River bed evolution processes under conditions of floodplain overgrowing with trees and shrubs vegetation

V B Zhezmer and A O Shcherbakov
All-Russian Research Institute for Hydraulic Engineering and Land Reclamation, Moscow, Russia
E-mail: asher5@mail.ru

Abstract. The article presents the investigation of the influence of tree and shrub vegetation on the discharge capacity of a river bed during high water. It was traced, that the calculating methods for roughness code and floodplain throughput capacity are good enough in case of a simple form of a river lengthwise section, but they do not work in case of meandering channels and in case of overgrown floodplain with vegetation: calculating errors significantly exceed the permissible ones. The method for eliminating the adverse effects of vegetation is proposed. The studies use the field observations results of the processes of vegetation influence on erosion effect and the sediment deposits. The field of observation is located in the middle part of the Volga-Akhtubinskaya floodplain (Kharabalinsky district). Space images (Yandex maps, Sputnik) of this area are used to improve the results of investigation. To correct the calculations in each specific case, it is necessary to carry out additional field hydrological studies. These studies will undoubtedly be much cheaper than the reconstruction costs of the hydraulic systems, and the costs of eliminating the accident results. Based on the research results, a simple and low-cost method for eliminating the impact of vegetation is proposed.

1. Introduction

Channel formation, as a self-regulating process, is function of the transporting ability of the stream. Channel deformation can be predicted by means of hydrodynamical calculations. Such calculations are based on both the use of flow kinematic characteristic and the use of balance and sediment transport equations [1]. The transport and accumulation of sediments depend on the sediment-bearing stream capacity. When the bottom velocity exceeds the level of the non-displacement velocity for sediments of a definite particle size, bottom sediments become suspended or saltation ones. Consequently, provided that the sediment discharge in a given flow section is \( q \), and the transporting capacity is \( q_t \), if \( q < q_t \) erosion occurs in a channel, in case \( q > q_t \) occurs sediment accumulation [2,3].

Under conditions of overgrowth of floodplains with herbaceous, woody and shrub vegetation, the determination of hydraulic resistances arising from the movement of bottom sediments becomes much more complicated. Calculating methods for the coefficients of roughness and carrying capacity of floodplains that work satisfactorily on channels with simple cross-sectional shapes do not work for calculating the same characteristics of meandering channels and floodplains overgrown with vegetation. The errors in calculating the coefficients of roughness according to the available tables (Sribny, Chow, Bradley and Karasev) in this case significantly exceed the permissible [4].

The paper analyzes the influence of tree and shrub vegetation of a floodplain on meandering and channel reformation on the territory of the Volga-Akhthuba floodplain. A method is proposed for
reducing the intensity of the river erosion. This is very important for the safety of hydraulic structures located in the immediate vicinity of the coast (e.g. water supply facility) [5].

2. Materials and methods
The field of observation is located in the middle part of the Volga-Akhtubinskaya floodplain (Kharabalinsky district). The geographical values are the following: latitude - 47°14.40″N, longitude - 47°13′54″E. In the area under study, the river is divided by an island about 2.5 km long into two branches of approximately equal width (during the low-water period 100-250 m) (Figure 1). The average depth of the channels is 5-6 meters. Bottom sediments are mainly represented by fine sands, in shallow and floodplain areas there are clays and silts.

The studies use the results of field observations of the processes of the influence of vegetation on erosion effect and the sediment deposits of the Akhtuba river bed. The evaluation of interaction principles of channel-forming processes and the degree of floodplain overgrowth were established in the basis works on river hydraulics and channel processes. The work used space images located in the public domain (Yandex maps, Sputnik).

![Figure 1. Location of the observation site (the approximate position of the currently eroded dam with pipeline for an irrigation system using DDA-100MA is indicated by a dotted line).](image)

3. Results
One of the reasons for the occurrence of errors in the carrying capacity calculating for floodplains is the presence of vegetation on it.

According to our data, the roughness coefficient increases not only because of the existence of vegetation. One should regard the multiple interaction of these facts. The impact of vegetation is much more diverse.

During the low water period – period of maturation of wind-pollinated trees seeds (in our case, willow and poplar), sufficient amount of willow and poplar fluff is carried by the river current and deposited in the wave-breaking zone. Under favorable conditions, the seeds germinate.

To ensure the formation of seedlings, it is necessary that the formed roller of fluff must be moisty and the seeds could not be washed out during seed germination. Further, the water level should
decrease, and only if these specified conditions are fulfilled, the seedlings can reach the degree of development at which overwintering is possible (Figure 2). In the flood of the next year, the newly formed shoots are usually destroyed, the plants survive no more than once every 7-10 years.

![Figure 2. Sprouts of the current year. Photo is taken by the authors.](image)

Woody plants grow in long, elongated, isolated stripes (Figure 3)

![Figure 3. Formation of strips of woody vegetation, contributing to the sedimentation of suspended sediments](image)
Figure 4. Formation of strips of woody vegetation, contributing to the sedimentation of suspended sediments. The photo is taken by the authors.

From the water's edge to the ledge, the slope angle of the deposited suspended sediments is preserved. Since in our case the sediments deposited under water consist of sand of medium and fine fraction, the angle of repose is 20-25 degrees [6]. In addition, the presence of vegetation prevents the ledge from erosion during the flood recession. As a result, the sand massif becomes more stable and new deposits appear on their surface [7]. Above the scarp, sediment deposits are gentler, almost horizontal (Figure 5).

Figure 5. Location of sediments above the tree line. The photo is taken by the authors.

This arrangement of sediments is facilitated by herbaceous vegetation that forms between the woody strips. According to the widespread opinion, during the spring flood, accompanied by flooding of floodplains, there is no vegetation on the latter [4]. In this case, dried tough gramineous vegetation
(Figure 5), which persists in winter, significantly increases the roughness of the soil surface and the intensity of sediment accumulation during the flood. This phenomenon is fully consistent with the point of view of Verbitsky [8] that the movement in separate sections of the composite profile is completely independent, thus the total throughput is defined as \( K = \sum K_i \), i.e. will be equal to the sum of the throughput, calculated for the individual plots.

The next ledge is on a parallel strip of woody vegetation. There may be several such ledges. In flood conditions, when the flow direction is parallel (or close to parallel) to the stripes of woody vegetation, they serve as flow guides and contribute to the horizontal arrangement of sediments. Since the presence of vegetation prevents the erosion of the ledge during flood recession (Figure 4), the deposition rate can be several times higher than the calculated one (determined using the generally accepted roughness coefficient) [9,10,11].

4. Discussion

According to the investigations we deduce that the increase of the roughness coefficient is not the only one consequent effect of the floodplain vegetation influence. The vegetation influence, especially woody, on the stream is quite diverse, poorly studied and, apparently, is not limited by the examples that were written above.

This information is of vital importance in determining the location and expected service life of hydraulic and irrigation and drainage structures located in the immediate vicinity of the watercourse.

The accumulation of sediments on a convex bank reduces the cross-section of the flow, while, according to the Shezy formula, the average water flow rate and, accordingly, the degree of erosion of the concave bank increase.

Based on the observations, the presence of vegetation contributes to the deposition of sediments, increasing the erosion of the opposite bank to the grown-over one. It leads to a significant reduction in the actual service life of the structures in comparison with the calculated one. So in figure 1 we can see, that the sediments caused by the influence of vegetation contributed to the erosion of the dam with a water supply pipeline for the irrigation system (in this case, the irrigation system using DDA-100MA, irrigation canals are visible at a distance of 100 m from each other).

Since the river erosion effect on the bank that is opposite to the grown-over one increases with the growth of sedimentation it is absolutely obligatory to take in consideration this fact while the project development of hydrotechnical and other important constructions, that located in the immediate vicinity of the eroded bank, it is necessary to calculate the approximate service life of the structures.

The presence of strips of woody vegetation on a concave bank increases intensity of erosion almost always. It requires additional appropriate adjustments in the calculations. Due to significant differences in the intensity of channel formation, as well as the rate of growth and development of woody vegetation, depending on the location of the studied object, it is necessary to carry out additional full-scale hydrological studies in order to correct the calculations in every specific case. Undoubtedly these studies will be much cheaper than the costs of reconstruction of the hydraulic system other engineering structures designed in the river influence area, and, moreover will be much cheaper than, the costs of eliminating the results of the accident.

5. Conclusion

According to our data, in order to reduce the intensity of erosion of the opposite bank, it is necessary to destroy the arising tree growth of the current year regularly (Figure 2). The shoots are destroyed in late summer and autumn during the low water period with the help of a motor-cultivator. The best results are obtained by double treatment with an interval of 15-20 days. When the influence of vegetation is eliminated, the calculation errors in determining the channel roughness coefficients according to the generally accepted tables (Sribny, Chow, Bradley and Karasev) approach the permissible level.
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