness coefficient made by bushes or trees on sediment deposition was estimated for the cases where a transverse road bank either existed or was dug up.

This shows that removal of the road bank would increase sediment deposition by nearly 2%, which is not a major change. However, should the excavated ground be required for other projects, the bank could be removed.

When the transverse road bank exists, and bushes and trees are growing in the valley, ponding of the water inflow into the valley increases, decreasing sediment deposition. When the bank is removed, the bushes and trees would not cause a significant decrease in sediment deposition, as long as their hydraulic roughness coefficient does not increase to more than 0.05. Any further increase of roughness, caused by thicker growth or larger areas of growth, would begin to pond the water inflow into the valley and decrease sediment deposition.

A railway and a highway cross the Nemunas delta. As they are close to the main water overflow in valley, they cause a decrease in sediment deposition of approximately 30%, which is more significant than that caused by the transverse bank. However, deepening the water overflow at Panemunė compensates for this negative influence as well as increasing the water discharge flowing into the valley.

4. Conclusions

1. Mathematical modelling of silt dynamics and distribution of flow velocities in the urban section of the Nevėžis River in Kėdainiai established that the water flow in the study section was even. Bottom and submerged silt was washed further downstream by the flow. Field measurements of the river bottom, carried out in 2006, proved that there are no conditions for an undesirable layer of silt to form on the self-armoured river bottom.
2. It was estimated that a spillway dam near Skongalis, stalling the Nevėžis River in Kėdainiai, did not stimulate bed silting. It is a low dam and is submerged during floods. As a result, water velocities in the riverbed above the dam are virtually unchanged during floods and the dregs carried by flood water are not deposited. The remains of grasses which have grown and decayed are washed away. When water levels are low, the Nevėžis water is only slightly turbid, i.e. it is relatively clean, with a turbidity of 2–6 mg/l.
3. We suggest solving the issue of ensuring the environmental discharge in the Nevėžis by using technical and administrative measures. One possible solution is the renewal of the 1 m^3/s discharge coming from the Šventoji River, which was stopped in 2000, and the restriction of discharge quotas taken for use by the chemical plant during the dry season.
4. To increase flow velocities and reduce grass growth in the river bed it is expedient to level and tidy up the urbanized riverside section, by narrowing the river bed to 30 m in width in the section from the Smilga tributary to the footbridge, as well as forming berms submerged during floods and reinforcing them with grass turf. The intensified flow in the narrowed section would improve the transport of silt, increase depths and thus reduce river bed overgrowth.
5. Excavation of the channel in the upper part of the Nemunas delta through the natural water wash near the town of Panemunė can increase sediment deposition in the floodplain by 50–70%. The optimal depth of this channel is 2.5–3.0 m. The width of the channel will depend on the desired increase of sediment deposition and could reach 150–170 m.
6. The efficiency of deepening and widening of the natural wash into the Nemunas valley depends on the possibility of further spreading the inflowing stream over the whole valley width. Any increase in sediment deposition will depend on available financing and on any potential build projects which would use the excavated ground. These could be new roads or protective dykes.
7. The growing of bushes and trees in certain areas of the Nemunas floodplain does not increase sediment deposition in the valley. Deposition may even decrease if bushes or trees grow too thickly or the valley areas overgrown by them are too large, resulting in ponding of the water inflow into the valley.

8. The road banks built across the floodplain decrease water inflow and sediment deposition into valleys. Their negative influence increases if they are traced too close to the main inflows into the valley causing them to pond. It is advisable to find the optimal trace when designing new roads.

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SKENDINČIŲJŲ NEŠMENŲ IR NUOSĖDŲ DINAMIKOS KAI KURIŲ LIETUVOS UPIŲ VAGOSE IR DELTOSE MODELIAVIMAS

S. Vaikasas

Santrauka

Upių taršos mažinimo inžinerinių priemonių projektavimas ir jų būklės kontrolė įmanoma tik matematiškai sumodeliavus skendinčiųjų nešmenų hidrodinamiką bei ištyrus tų priemonių veiksmingumą taršai sumažinti ir nešmenims nusodinti. Tam Nevėžio reguliuotoji atkarpa Kėdainiuose ir Nemuno užliejama delta ties Pagėgiais buvo ištirtos taikant hidraulinį matematinį modelį DELTA. Nustatyta, kad Nevėžio vaga, nepaisant jos mažų debitų sausmečiu ($Q_{s.p.v} \approx 3$ m^3/s) ir greičių ($v \leq 0,5$ m/s), nedumblėja. Taip yra dėl to, kad per potvynius, kai upės vagą formuojantys debitai $Q_{v.f} = 70$ m^3/s, o tėkmės greičiai dideli ($v = 1,2$–$1,3$ m/s), anksčiau nusėdęs dumblas periodiškai išplaunamas ir išnešamas į slėnį bei žemupį.

Dvimetrinis vandens paimos slenkstis ties Skongaliu taip pat šio proceso neveikia, nes per potvynį yra apsemiamas. Vasarą čia vandens lygiai žemi, o tėkmės greičiai ne didesni kaip 0,1 m/s, todėl Nevėžio vanduo palyginti skaidrus (drumstumas 2–6 mg/*l*), o jo skendinčiųjų nešmenų reguliavimo priemonės gali būti konstruktyvios arba visai nereikalingos.

Iš skaičiavimų akivaizdu, kad per potvynius Nemuno deltoje nemažai anksčiau atneštų skendinčiųjų nešmenų kartu su vandeniu išplukdoma į slėnį ir jame nusėda. Dėl čia sulaikomų nešmenų sumažėja vandens, patenkančio į Kuršių marias ir Baltijos jūrą, drumstumas ir biogeninė tarša. Taigi reikėtų didinti išsiliejančius į slėnius potvynių debitus ir jų išnešamų skendinčiųjų nešmenų nusodinimą. Straipsnyje aptartas įvairių slėnio tėkmių debitų ir greičių reguliavimo priemonių – senvagių atvėrimo bei gilinimo, slėnį pertveriančių kelio pylimų įrengimo ir krūmų bei medžių užauginimo efektyvumas skendintiesiems nešmenims sulaikyti.

Reikšminiai žodžiai: hidraulinis modeliavimas, vaginiai procesai, užliejami slėniai, nešmenų reguliavimas.

МОДЕЛИРОВАНИЕ ДИНАМИКИ ВЛЕКОМЫХ НАНОСОВ В НЕКОТОРЫХ РУСЛАХ И НИЗОВЬЯХ РЕК ЛИТВЫ

С. Вайкасас

Р е з ю м е

Проектирование инженерных средств для регулирования загрязнения рек и определение их эффективности возможно лишь при математическом моделировании гидродинамики и осаждения влекомых наносов. С этой целью при помощи двухмерной математической модели DELTA был исследован участок реки Нявежис в городе Кедайняй и дельта реки Нямунас у поселка Пагегяй. Установлено, что несмотря на сравнительно малые расходы воды в межсезонный период ($Q_{s.p.v} \approx 3$ м^3/с) и скорости течения ($v \leq 0{,}5$ м/с), в русле р. Нявежис ил и взвешенные наносы не скапливаются, так как они регулярно выносятся во время паводков при наличии руслоформирующего расхода ($Q_{v.f} = 70$ м^3/с) и возросших скоростях ($v = 1{,}2–1{,}3$ м/с).

Влияние подтопления двухметрового порога у Сконгалис в это время ничтожно, а сам порог бывает полностью подтоплен. При помощи расчетов на модели DELTA также установлено, что значительная часть влекомых наносов в низовья р. Нямунас может быть осаждена и задержана при их выносе паводковыми течениями на периодически затопляемую дельту. Осаждаемая часть зависит от распределения расходов между основным руслом и поймой. Поэтому необходимо увеличивать выливание воды в пойму. В статье приведены результаты математического моделирования эффективности различных средств регулирования воды: открытия и углубления старых русел и вымоин, устройства дамб, дорожных насыпей в пойме, уменьшения скоростей течения при помощи посадки кустарников и деревьев в виде полос.

Ключевые слова: гидравлическое моделирование, русловые процессы, затопление поймы, регулирование наносов.

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