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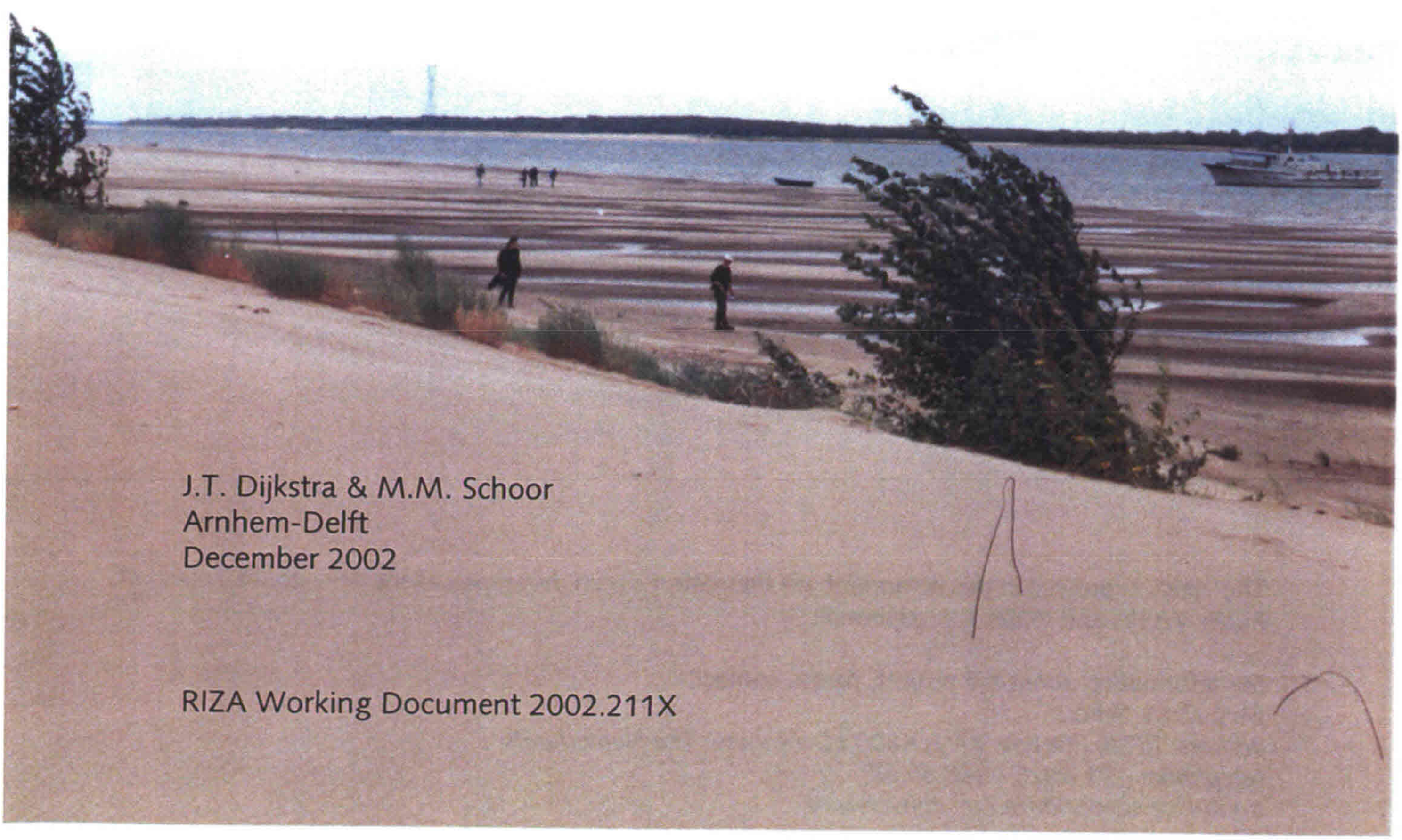
POINT BAR DEVELOPMENT AND VEGETATION SUCCESSION ON THE VOLGA-AKHTUBA FLOODPLAIN, RUSSIA

Final report of the project Morphodynamics Lower Volga and Waal



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Arnhem-Delft
December 2002

RIZA Working Document 2002.211X

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Point bar development and vegetation succession on the Volga-Akhtuba floodplain, Russia

Final report of the project Morphodynamics Lower Volga and Waal

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Preface

The research program concluded by this report started in 1999. In the three years it continued many people and many organisations contributed to it. Not only was the scientific co-operation very pleasant and interesting, it also lead to opportunities for further co-operation and sharing of knowledge.

Therefore we would like to thank the following people in Russia: Dmitry Babich and Andrei Alabyan of Moscow State University and their students Mihail Samohin and Sevolod Moreido; Evelina Sokhina and Maria Kalioujnaia of the Regional Centre for Study and Conservation of Biodiversity and their students Tatiana Baluk, Sergei Goncharov and Irina Kalioujnaia; Evgeni Kartunov, Natalia Lopantseva and Anja Kartunov of the Management of the Volga-Akhtuba Floodplain Nature Park; Mihail Shoubin of the Volga Water Resources Research Insitute; Anatoli Bykov and Elena Kilyakova of the State Committee for Natural Resources of Astrakhan/Volgograd Oblast; Gnady Losev; and Harald Leummens of RIZA.

We also would like to thank the people in the Netherlands that contributed to the project: Hans Middelkoop, Jurgen de Kramer and Janrik van den Berg of Utrecht University, together with their students Anouk Cormont, Sietske van der Sluis and Tamara van de Ven (now working at NEO). Also thanks to Geert Menting and Perry Cornelissen of RIZA for their collegial support.

Summary

The 'Room for the River' strategy for Dutch river management asks for more information about morphodynamics and vegetation succession in natural rivers. In order to obtain such information, the Lower Volga River in Russia is chosen as a natural reference river for the Dutch Waal River. Objective of the project Morphodynamics Lower and Waal is to provide more insight in:

- The natural coherence between morphodynamics and vegetation succession;
- The rate at which succession of ecotopes is to be expected as a reaction on morphological changes;
- The effect that vegetation and vegetation succession have on morphodynamics of rivers, mainly on point bar growth, bank erosion and sedimentation on the floodplain.

Both the large Lower Volga River and its smaller side-branch the Akhtuba River are dynamic sandy rivers with a small gradient. Satellite image analysis gives large-scale information about migration of these rivers, whereas several fieldworks provide information on a smaller scale; i.e. that of a point bar.
Aim of the 2002 fieldwork is a quantification of short-term morpho- and vegetation dynamics, obtaining additional information about tree ages and using the Akhtuba River to scale down the results from the Volga River. At the Volga River one bend, the Zakrutsky area, is studied by levelling several profiles, mapping contours using GPS, sounding the riverbed and determining the vegetation age by auging trees. This not only provides information about the current situation, results also can be compared to data obtained during earlier fieldworks. At the Akhtuba River more cross-sections of point bars are levelled and the vegetation development along two of them is recorded by pictures and drawings. This river has not been studied before.

The bend at Zakrutsky shows a lot of morphological activity with a high water channel, an accreting scroll bar, and average outer bank erosion of 19 m/yr. Most morphological activity at the point bar raises the terrain level, thus decreasing inundation time, soil moisture and flow velocities, which asks for other species. Furthermore, the morphological changes give pioneering vegetation the chance to develop almost every year after a flood because existing vegetation becomes covered with sand and dies, or because new land like the scroll bar is created. This means rejuvenation takes place continuously.
The height of the terrain is found to be a key factor for which species are present: On low and moist areas dense willow (*Salix alba*) woods can be found, as well as moist herbage and grasses. On higher and therefore dryer areas sedimentation and germination occur more spread out, which creates a more open landscape consisting of trees (mainly *Populus nigra*) of different ages along with dry grasses and herbs. After about 20 years also hardwood species (*Fraxinus Langustifolia*) can be found on the higher areas. Generally the difference between moist and dry lies around 4 meters above low water level.

The situation at the Akhtuba River is different, because this River is less dynamic: erosion rates are at most 2 m/yr. The sedimentation on the point bars also occurs very gradually, only in the lower areas bare sand and pioneer vegetation is found. This means there is less rejuvenation, which is confirmed

by the smaller number of young trees among older ones. Very little moist vegetation is found here. Grasses, herbs and *P. nigra* are very common, and also hardwood (*Fraxinus, Tamarix*) is present on the higher places. Another difference with the Zakrutsky area is that some areas are grazed. These areas show a park-like landscape with older trees, very short grass and *Xanthium*, a thorny herb.

In order to relate the dynamism of the two Russian rivers to the Waal River, a comparison is made of their physical parameters, the vegetation that is present and the management that is applied. The parameter comparison shows that the dynamism of the Lower Volga River at the Zakrutsky bend is well comparable to the dynamism of the Waal River in 1800. The morphological and vegetation changes observed at Zakrutsky can not be applied to the present Waal River however: As for the Waal River economy and safety are much more important than nature, the river is not allowed to move freely, and woods are not allowed to develop in order to warrant the flood conveyance capacity. Also the 'Room for the River' concept does not solve this: The river is still very limited in its dynamism, and therefore sedimentation rates and stream velocities are too low to ensure natural rejuvenation

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1 Introduction

1.1 Background of research

After ages of raising the dikes and deepening the river to reduce flood risks in the Netherlands, a new strategy seems promising: to give the river more space. Besides improving safety measures to increase the flood conveyance capacity of the river, like the excavation of side channels and floodplain widening and lowering, will also provide an opportunity for ecological benefits. However, sedimentation and vegetation growth during the years will reduce the extra conveyance capacity, thus causing a safety risk.

Therefore this strategy is extended to the so-called 'Cyclic Floodplain Rejuvenation' (CFR). This management strategy aims at a regular human - unlike natural- removal of vegetation (softwoods) and sand excavation as a compensation for channel migration and sedimentation, in order to restore the safe conveyance capacity. The same processes occur in natural rivers like the Lower Volga River: if the vegetation becomes too dense or the floodplain to small, the river will make the room it needs. Rejuvenation creates an opportunity to start the ecological succession once again.

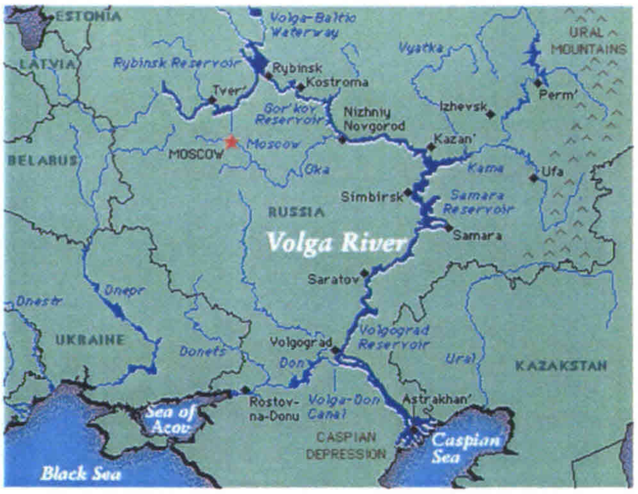


Figure 1-1
The Volga River in Russia.

By studying the natural rejuvenation characteristics of rivers comparable to the Waal River predictions can be made about rejuvenation and succession rates for the Waal River itself can be made. However, it is very difficult to find rivers that are both similar to the Waal River as well as in a still more or less natural and dynamic state. A lot of research has been done on the Allier River in France but this river is smaller, has a gravel bed and a steeper gradient. The Lower Volga River and the Akhtuba River are chosen because their morphological characteristics are at the other end of the spectrum: the Lower Volga River is much bigger, its slope is smaller and its sand is finer. That makes the Allier River and the Lower Volga River suitable as boundaries of how the Waal River might develop.

1.2 About the project: earlier visits and reports

The project 'Morphodynamics Lower Volga and Waal' started in 1999, as a part of a joint ecology project of the Dutch RIZA, the Regional Centre for Study and Conservation of Biodiversity and the Russian State Committees for Natural Resources of Volgograd and Astrakhan Oblast. This resulted in an ecological map of the Volga-Akhtuba floodplain. In this year also the first fieldwork took place, a reconnaissance between Volgograd and Astrakhan. In 2001 the second river-morphological fieldwork followed, carried out in co-operation with the Physical Geography departments of Utrecht University and Moscow State

University. This fieldwork concentrated on a smaller area and a smaller scale. The most recent fieldwork was carried out in August 2002 with the same parties as in 2001. In 2002 just one area in the Volga River was investigated, but more elaborately, and also the Akhtuba River was studied.
The Russian-Dutch co-operation is a great opportunity for the Dutch researchers to study a very interesting area in the presence of specialists that know the area very well. For the Russian scientists and park management it offers insight in other research methods and management practices, besides providing valuable information about the area at very low cost, like for example satellite images.
In the future similar research will continue, but in a different form and largely without RIZA. More about this research, which is supported by NWO, can be found in annex 4.
The series of project reports starts with an analysis of satellite images by Van de Ven (2000). Second, the 1999 expedition is treated by Schoor and Middelkoop (2001). In report no. 3 Shoubin and Babich (2001, Eds.) discussed the geology and hydrodynamics of the floodplain.
An inventory of information available at Moscow State University was made also by Van de Ven (2001) in the fourth report. Results of the 2001 fieldwork can be found in the report of De Kramer (2001) and in the report the two UU-students made (Cormont and Van der Sluis, in prep.). The sixth report contains an analysis by Van de Ven (2002) of Volga-Akhtuba morphodynamics based on Landsat images of several years.

1.3 About the report

This report is the final in a series of RIZA (Dutch Institute for Inland Water Management and Wastewater Treatment) studies about the morphodynamics of the Lower Volga River in Russia. These studies were carried out to learn more about morphological and vegetation development and their mutual influences. Such insight is necessary to predict changes and to support decisions for a new form of river management in the Netherlands: a more natural river. The Lower Volga River and its Akhtuba-branch are chosen as a reference case because they are quite similar to Dutch rivers like the Waal River, and because they are still very natural rivers. The complete RIZA research project includes several forms of research, like satellite image analysis and several fieldworks.
Besides summarizing conclusions of the earlier studies, this report will also describe the results of the last fieldwork in the Volga-Akhtuba floodplain, which took place from August 26th until September 5th 2002. The object of this fieldwork was to gather more information about the morphological and vegetation development of a point bar and the interaction between morphology and ecology, both on a timescale of decades.

1.4 Contents

The objectives of the project and the methods used are treated in chapter 2. The third chapter provides an overview of both Volga and Akhtuba, including summarized results of the earlier studies. Chapter 4 contains the results of the fieldwork of 2002 in the Volga River; chapter 5 interprets these results and discusses the difficulties and errors in measuring and interpreting. The same approach is followed for the Akhtuba River in chapters 6 and 7. Based on these results, a comparison with other rivers is made in chapter 8. In chapter 9 conclusions are drawn, together with recommendations for further research in both Russia and the Netherlands.

2 Objectives and methods

This chapter starts with stating the overall project objectives and the goals for the 2002 fieldwork, concerning both vegetation and morphology. After this, the study area is treated. Desk study methods used for preparation and analysis of measurements and the methods used in the field are discussed in the last two paragraphs. The treatment of fieldwork methods is split into a Volga and an Akhtuba part; though several methods are the same for both rivers, the nature of research is a little different.

2.1 Project objectives

The aim of the project is to provide insight in:

- The natural coherence between morphodynamics and vegetation succession;
- The rate at which succession of ecotopes is to be expected as a reaction on morphological changes;
- The effect that vegetation and vegetation succession have on morphodynamics of rivers, mainly on point bar growth, bank erosion and sedimentation on the floodplain.

To attain these insights the following goals need to be achieved:

2.1.1 Morphology

- Quantification of morphodynamics: sedimentation and erosion rates of point bars, scroll bars, banks and shoals;
- Derivation of a relationship between morphodynamics and river parameters;
- Reconstruction of morphological developments of several river stretches, using existing data and maps.

2.1.2 Vegetation

- Analysis of vegetation types, -ages and –succession, and their relationship with morphology.

2.1.3 2002 Fieldwork goals

The goals for the 2002 fieldwork are:

- Quantification of short-term morpho- and vegetation dynamics;
- Obtaining additional information about tree ages;
- Investigating whether the Akhtuba River is suitable as a reference for Dutch rivers;
- Using the Akhtuba River to scale down the Volga River results.

2.1.4 Additional research

Outside the scope of this project, but nevertheless interesting is the complementary study about the influence of vegetation on scroll bar development done by the student of Delft University of Technology. Besides providing information about this influence, the study will also provide information about the applicability of the numerical model used (Delft3D) for this kind of research. A conceptual model of the Zakrutsky bend will be made. The only additional fieldwork data necessary for this research is the density of the vegetation. Results are expected in March 2003.

An other activity that is to take place in the future is the NWO-project, of which a description can be found in annex 4.

2.2 Choice of study area

The two specific research areas are chosen for different reasons. Foremost criterion for both areas is the morphological and vegetation dynamism, which can be observed from satellite images. The Zakrutsky / Bulgakov area at the Volga River is chosen because it was studied once before (in 2001), so changes can be observed and information can be complemented. Furthermore this area can be reached easily and camping facilities are close. The latter also determined the selection of the Akhtuba-area near Veterok. Other criteria here are the absence of human constructions (i.e. not too close to villages) and a position upstream of Leninsk because downstream of Leninsk the river leaves its bed during high water.

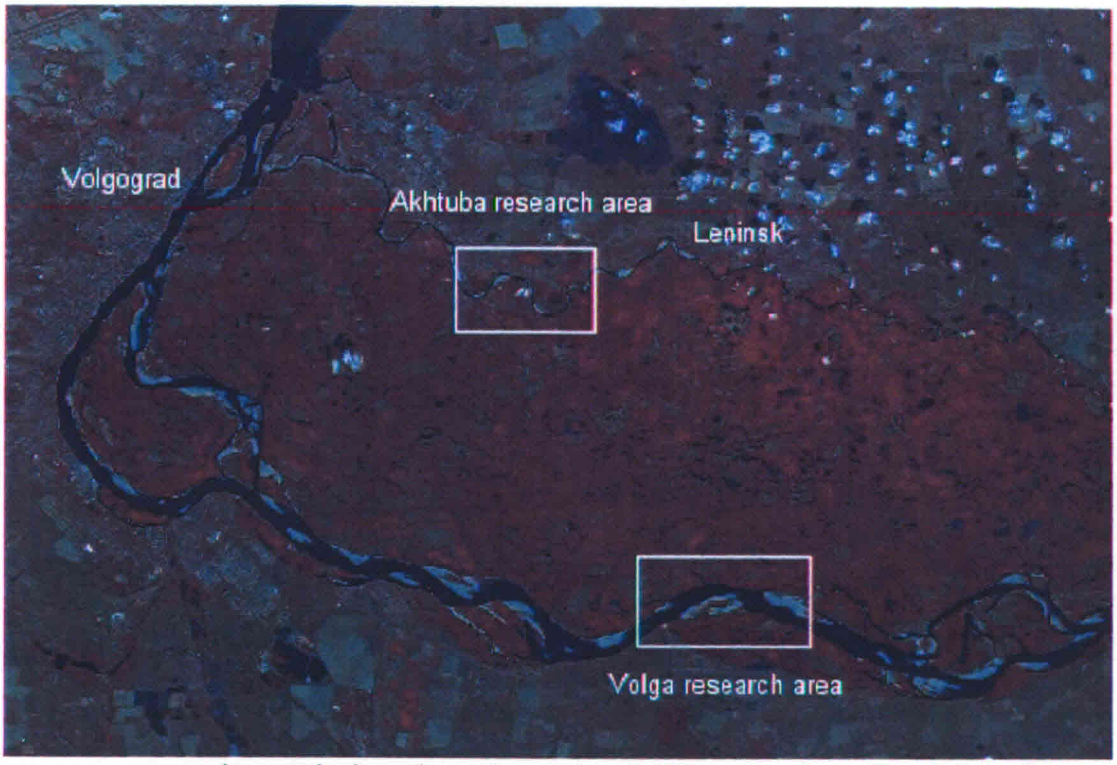


Figure 2-1
The Volga Akhtuba Floodplain, Volgograd and the two research areas.

2.3 Desk study methods: maps and satellite images

Besides the literature mentioned in paragraph 1.2, the Landsat-images of the years 1986, 1996, 1999 and 2000 are a very important source of information, used for preparation and analysis of the fieldwork. However, they have two important shortcomings: their pixel size is 30 by 30 meters –too large to see details like a sharp waterline or relatively small groups of trees, they do not provide information about the situation before 1986, and they have not been georeferenced accurately, which for the Zakrutsky area results in a systematic error of about 200 meters. The first two could not be solved, the last one was solved by cutting the areas of interest out of the complete image, and giving them new coordinates based on a visual fit of morphologically stable marks (the right bank upstream of the point bar and the left bank downstream of it, close to the sand banks) with GPS points. These corrected images can still have an estimated error of less than one pixel (<15 meters) with respect to their actual location. Therefore this is an important improvement, which makes it possible to see and quantify morphological changes.

Older spatial information is only available in the form of navigational maps. Because these are made for shipping they mainly display the navigational channel; they do not provide very accurate dimensions of other entities like banks, shallow water or landscape forms. Nevertheless they do show general morphological changes because they span a rather long time: 1914, 1940, 1964, 1974 and 1981.

2.4 Fieldwork methods

2.4.1 Volga

Besides specific measuring equipment like a leveller and sounder, also more general equipment like laptops, GPS-handhelds, field maps, photo cameras and a boat are used. Apart from being a form of transport, this boat also functions as a measuring platform. Unfortunately the ship's draught of 1.4 meters made measurements in the shallower parts impossible. The field maps were made on the basis of the most recent low water satellite image (2000), some of them were equipped with data measured in 2001 (e.g. locations and ages of auged trees, levelling profiles) to provide additional information.

Figure 2-2
The boat used for transport and mesasurements at the Volga River.

Morphology

To measure the morphological changes in the area several methods are used:

- Mapping contour lines of medium-scale morphological entities like scroll bars, edges and banks by walking along them while storing their coordinates with a GPS. These contours can be compared to those of earlier years using a GIS and satellite images.
- Levelling a profile that was levelled in 2001 as well, comparing both profiles in Excel. The locations of the levelled points are stored in a GPS, plus they can be calculated using the angles and distances measured.
- Levelling of two new profiles at places where this has not been done earlier.
- Sounding the river bend from the boat with GPS-aid like in 2001, but now for a more extended area with cross-sections every kilometre. This also can be compared using a GIS.

Additional measurements that are made to get a better picture of the area:

- Measuring outer bank height with a laser distance meter and a compass, storing locations with a GPS.
- Measurement of flow velocity profiles in the river from the boat using Ott-mills.
- Digging of a profile hole in a morphologically active area using a spade and a trowel; interpretation of the sedimentation pattern.
- Checking whether the grain size throughout the area is more or less the same using a set of standard samples (a sand ruler).

By comparing contours in a GIS and levelled profiles a quantification of changes can be made. Some, like the waterline contours, can be compared over several years, for others it is only possible to make a comparison between 2001 and 2002.

Vegetation

The following activities are performed to study vegetation and its relation with morphology:

- Auging/sawing and measuring the stem perimeter of a few dozens of thick trees to determine their age. The locations of these trees are stored using a GPS. The distribution of tree-ages over the area can be visualized in a GIS.
- Administrating what species grow where in combination with morphological entities, taking pictures and making sketches.

And for the modelling of the influence of vegetation on scroll bar development:

- Mapping tree density: counting how many trees are on a certain area, measuring their stem perimeter and height, estimating coverage and height of smaller vegetation and locating this with a GPS.

Figure 2-3
Auging a tree.

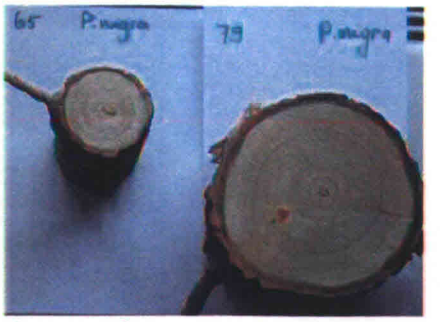


Figure 2-4
Examples of sawed poplars.

The age of the trees is determined by auging or (in case of young trees) sawing them, and counting the year-rings of their stems, like the measurements done in 2001. This gives a rather good idea of their age, but they can be one year younger or a few years older. This inaccuracy is caused by differences is measurement height, errors in counting or accidentally measuring the top of a sanded-in tree. This is explained more elaborately in the report of Cormont and Van der Sluis (2002), who also tried to find coherence between tree age and perimeter.
After plotting the ages of the trees on a map of the area, this provides information about the minimum age of certain parts of the area, and about how long it takes for vegetation to develop on fresh ground. To date new ground as far back as possible it is necessary to measure the oldest and therefore thickest trees one can find in the area. Younger and very young trees are indicative for more recent development.

2.4.2 Akhtuba

On the Akhtuba a small boat was used for transport and soundings. Since this area was not visited before, it was not possible to measure changes. Therefore everything was aimed at making a detailed description of the current situation, and trying to reconstruct what happened the past decades on the basis of morphological and vegetation characteristics.

Figure 2-5
The small craft used at the Akhtuba River.

Morphology

- Levelling of a number of profiles from waterline (or in the water) to the floodplain limit, if possible.
- Sounding a part of the river from the boat with GPS like on the Volga but with a smaller boat.

- Walking around on the riverbanks: estimating and asking fishermen and locals how things have changed (erosion rates, discharges).
- Measuring bank height like on the Volga, to see if the river is incising.
- Measuring morphological and/or vegetation contours with GPS.

Vegetation

- Making a detailed description with sketches and photos of two levelled cross-sections.
- Auging and sawing more trees, like on the Volga.

3 The Volga-Akhtuba floodplain

This chapter summarizes the most relevant results of earlier reports and visits. The first paragraph describes briefly the history of the project and what results have been obtained when. The next paragraphs give an overview of the geographical and hydrological situation in and around the Volga-Akhtuba floodplain. These are followed by a description of morphological and vegetation entities and changes on different scales. The land use and other activities in the area are dealt with in the last paragraph. For a more elaborate description of results and how they were obtained it is necessary to read the specific report.

3.1 Geographical situation

The Volga River (figure 1-1) is a large river flowing through the Russian Plain, which has its origin several hundreds of kilometres north of Moscow. The northern part of its drainage basin consists of taiga and woods, the southern part of steppe and (semi-)desert. The Volga River usually is divide in three parts: the Upper Volga River from the source to the Rybinsk dam, the Middle Volga River from the Rybinsk dam down to the confluence with the Kama River, and the Lower Volga River that ranges from this confluence until the Caspian Sea. The part of interest for the project is the southern part of the Lower Volga River, downstream of Volgograd where the river is almost entirely natural. The Lower Volga River upstream of Volgograd is merely a cascade of reservoirs.

Figure 2-1 gives an idea of the position of the Lower Volga basin, the Lower Volga River and his main side-branch the Akhtuba River, the Volga-Akhtuba floodplain and important cities in the area. The length of the rivers between Volgograd and Astrakhan is about 450 km. Downstream of Astrakhan the Volga River flows out in a delta in the Caspian Sea.

Together, the Akhtuba and Volga Rivers create a 15 to 30 kilometre wide wet zone in the otherwise dry steppe area. The upstream connection of the Akhtuba River to the Volga River is situated just upstream of Volgograd, the downstream connection is less clear because at high discharge the Akhtuba River leaves its banks and at low discharge it has several connections to the Volga River. The Akhtuba River has a meandering pattern; the Lower Volga River shows both meandering and braiding characteristics.

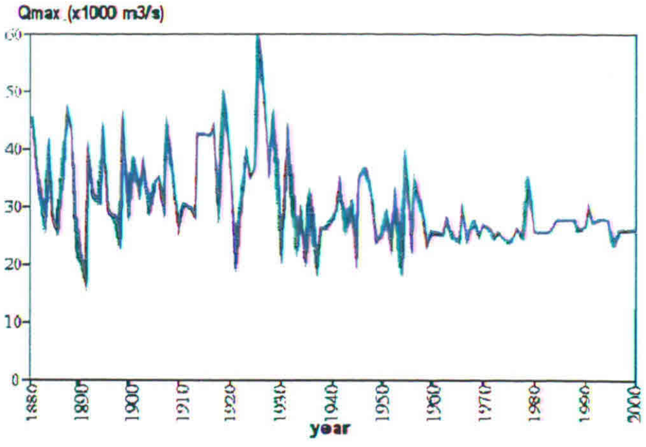
At some places the right bank of the river erodes the cliffs of the steppe situated 20 meters higher, at most places it erodes is own sediment deposits or older low-lying soils (see the geological map of Babich, in prep.). At most places the top layer of soil, which is several tens of meters thick, consists of Caspian Sea deposits (clay, loam and fine sand). Therefore the sediment transported by the river is very fine.

The climate in the area is continental: hot in summer (July-average in Volgograd: 24,2 °C), cold in winter (January-average in Volgograd: -9,6 °C) and dry (368 mm/yr). The warm period lasts from mid June until half September; transitions occur quickly. In winter the river is covered with ice for about three months, in summer the water temperature is 24-29 °C (Mordukhai-Boltovski, 1979).

3.2 Hydrology

Figure 3-1
Maximum discharges at Volgograd through the years (from MSU/RIZA, 2002).

3.2.1 Lower Volga River



In 1959 a very large dam was completed just north of Volgograd to support irrigation, shipping and hydropower generation. Since the construction of this dam the maximum discharge decreased from over 50.000 m^3/s to 34.000 m^3/s; the average peak is around 27.000m^3/s. Also the duration of the spring flood in April / May decreased from 8 weeks to 5-7 weeks, but the discharge during summer is higher; see Van de Ven 2000 and figures 3-1 and 3-2. Just downstream of the dam this discharge is distributed over the Akhtuba River and the Lower Volga River. Since the Akhtuba is very small in proportion to the Volga River, the discharge of the latter can be regarded as almost equal to the discharge at the dam.

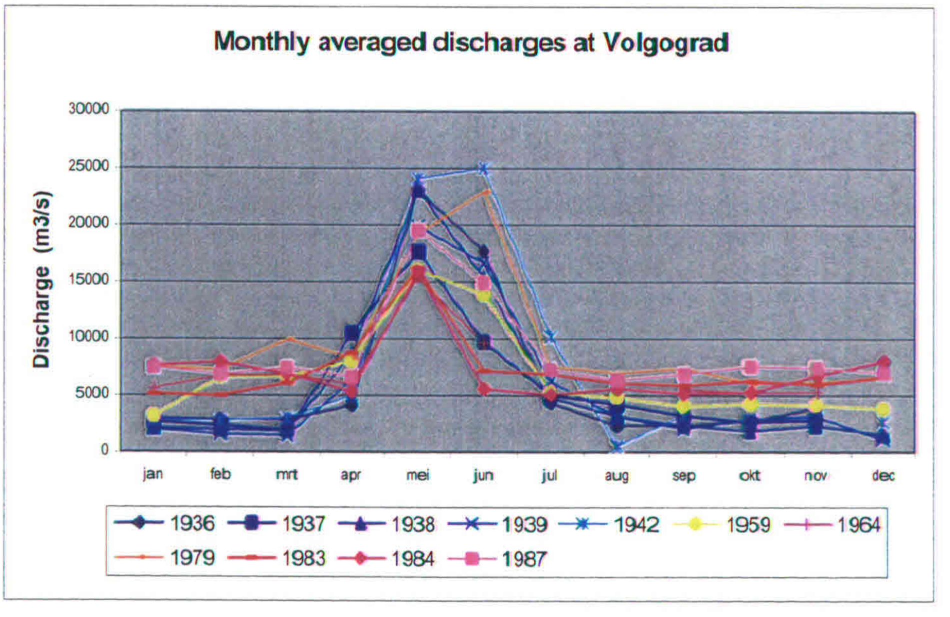


Figure 3-2
Monthly averaged discharges at Volgograd for several years. The red lines (after dam construction) show a more equal discharge distribution than before dam construction (blue lines). After van de Ven (2001).

3.2.2 Akhtuba River

A striking feature of the Akhtuba River is that flow velocities during low discharge are very low. On some places the water hardly seems to flow at all. Hydrological data of 1962 from a station near Akhtubinsk indicate velocities between 0.1 and 0.3 m/s with a discharge ranging from 10 to 30 m^3/s at the end of August. During high discharge (in May) these values are 0.56 m/s and almost 900 m^3/s. These low values are a result of the small riverbed slope (3-4 10^{-4}) and the awkward upstream connection with the Volga River. More recent data are not available, nor are data from closer to the research area.

3.3 Morphology

The morphology in the Lower Volga River has been studied in two ways: A large-scale analysis using only satellite images and navigation maps for the

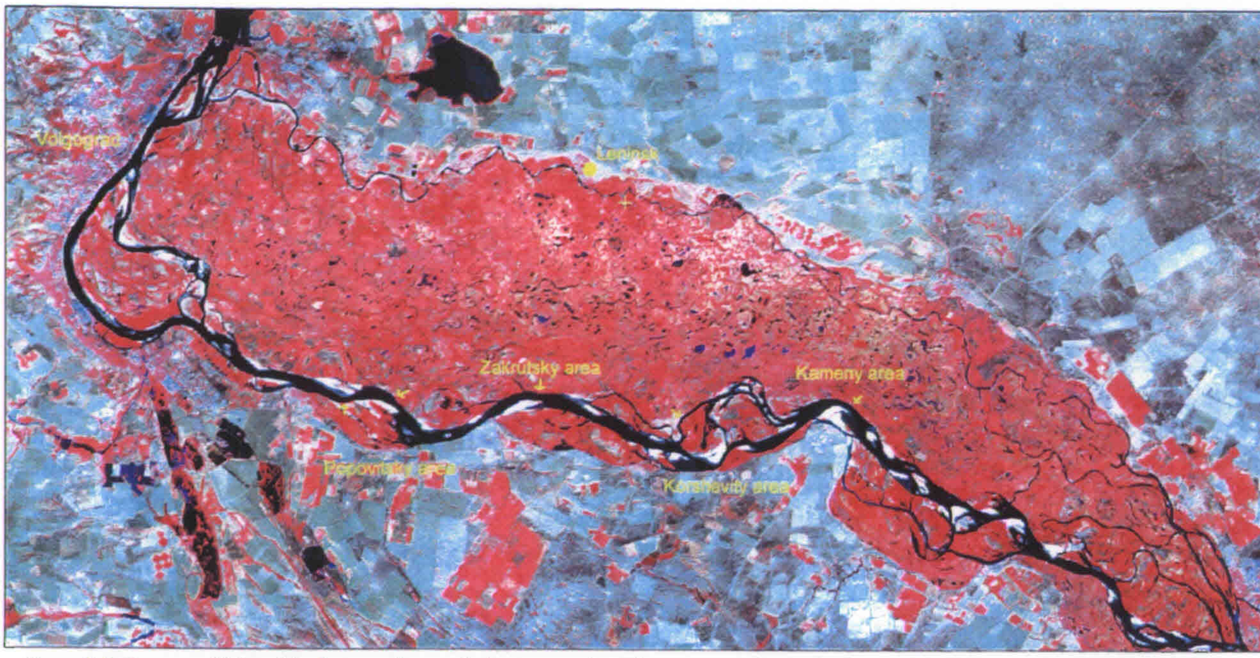
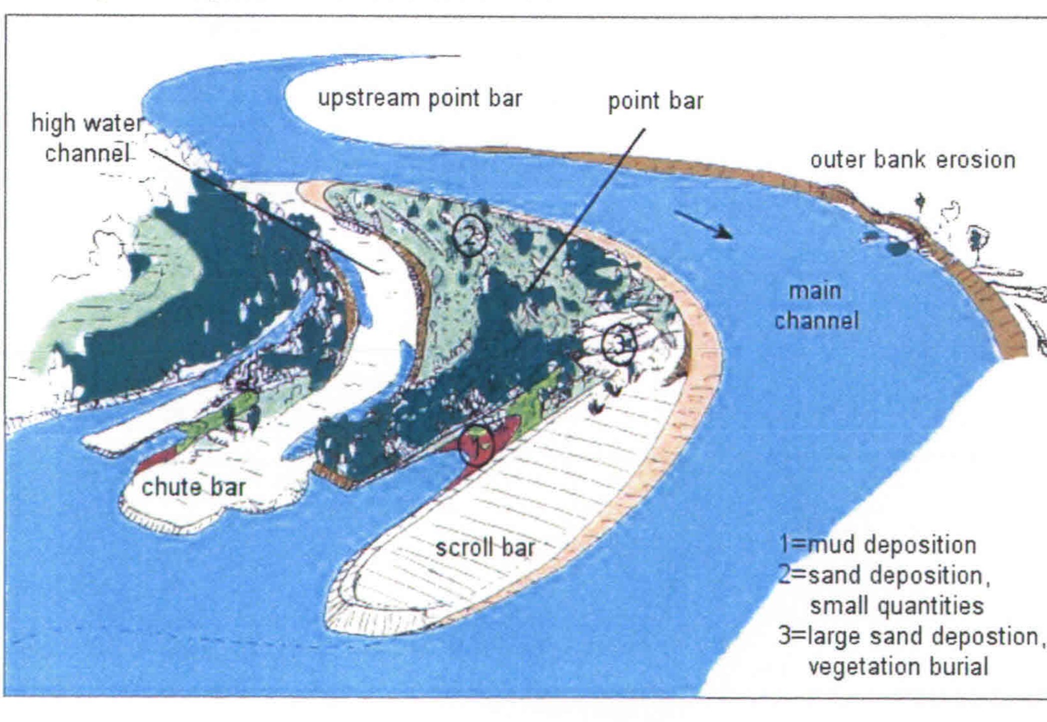


Figure 3-3 The area of interest for large-scale morphology research. Yellow arrows indicate the five areas used to measure erosion rates. After Van de Ven (2002).

Figure 3-4 Changes in the Zakrutsky area between 1986 and 2000. Yellow indicates sedimentation, orange indicates erosion of sandbars, red means erosion of river banks and green is overgrowth of sand bars (Van de Ven, 2002).

Figure 3-6
A sketch with several morphological phenomena, inspired by the Zakrutsky area. After De Kramer (2001).



stretch between about 50 and 200 kilometres downstream from Volgograd (figure 3-3), and a study of morphology on a much smaller scale (point bar scale), based on field visits.

3.3.1 Large scale morphology

The river in the area shown by figure 3-3 is more dynamic than it is downstream of this area: the downstream part is deeper and narrower, its gradient is smaller and more sand banks are vegetated (Schoor and Middelkoop, 2001, Van de Ven 2000). Van de Ven (2002) concluded the following: The dominant morphological processes in the Volga River are the downstream movement of river bends and the movement of sandbars. Upstream of the Korshevity area (see figure 3-3) erosion of the riverbank is more intense than in the downstream area. Movement of sandbars occurs in the whole main channel of the Volga. Changes in the Akhtuba River occur at a smaller scale. The Akhtuba River often shifts its whole riverbed. Both Akhtuba and Volga show a correlation between morphodynamics and turbidity; morphodynamics of sandbars and riverbed are strongest developed in areas where riverbanks are high and overbank flow is rare.

Results of this study are for example erosion rates of several areas along the river (see table 3-1) and pictures showing erosion, sedimentation and vegetation covering sandbars (figures 3-4 and 3-5).

Table 3-1
The erosion of the riverbed (in meters) for five different areas along the Volga River. By Van de Ven (2002).

	Popovitsky area 1	Popovitsky area 2	Zakrutsky area	Korshevity area	Kameny area
1986-1996	210	140	110	200	155
1996-1999	65	25	20	70	50
1999-2000	15	10	0	1	0
1986-2000	320	220	140	235	240

The hydropower station near Volgograd and its dam (completed in 1959) do have a big influence on morphological processes in the Lower Volga and Akhtuba Rivers: sediment is stopped at the upstream side of the dam and the discharge is regulated. It appears that both the Lower Volga River and the Akhtuba River are incising because of the low sediment load just below the dam, but this is not proven yet. Another possible effect of the dam is the reduced discharge of the Akhtuba River.

3.3.2 Local scale morphology

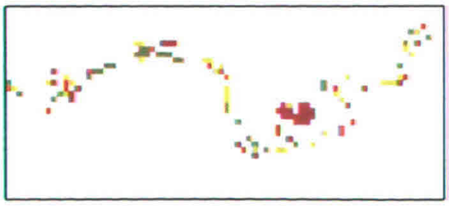


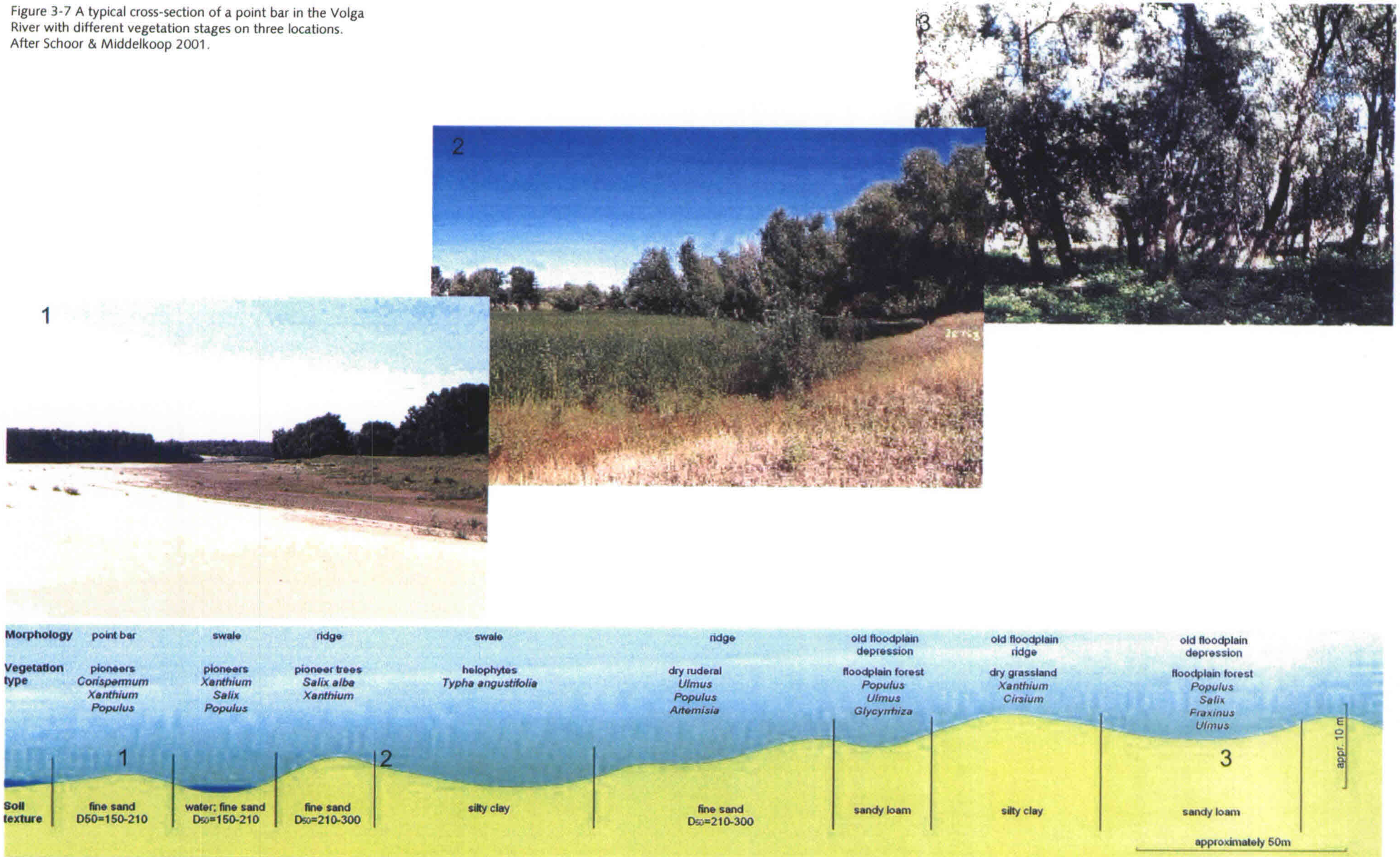
Figure 3-5
Changes in the Akhtuba research area between 1986 and 2000. The legend is similar to figure 3-4. After Van de Ven (2002).

Investigations on a smaller scale so far are difficult to summarize. De Kramer (2001) describes many examples of interaction between morphology and vegetation on this scale. Figure 3-3 shows the three research areas of the 2001 fieldwork: the areas Popovitsky, Zakrutsky and Korshevity. Figure 3-6 is a sketch inspired by the Zakrutsky area that contains several local morphological elements.

3.4 Vegetation

The Volga-Akhtuba floodplain can be regarded as a kind of oasis in the steppe and semi-arid zones around it. Over 300 species of flora are present in this area, a number of them rare and endangered. The ecological map made by RIZA (1999) gives an idea of what kind of ecotypes are present. Lists of species present in the area can be found in De Kramer (2001) and Schoor & Middelkoop (2001; list is in Dutch).

Figure 3-7 A typical cross-section of a point bar in the Volga River with different vegetation stages on three locations. After Schoor & Middelkoop 2001.



For the project, research did not concentrate on the vegetation as such, but on the relation between vegetation and morphology. Results of such studies are the vegetation map in figure 4-10 and the point bar cross-section in figure 3-7. These show different stages of vegetation succession on point bars, depending on the morphological circumstances and age of the terrain. Similar descriptions are made by De Kramer (2001) and Schoor & Middelkoop (2001).

3.5 Land and river use

The Lower Volga River still is quite natural because of the land use in the area: a large part of the floodplain and surrounding area is a Nature Park, with very limited land use. Industrial and residential areas are situated near Volgograd; therefore bank protection in the Nature Park is not necessary. The Nature Park area is not completely natural however, but also used for limited farming and recreational activities, especially fishing. Because of these activities several villages and roads exist within the Park. The human pressure on the area probably will increase further after completion of a bridge that facilitates an easy connection between Volgograd and the Nature Park on the other bank.

The Volga River is an important shipping route, but the amount of ships passing is rather low. Moreover, the river in its natural state is deep enough for most shipping, and dredging is too expensive. Besides its transport function, the Volga River is also a very important source of water for irrigation of the surrounding steppe area.

Besides influencing morphology, the dam and discharge regime also cause ecological problems. The flooded area and the flood duration are smaller, which has a negative effect on the reproduction of economically very important sturgeons. Many fishermen are complaining.

The water quality of the Lower Volga River is quite good. Pollution by industry or domestic wastewater is relatively low, also because of the large amount of water with respect to the limited amount of people that live in the area. Remarkable however is the number of plastic bottles and old fishing equipment that can be found everywhere.

4 Results Volga

This chapter presents the results obtained with the different fieldwork methods: first a description of morphological changes, followed by the results of the vegetation studies. The results ate interpreted and discussed in the next chapter.

The position of the different morphological entities mentioned in this and following chapters are indicated in figure 4-1 below. An explication of ecological and morphological terms used in this and following chapters can be found in annex 6.

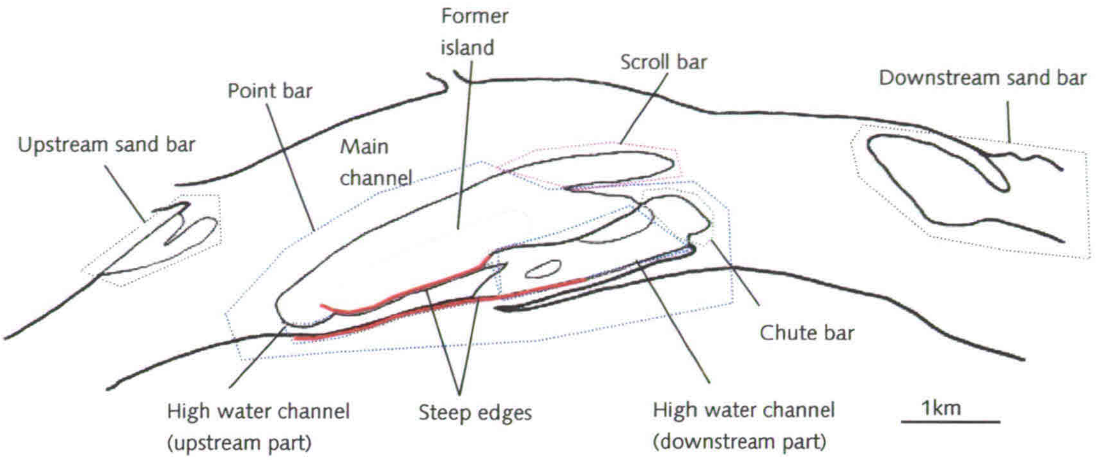


Figure 4-1
Areas and entities.

4.1 Morphological activity, migration rates

The four most important fieldwork activities for morphology are: contour mapping, bathymetry sounding, levelling and studying very local phenomena. The results of all four methods will be presented here; the interpretation is done in the next chapter about Zakrutsky's development..

4.1.1 Contours and soundings

Figure 4-2 gives the best idea of what contours are mapped. The most important ones are:

- The edge of the outer bank (horizontal distance to the waterline differs about 3 to 12 meters); red dots.
- The waterline of the scroll bar, chute bar and west part of the point bar; light blue, grey-blue and purple dots.
- (Erosive) edges of the high water channel and on the west of the point bar; light blue dots.
- Waterlines in the high water channel; light blue dots.

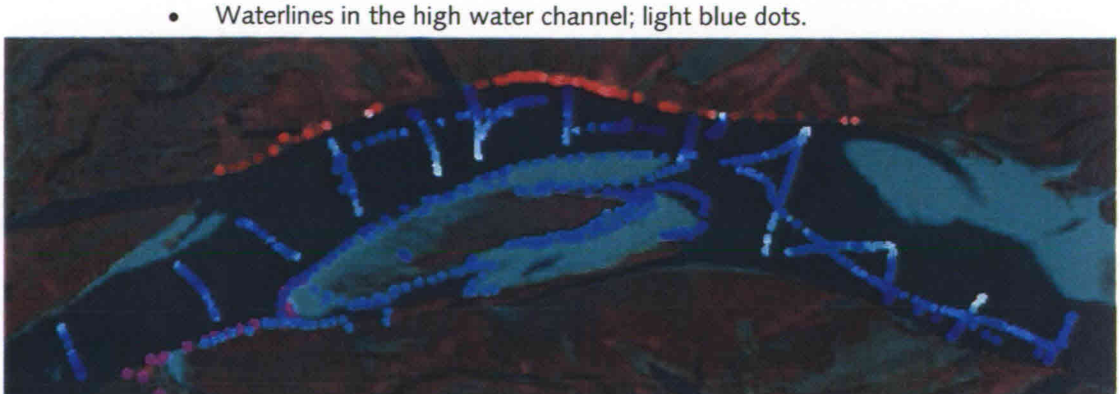


Figure 4-2
Countours and depth points measured in 2002 on the 2000 Landsat image.

Table 4-1: Description of changes for the years 1986, 1996, 2000 and 2002.

Year	No.	Size (m)	Change or movement (m) compared to 2002	Remark
1986	1	-	2225	No scroll bar present in 1986, but connection of scroll to island is clear. A small possible start of it however is visible (wet sand).
	2	-	312	No scroll bar present in 1986.
	3	875	-313	The nav. maps of 1964 and 1981* both show this width is about 700m, on the 1974 map it is 800m. There are two locations with this width: at the toe of the current scroll bar (the twist on the 1986 image) and near the east of the point bar.
	4	300	300	According to the nav. maps of 1964 and 1981 this is about 445m (outer bank was drawn at same location).
	5	n.a.	n.a.	No chute bar present in 1986, a starting point cannot be defined.
	6	125	75	It is a lot smaller than on the 1964 map, newer maps do not show a channel.
	7	500	500	A lot of wet sand, comparison with earlier years is not possible.
	8	2960	2960	Upstream movement with respect to estimated centre of 2002.
	9	340	n.a.	About 1/3 of channel width. Change cannot be measured; 2002 width is unknown.
1996	1	1350	875	Scroll clearly visible; quite large angle with main channel.
	2	450	-138	Wide and short.
	3	500	62	Scroll fills a large part of the channel. Narrowest cross-section is now clear, it has or not significantly moved, or it shifted 2375m.
	4	150	150	Maximum erosion about 100m upstream of narrowest section, more downstream than in 1986.
	5	500	500	East part of high water channel is almost completely filled with sand.
	6	175	25	Much wider than in 1986, seems to be eroded on both sides.
	7	200	200	Waterline is more definite, clear shift upstream.
	8	1240	1240	Upstream movement with respect to estimated centre of 2002.
	9	390	n.a.	About 1/3 of channel width. Change cannot be measured; 2002 width is unknown.
2000	1	1850	375	Scroll becomes longer.
	2	350	-38	Scroll gets thinner and slowly shifts from main channel to inner bank.
	3	525	37	Channel becomes gradually wider; narrowest cross-section has moved about 625m downstream.
	4	50	50	Point of maximum erosion difficult to determine but close to narrowest cross-section.
	5	250	250	Clearly a chute bar has formed.
	6	175	25	Little change since 1996, a small beach has formed just upstream.
	7	0	0	Erosion until 2002 contours.
	8	440	440	Upstream movement with respect to estimated centre of 2002, partly vegetated.
	9	300		Less than 1/3 of channel width. Change cannot be measured; 2002 width is unknown.
2002	1	2225	n.a.	Scroll grows longer.
	2	312	n.a.	Scroll gets thinner and slowly shifts from main channel to inner bank; channel behind it becomes smaller.
	3	562	n.a.	Channel becomes gradually wider.
	7	200	n.a.	Right bank could not be measured in 2002; position of 2000 is used.
	9	280	n.a.	Estimated from soundings

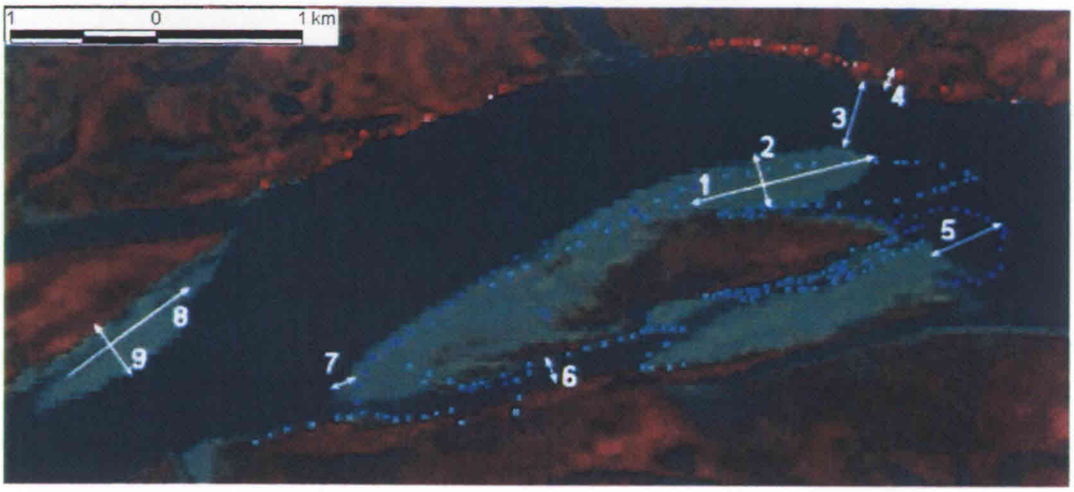
* See also the discussion of the accuracy of the navigational maps in paragraph 5.3.

Table 4-2: Change and movement rates with respect to 2002.

			Change- or movement rate (m/yr) with respect to 2002		
No.	Entity	Description	1986	1996	2000
1	Scroll bar length	From fixed GPS point to tip	139	146	188
2	Scroll bar width	Widest	20	-23	-19
3	Smallest channel width	Perpendicular to stream direction	-20	10	19
4	Maximum outer bank erosion	Perpendicular to waterline	19	25	25
5	Position of chute bar (growth)	From fixed GPS point in stream direction	-	83	125
6	High water channel width	Fixed location	5	4	13
7	Position of upstream side (erosion)	From fixed GPS point in stream direction	31	33	0
8	Position of upstream bank	Of estimated centre of gravity	185	207	220

These contours are plotted on the images of 1986 (September 7th), 1996 (June 14th), 2000 (August 20th) and 2001 (May 19th;flood) to make comparison possible. These images can be found in annex 1. The quality of those printed images is rather poor, but they are just meant to give an idea of changes; for analysis better quality images were used. Also interesting to see is the result of the satellite image analysis by Van de Ven (2002), included as figure 3-4 in this report.

Figure 4-3
Arrows indicating measured changes on the 1996 satllite image.



Explanation of the tables:

- Size (m) simply shows the dimension of an entity in a certain year. The change or movement (m) of an entity is determined by comparing the dimensions or location of an entity in the year of interest with those in 2002. The movement rate (m/yr) is calculated by dividing this value by the number of years between the year of interest and 2002. For entities that do not move but do deform, the value in this column means the rate of change (m/yr) of the measured dimension.
- The year 2002 is chosen as the reference year because then all movement rates are in the same direction (towards the 2002 situation). Choosing 1986 for as the reference would give the same advantage, but then not al morphological entities are present yet, so a starting point is missing. Besides, for this year no fixed GPS points are available to use as a basis for changes.
- High water images are not analysed this way because they do not show the features used here. Also the image of 1999 is not used; the differences with the 2000 images are very small and the image does do not show anything that would not be expected between 1996 and 2000.
- Though changes and dimensions are given in meters, this is a fake accuracy since the satellite images have an accuracy of no better than 30 meters. A better accuracy however can be achieved by estimating what is in the pixel itself, and of course rates have a better accuracy since they reflect changes over several years.
- The remarks explain difficulties and choices in measuring, or how the situation has changed with respect to the image just before it: unlike the values it does not tell the change with respect to 2002!
- The dimensions of the downstream bank are not measured. Changes are certainly visible, but it impossible to represent them with figures.

Figure 4-4
The heights and depths measured in 2001.

Figure 4-5
Three cross-sections in the Zakrutsky bend. In downstream direction they are: red (at the sand bar), blue (narrowest c.s.) and green. The last shows a shift of main flow to the right bank (riffle).

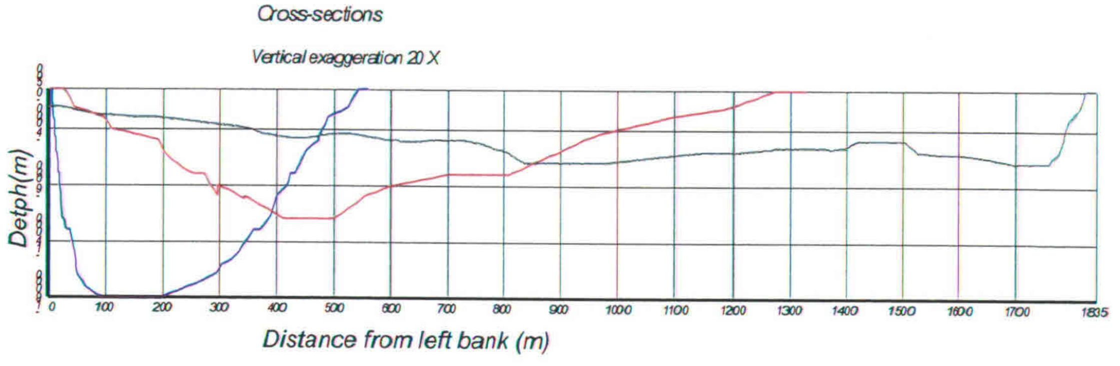
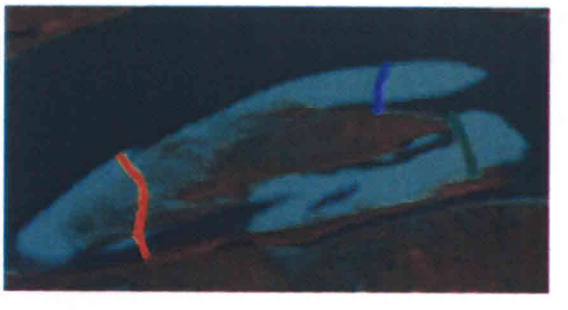


Figure 4-6
The locations of the levelling profiles on Zakrutsky. The blue (28-08-2002) one was levelled in 2001 as well, the red (29-08-2002) and green (28-08-2002new) are new.



4.1.2 Levelling

Three profiles were levelled (figure 4-6), one of them on the same location as last year to quantify changes. The profiles can be found in annex 1a.

Unfortunately the accuracy of these measurements prohibits a good comparison: plotting the 2001 and 2002 profile in the same graph does show some differences, but those are of the same size as the possible error. Moreover the profiles were not measured on exactly the same location, but 10 to 20 meters apart, which could make some differences as well.

The horizontal error depends on the method used. If GPS-coordinates are used, the RMS-error of a point is at most 15 meters according to the manufacturer's information. Most points seem to be more accurate, but several others show much larger deviations. If the angle and distance of the levelling equipment are used to calculate the position the error is smaller for the first few measured points, but small deviations in the only roughly measured angle cause large deviations in points that are farther away. The vertical error is estimated at 10 to 20 centimetres because of reading errors, a not exactly levelled leveller or beacon, and micro relief.

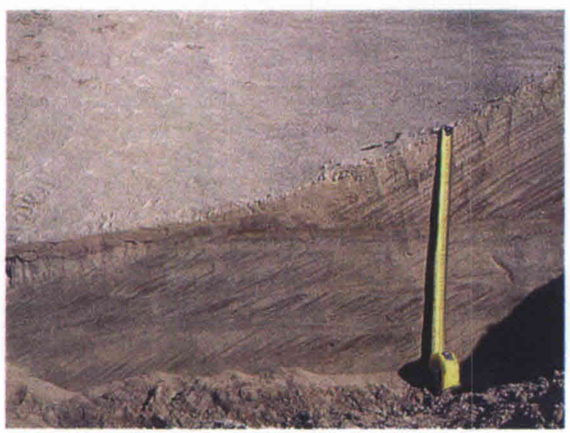
Despite the errors in the levelling results, they are still useful for getting a better idea of the heights in the area, and they do show some dimensions of

Figure 4-7 Examples of small-scale morphological activity.

Vegetation buried by large amount of sedimentation.

Small 'tidal' channel.

Fresh deposited sand; still bare (several locations).

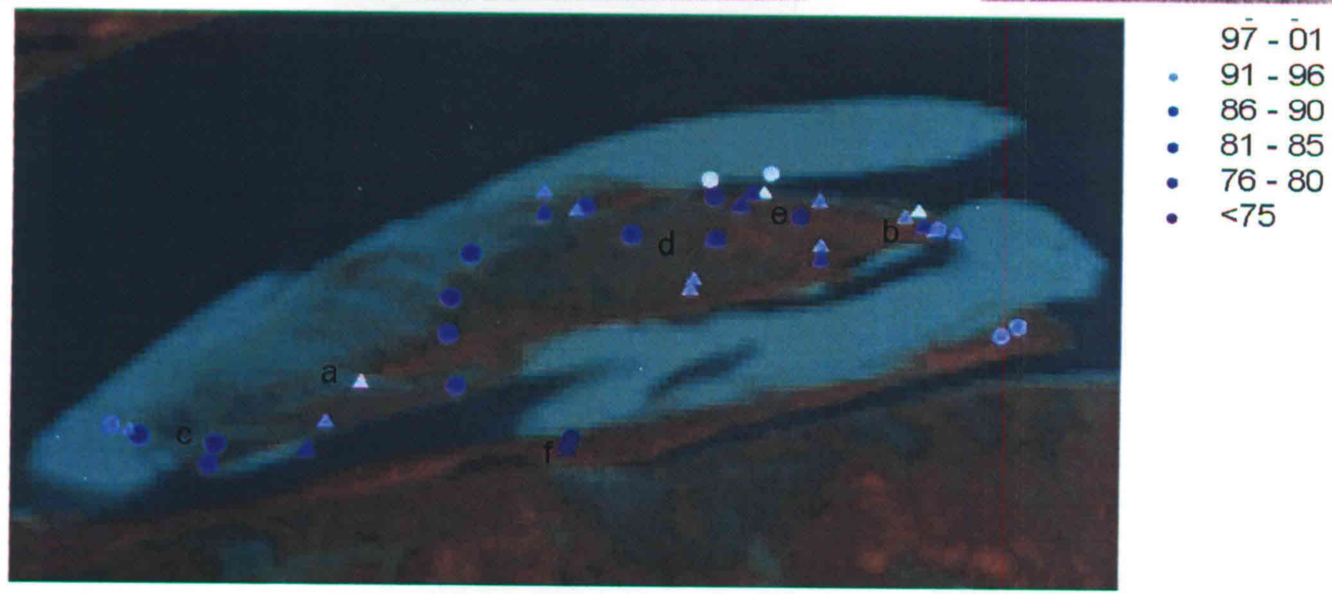


Profile of a dune at the entrance of the high water channel. Several new layers on top of old deposits show accretion.

Small high water channel on point bar.

Bed forms in the high water channel.

Figure 4-8 Different vegetation ages on the 2000 image of Zakrutsky. The years at the right of the image indicate the germination years of the trees.



morphological entities like for example the depth and width of the high water channel. They are also useful for the Delft3D modelling.

4.1.3 Very local morphology

Some interesting features are observed in the field that can not be quantified but nevertheless provide useful information:

- Dunes in the high water channel.
- A small high water channel with some vegetation across the point bar.
- Fresh deposition of a lot of sand at the connection between scroll bar and point bar.
- Fresh unvegetated sediment at several locations on the point bar.
- A small channel between the eastern lake in the high water channel and the water behind the scroll, which functions as a kind of tidal channel depending on the dam discharge regime.

These features are shown in picture 4-7.

4.2 Vegetation

Two features of the vegetation are measured: the density and the age. This part of the research focussed on trees for a practical reason: for trees it is possible to determine their age. Besides these qualitative measurements also the species of the trees and other vegetation are noted.

4.2.1 Age of vegetation

Figure 4-8 shows some of the oldest trees (>15 years old) on the high edges along both sides of the high water channel. Very old trees (>40years) can only be found on the high edge at the south side of the high water channel; here also hardwood is present. The eastside of the former island also shows quite a lot of older softwood trees, with ages up to 22 years (1979), and some young hardwood (*Fraxinus langustifolia*; ash).

Younger (<10 years) trees can be found almost anywhere in the area. On areas that are still dark (water) in 1986 the maximum tree age is about 5 years (see figures 4-8 and 4-9), which means the oldest trees here date from 1996.

On the south bank of the high water channel young trees (not measured, but clearly visible) appear as second-generation forest between the older trees. On the point bar hardly any second generation forest is found. Most of the woods

Figure 4-9
Germination years of measured trees present in 1986 on the 1986 image.

present on the east side of the point bar, with trees (*Salix alba*) between 8 and 13 years old, are too dense to allow new trees to develop. Younger trees are present at the edges of this forest, and on the large rather open area on the higher grounds (*Populus nigra* and *Salix triandra*) west of the forest. It should be noted however that measurement focussed on old trees, which makes that lots of younger trees are not present in the picture.

4.2.2 Vegetation density

The density of the trees tends to vary more in cross-sections perpendicular to the flow direction than in the stream direction. Tree density is especially high (over 30 trees on 10x10 m) at the mostly lower and humid areas close to the (former) waterlines of the high water channel and the channel behind the scroll bar at the east side of the point bar, and the former high water channel across the middle of the point bar. At the higher and dryer parts the trees stand more apart from each other. Trees in dense bushes are generally younger and smaller (both in height and stem perimeter) than those in more open areas. The false-colour (RGB 432) image of 2000 gives a rather good idea of the tree (and other vegetation) density: the bright red areas are covered with dense forest or other vegetation.

The density of other, smaller vegetation is more difficult to visualize. Areas that look like bare sand on the satellite images sometimes are covered with sparse vegetation (mostly small poplars), sometimes they are really bare. It is also more difficult to describe a spatial tendency. Generally the density of small vegetation in high and therefore dry parts of the area is lower than in low and wet parts.

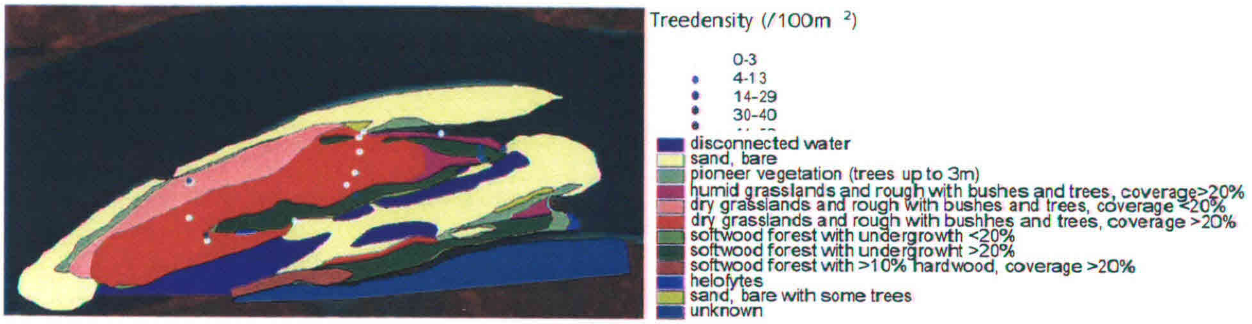


Figure 4-10
Vegetation map of 2001 with tree densities of 2002.

It is clear that vegetation density is very low on morphologically active parts like the high water channel, the beach, the chute bar and the scroll bar; these are sandy areas. In most cases -but not always- dense forest areas have a dense undergrowth also.

5 Interpretation and discussion: development of the Zakrutsky area, mutual influences

Combining all information sources over a number of years shows several morphological and vegetation changes, some of them may influence each other. The typical timescales of these processes range from several years to decades; the time span of interest for the project. Although morphology and vegetation seem to be treated separately, also mutual influences are discussed if they apply. The difficulties in interpreting the available information and their consequences will be discussed in the last paragraph. For a better understanding of the terms used in this and following chapters the glossary in annex 6 may be useful.

5.1 Morphology

5.1.1 From island to point bar

The morphological process with probably the longest timescale is the transition of the island to a point bar. The navigational map (see figure 5-1) of 1940 shows an island, on the 1964 map this island is much larger and has a connection with the solid bank at its upstream side, which is presently the entrance of the high water channel. This means that the study area originally is not a point bar, but the more recent developments (after 1964) can be seen as developments one would expect at a point bar. Therefore the area is treated and referred to as a point bar. In case the term 'former island' is used, only the highest and grown part is meant.

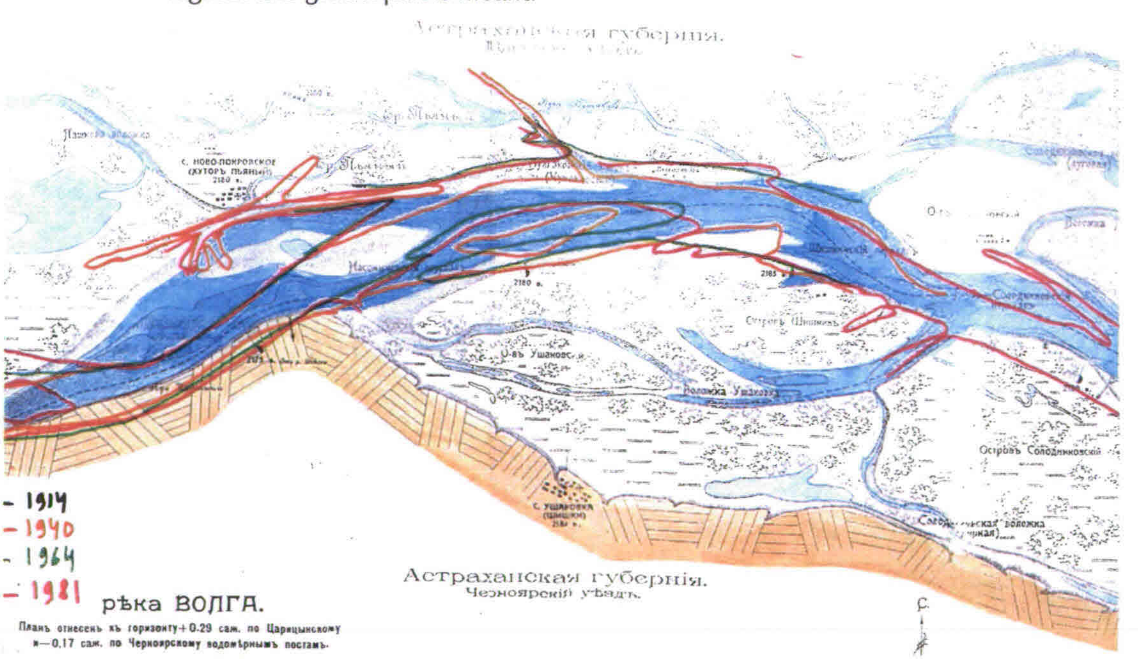


Figure 5-1
Bank contours of several navigation maps plotted on a map of 1914.

A still clearly visible effect of this way of development is the high water channel. This channel was not formed as a cut-off in a point bar, but it is the remnant of the channel at the inner bend side of the former island. This channel is interesting enough to treat separately, which is done in the 'high water channel'-paragraph (5.1.4).

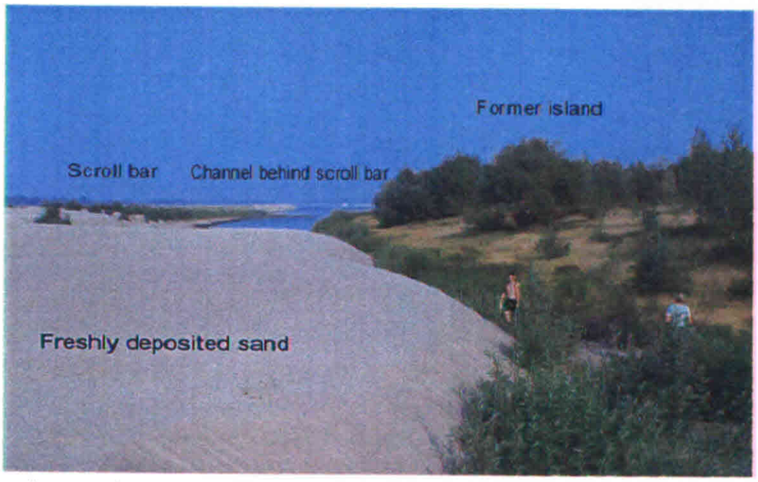
The island itself could have been formed at the location shown on the 1940 navigational map, but it is also possible that it is the remnant of the island on the 1914 map, which migrated downstream. Since this is not much more than speculation, and since it is outside the scope of the current project, this hypothesis will not be discussed further.

5.1.2 The scroll bar and outer bank erosion

The formation of scroll bars can be seen as a cyclic process: the outer bank erodes, the channel becomes too wide, a scroll bar forms which makes the channel too narrow, and the outer bank erodes again quickly. The situation at Zakrutsky seems to be a nice illustration of this process: The channel has become wider since 1964 as a result of outer bank erosion. The 1981 navigation map strangely shows some inner bend erosion that is almost certainly incorrect; see the discussion at the end of this chapter. The 1986 picture shows a very wide channel, with a strange bend at the point bar side. At the leeside of this twist the scroll bar has its origin. After forming the initial part the scroll bar creates its own leeside that causes it to grow further downstream. The scroll bar narrows the profile very much, causing more outer bank erosion than before its formation; 25 m/yr instead of 15m/yr. However, it should be realised that the increased outer bank erosion also can be caused by the slowly increasing curvature of the bend. The bed also is eroded after scroll bar formation: the 1974 navigation map shows a maximum depth of 13 meters close to the outer bank, the 2001 soundings show this is 19 meters.

The shape and location of the scroll bar also cause it to shift to the inner bend: the flow direction is not really parallel to it, but also partly across. This makes the main channel side erosive (because of the powerful flow) and the inner side is filled up because there is a sudden drop in flow velocity. This pattern is clearly visible in the field.

Figure 5-2
Local sedimentation at the upstream end of the channel behind the scroll bar (looking downstream).



The channel behind the scroll bar is gradually filled with new sediment, but mainly at the downstream end. The upstream side is also filled with sand, but this is a very local phenomenon due to the sudden drop in height the flow encounters (see figure 5-2). In the middle part the flow is more parallel to the scroll bar, which results in a more constant velocity and therefore little sedimentation. On the downstream part the outer bank shape directs the flow more across the scroll bar, which causes it to shift towards the inside. The middle part allows vegetation to develop on its leeside: it is sheltered, but not immediately filled with sand. At the upstream end sand slowly covers older vegetation, while at the downstream end the yearly accretion happens too fast for vegetation to develop.

5.1.3 Downstream migration and erosion rates

Like Van de Ven concluded in the 1st (2000) and 6th (2002) report, longitudinal migration and sandbar relocation occurs on the entire Lower Volga River. In the Zakrutsky bend this is also true, though for the downstream sandbar it is

1986

1996

1999

2000 with contours from 2002

Figure 5-3 The changing situation around Zakrutsky 1986-2002.

difficult to see any movement; it is only accreting, see figure 5-4. This might be a result of the changing flow direction due to the erosion of the outer bank. Positioned on a riffle, the upstream bank moved around 200 meters per year. This is likely to change now it has reached the pool and the cross-sections narrows. The sand bar also influences the flow across the point bar.

The first report by Van de Ven (2000) also contains an analysis of migration rates related to the curvature (radius over width) of 25 bends along the Lower Volga River. The Zakrutsky bend has a radius of about 4 kilometres and a mean width of 1 about kilometre at low discharge; the corresponding r/w ratio has a value of 4, which means it is a rather flat and therefore slowly migrating bend.

Estimating eroded areas from the satellite images (see figure 5-3) and measured contours give an erosion of the high and vegetated outer bank of 77 hectare in 16 years (from 1986 until 2002), while the upstream part of the point bar eroded about 14 hectare. The scroll bar and chute bar accreted 52 and 29 hectares respectively, and the middle of the point bar accreted some 4 hectare. The filling up of the wide downstream part of the high water channel is not taken into account because this is already very shallow on the 1986 image. With 91 hectare of erosion and 85 hectare of accretion the migration seems quite balanced, but this is only two-dimensional.

The rates mentioned above are measured in an area of 1282 hectare (that is used during high discharge), which means that 7.7% of this area is eroded in 16 years. This is a yearly erosion rate of 0.48% or 5.7 hectare (at a local maximum of 19 m/yr). Compared with the average of 40 m/yr or 5.9 hectare/yr Van de Ven (2000) calculated this is a little lower, but similar to bends with the same r/w ratio.

5.1.4 The high water channel

The origin of the high water channel probably is the channel at the inner bend side of the island in 1940. When the outer bank eroded, more water went through the outer bend channel, which caused sedimentation in the entrance of the inner bend channel during low discharges. In 1964 or earlier the island was connected with the mainland. The maps of 1974 and 1981 do not tell anything about this area since it is insignificant for navigation. The 1986 map shows a narrow high water channel, with wet sand at the entrance. Probably the main flow during high discharge follows the outer bend because in 1986 this is at its widest. After formation of the scroll bar the main channel width is much smaller, which causes more water to flow through the high water channel during high water. At the same time the point bar becomes more vegetated, which also concentrates the flow in the high water channel. Because of this higher discharge, the first part of the high water channel is eroded. In the second half however sedimentation takes place because the cross-section is much wider, therefore flow velocity is lower. In recent years the entrance seems to accrete again, however this can not be concluded from pictures alone since the water level during measurements is unsure. Nevertheless, the

Figure 5-4
The high water channel; looking southwards.

Figure 5-5
The sanded entrance of the high water channel; looking in south-west direction.

sedimentation pattern in figure 4-7 supports the idea it is accreting: deposits of earlier dunes are covered by newer ones. An explanation of this accretion could be the outer bank erosion: the main channel is getting wider again and takes a bigger part of the discharge, which decreases discharges and flow velocities trough the high water channel. Nevertheless still a lot of water flows trough the high water channel, otherwise it would not be as dynamic as it is now, and there would not be that much sedimentation at the chute bar at its end.
Flow velocities in the high water channel are too high for vegetation to grow for more than one or two years, though at the borders of the wider part of the high water channel it may stand a chance. At the leeside of the chute bar some vegetation developed, but this is gradually covered with sand.

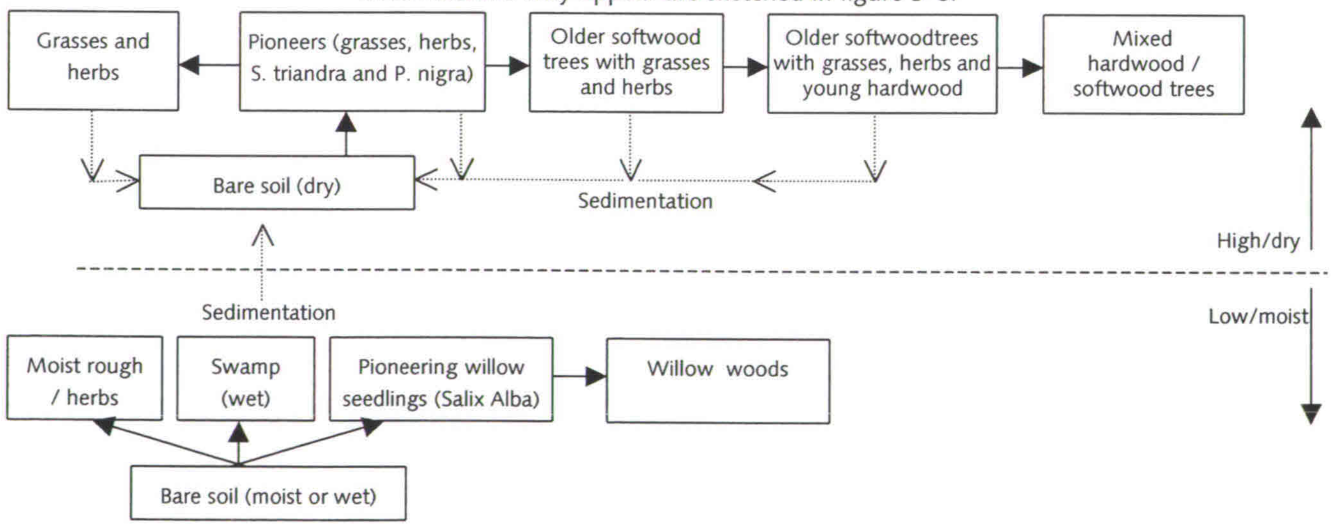
5.2 Vegetation

Vegetation patterns are studied for two reasons: vegetation is of ecological interest, and vegetation has an influence on the flow and morphology. Since vegetation changes every year –this process is called succession-, these changes and the rate at which they take place are important to study as well. Therefore the succession mechanisms at Zakrutsky in general are treated first, followed by a few examples in particular. The paragraph ends with describing the influence of vegetation on morphology.

5.2.1 Succession

The vegetation in the Zakrutsky area shows different succession mechanisms, depending on the circumstances at the particular location. An important factor determining these circumstances is the height of the terrain; this not only determines whether the soil is moist or dry, but it also influences the inundation time and the amount of sand deposited during floods. The boundary between high and low can differ locally, but generally it seems to be around 4 meters above summer water level, judging the vegetation species and the amounts of sand deposited. The different stages of succession and under which circumstances they appear are sketched in figure 5-6.

Figure 5-6
Vegetation succession schema of the Zakrutsky area.



Vegetation development starts on bare soil at places where flow conditions and sedimentation rates allow for it (see 5.2.3). The first vegetation can be grass and herb pioneers or softwood seedlings. These pioneers may develop into a more mature vegetation stage, which is depicted by horizontal arrows in the scheme. An other possibility is that they become sanded in; this is indicated by vertical arrows. Sedimentation provides an opportunity for new pioneers to germinate on the fresh bare soil. Therefore it allows other species to develop too: Without sedimentation grasses and herbs can become very dense, which tempers succession because it is very difficult for trees to germinate between them.

In low areas, e.g. near the waterline, the bare soil on which the succession cycle starts is moist or wet. On the wettest areas swamps can develop. Swamps are not succeeded by trees because they are too wet, unless accretion occurs and the soil becomes dryer. On moist areas herbs and grasses or *S. alba* seedlings may germinate (see 5.2.2.). The willow seedlings can develop into willow woods. Sedimentation raises the ground level, allowing more 'dry' species to develop.

On higher areas, e.g. on the scroll bar or the smaller deposits on the former island, the bare soil is dry. Here pioneers are dry grasses and herbs or seedlings of poplars and *S. triandra*. These softwood species germinate more spread out over the area than the *S. alba* on the low area, thus leaving room for other vegetation. This other vegetation can be grasses and herbs or younger seedlings.

In case of little sedimentation open grasslands can develop, otherwise grass is buried by sand, allowing younger softwood seedlings to germinate. In case of severe sedimentation, young trees can be covered with sand, thus stopping their development. After years, older softwood trees (25-40 years old) reach the end of their lives and die. Their place can be taken by younger softwood or hardwood trees, which are present after about 20 years. More about rejuvenation can be found in 5.2.4.

5.2.2 Dense willow woods near waterline

The 1986 image in figure 5-7 shows a wet area with some vegetation around it halfway the high water channel. On the 1996 image part of this area is still wet, but vegetation has developed around it on sheltered places. Closer to the high water channel (less protected) it remains sandy. In 2001 only a small lake is left, which cannot be seen on the 2000 or 1999 images. In 2002 this vegetation has developed into dense willow woods. No trees are dated exactly in this area however, so dating the emergence is not possible. Nevertheless it is an indication that dense willow woods develop on rather low areas close to the low water waterline. An other indication is that the other willows in the area are also found in dense rows parallel to the waterline. This probably is a result of the favourable germination conditions there at the end of a high water period: the soil is moist and contains some clay (still waters), and the seeds are deposited on the right place at the right time.

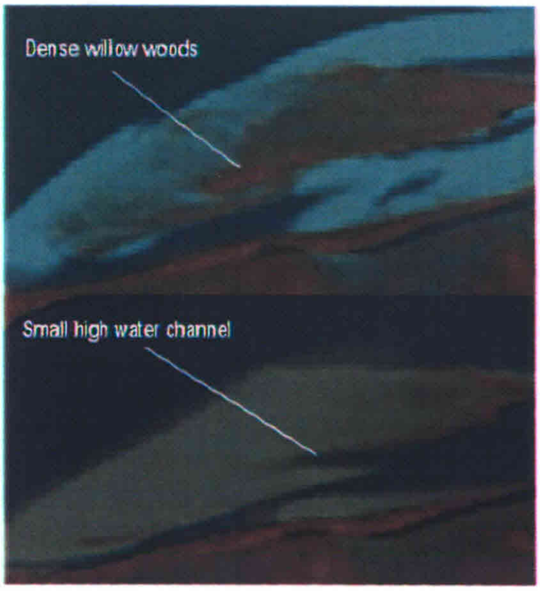


Figure 5-7
The 2000 Landsat image (upper) shows dense vegetation at the location of the former high water cahnnel on the 1986 image (lower).

5.2.3 Young vegetation on fresh soils

On three places very young (<5yrs) vegetation only is found: the inside of the scroll bar, the south side of the chute bar and in the high water channel. The vegetation in the high water channel (mainly poplars) only grows on the sides, and it is not older than 1 or maybe 2 years. This vegetation probably will be removed by an average high discharge; otherwise the high water channel would have been gradually filled with vegetation by now since this kind of young vegetation will come up regularly.

On the chute bar the vegetation (mainly willows) is a little older (up to 3 to 4 years; not measured), and grows on a wet and more or less sheltered area behind the steep edge of the bar. In this case it might be the beginning of a longer lasting vegetation like the vegetation developing on the south side of the scroll bar. Mind that the soil these trees grow on is also very young; it starts to form on the 1996 image, the 1999 image shows some vegetation but most of this is covered with sand by now. This is also an example of dense willow woods developing close to the waterline.

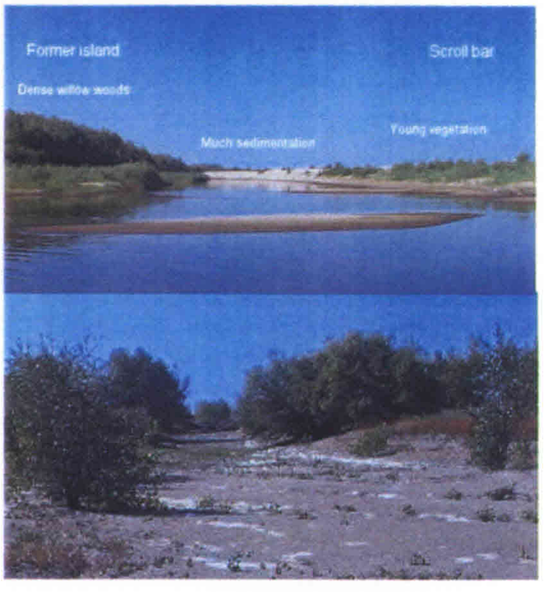


Figure 5-8
Examples of young vegetation on fresh sand: the scroll bar (upper) and a small channel on the former island (lower).

The vegetation on the south side of the scroll bar is a mix of willows and poplars. Here also other plants start to grow. The oldest trees here might be a little older than 5 years since their age is estimated based on their size only. The vegetation cannot be seen on the satellite images because it is only a small area; this makes it for this location impossible to say when vegetation started to develop on fresh soils.

On the former island also young vegetation on freshly deposited sand is found, but –unlike the cases mentioned above- here also older vegetation is present. Relatively small amounts of sand are deposited on top of existing vegetation like grasses and herbs. Normally the existing vegetation prohibits the growth of new seedlings, but the fresh sand gives them a chance.

In all these cases young vegetation is present at locations that receive new sediment (almost) every year. Under sheltered conditions vegetation can develop very quickly.

5.2.4 Rejuvenation

On the point bar not much vegetation rejuvenation seems to happen yet: probably most trees are still too young to die, and there is little erosion of vegetated areas. New trees do appear however, but only in relatively open areas on the point bar and on fresh sediment.

On other places trees are removed, whether because they have reached the end of their lives or because the area around them is eroded. The latter is the case at the outer bank and at the banks (mainly the right bank) of the high water channel. These woods are also old enough to see young trees appear underneath the older ones massively, and some hardwood can be found. The latter is only the case in higher and therefore dryer areas.

5.2.5 Influence of vegetation on point bar development

There might be a connection between outer bank erosion and vegetation development on the point bar. Before the outer bank is eroded, a lot of water flows across the almost bare point bar; conditions are too severe for vegetation to develop. Only sheltered and high areas allow vegetation development. During the years (approximately 1940-1980) the outer bank is eroded, and the main flow becomes more and more concentrated on the left bank. Flow velocities across the point bar become lower, accretion takes place and vegetation can survive. Here the interaction between vegetation and

morphology becomes clear: the partly vegetated point bar lowers flow velocities, which causes accretion on the point bar. The accretion raises the point bar, which protects the vegetation.
According to the limited information it can take decades for this process to get going, but after a few successful years (approximately around 1985) of accretion and vegetation growth it can gain momentum because the developments amplify each other. After a few years (from about 1995) the process slows down because a large area of the point bar is covered with vegetation. The majority of trees on the point bar are aged between 6 and 16 years, which corresponds with the period from 1985 to 1995. Older trees are only found on protected areas: the edge at the south side of the high water channel and amongst other vegetation at the east side of the point bar, see also figure 4-8.
In 2002 the traces of the still ongoing process of mutual accretion and vegetation can be seen in the field. The point bar is crossed by several smaller high water channels, which transport new material onto it. On this fresh sand young trees (mainly poplars) develop, which makes that trees of different ages can be found here (figure 5-8).

5.2.6 Influence of vegetation on scroll bar development

The trees on the point bar can also affect the development of the scroll bar. There are two theories about this: The first is that more accretion occurs because the vegetation causes a lower flow velocity. The second hypothesis is that the vegetation pushes the flow more towards the outer bend, causing more outer bank erosion and thus scroll bar formation. Which of these mechanisms is representative will be studied in the DUT thesis.

5.3 Discussion

Linking water levels with pictures

The accuracy of the waterline contours not only depends on the known GPS-error (15m), but also on the unknown water levels. On some places (e.g. the scroll bar) the transition from wet to dry is quite steep so the error will be small. On other areas however (e.g. the west side of the point bar) the beach has a much smaller slope and errors will be larger. In general however the trends in erosion and sedimentation are clear, it particularly affects the accuracy of the erosion/sedimentation rates.

Ice

Since the Volga River is regularly covered with ice, this will have its influence on the area. For example, ice can disturb 'normal' vegetation development, or even remove vegetation. According to local sources however, ice does not affect vegetation very much in this area since the water level in winter is below all vegetation. Therefore ice-effects are not taken into account.

Accuracy of navigation maps

Like mentioned earlier the information on the navigational maps about bank positions and what is on the banks is unreliable. The 1981 map for example shows a very illogical movement of the downstream side of the point bar: it is located more towards the inner bank than in earlier and later years, and it seems impossible to change the position in such a way in only five years. Probably the position of the outer bank (which is at the same location as on the 1964 map) was taken as a constant while making the map, and the main channel was found to be wider than in earlier years. This made the mapmakers draw the point bar further away from the outer bank, i.e. closer to the inner bank.

Correction of satellite images

Although the satellite images are corrected and seem to be on the right coordinates now, there still might be some errors in the positioning. The first reason for this has to do with the resolution: it is not possible to pinpoint them on the meter, but with interpretation of the pixels themselves an accuracy of about 15 meters is reached. The second reason is the lack of reference points like crossings etcetera. Now the morphological contours had to be used, and though the used points seem to be on a hardly dynamic area, this might introduce an error as well.

Choice of auged trees

Due to the fact that auging concentrated on old trees, very little young trees on morphologically young areas are dated. This hampers a good estimation of the lag between morphological and vegetation development.
One should also realise that though the research team especially searched for old trees some of these may have been overlooked given the circumstances (a large, sometimes densely vegetated area and limited time).

Visibility of vegetation

Not all vegetation that is found on the ground can be seen on the satellite images. There are two reasons for this. First, the resolution of the images is rather low, so small vegetated areas or single trees are overlooked. Second, the pictures are taken in different times of the year. The 1986 image for example was made in September, whereas the 1996 image was made in June. Sparsely vegetated areas or areas with dried-out vegetation may reflect to little to be noticed.

Age of vegetation

The auging data show no trees from before 1979 on the flooded areas, while especially has been looked for old trees. The 1974 navigational map however shows trees on many locations of the point bar. This can be a mistake of the map, since hardly any remains of very old trees (debris) were found. However, the single old willow found at the high edge on the north side of the high water channel could be a remnant of a willow bush near the waterline. Its rotten year rings made it impossible to auge, but these are an indication for an age of 30 to 40 years. The presence of this old tree could also mean that a cycle of rejuvenation already did take place: Sedimentation occurred, the willow(s) died and young poplars germinated on the higher soil. Another possibility is that the lowest and therefore oldest parts of old trees have been sanded in several meters. In this case the auging is made at a high and young part of the tree, thus underestimating the age of the tree.

6 Results Akhtuba

Like the chapter dealing with the results of the fieldwork at the Volga River, this chapter presents the results obtained during the fieldwork at the Akhtuba River. First morphological observations are presented, followed by the results of the vegetation studies. The results are interpreted and discussed in the next chapter.

6.1 Morphology

The morphology at the Akhtuba River is studied by levelling cross-sections every kilometre, sounding, satellite image analysis and by looking around in the field.

6.1.1 Levelling and sounding

The levelled profiles are presented in annex 1b. The length of the profiles depends on the terrain: all profiles are levelled from the waterline to the high water edge wherever possible; sometimes fences or very dense woods prohibited measurements. Figure 6-1 displays the locations of the levelled profiles, together with the soundings. The average depth of the Akhtuba River is estimated using these soundings, for the depth during floods also the flooded area and flood traces are taken into account. The depth seems to be slightly less than 2 m during low discharge, and about 5 m during floods.

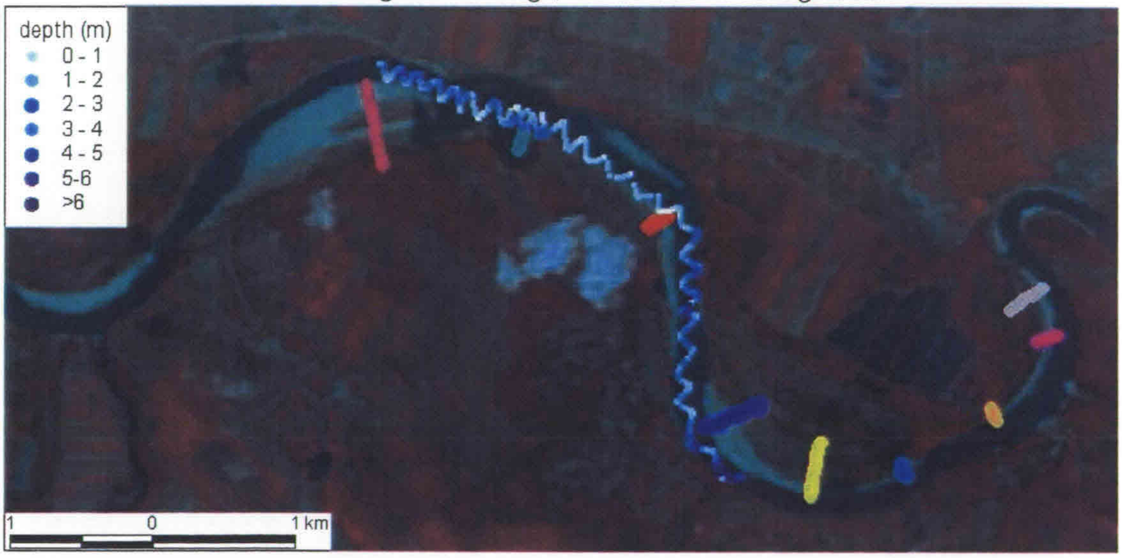
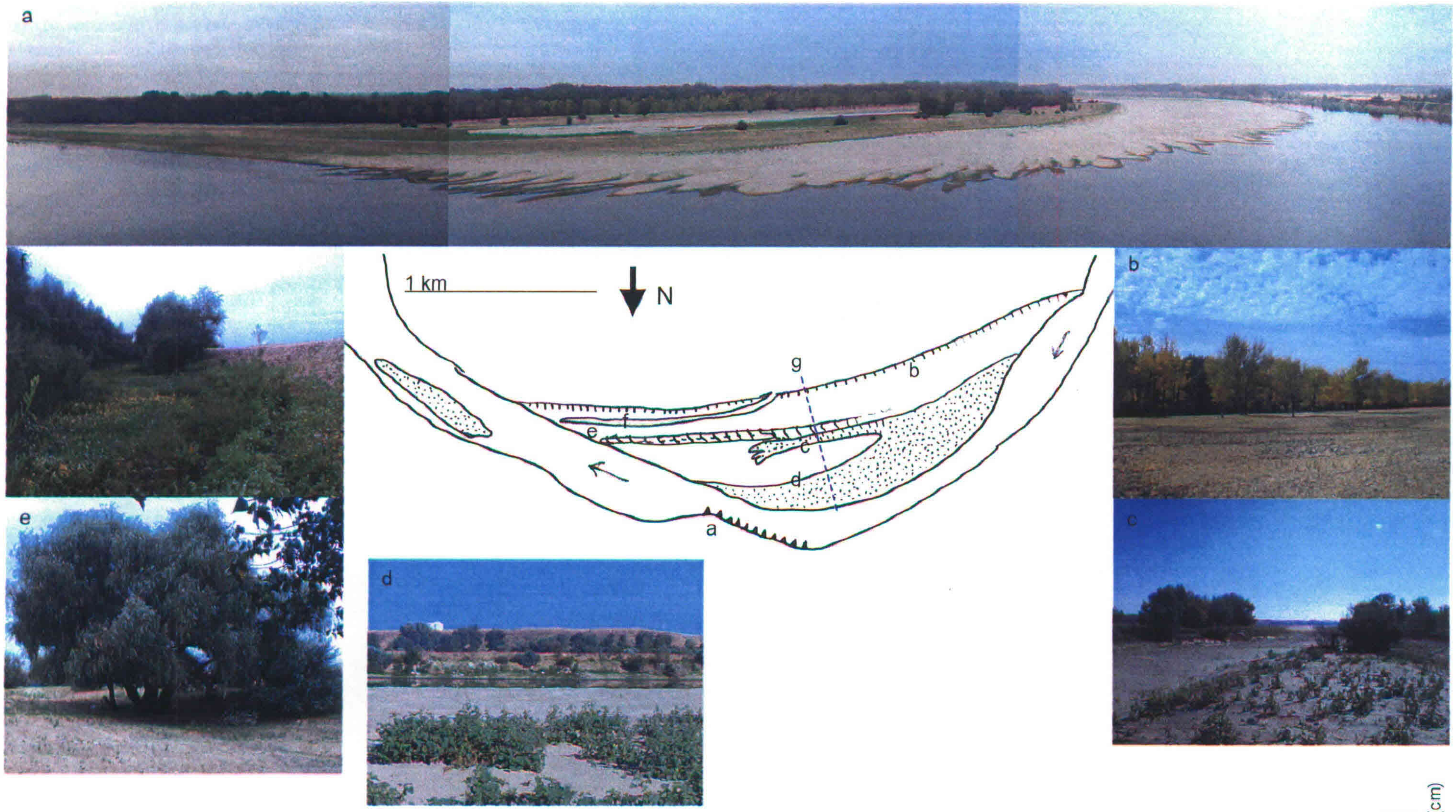


Figure 6-1
The soundings and levelled profiles in the Akhtuba research area on the 2000 Landsat image. They are numbered 1-9 from left to right (downstream). The camp at Veterok is situated close to the second profile.

6.1.2 Estimated erosion rates

The research of Van de Ven (2002) gives some idea of the erosion and sedimentation at the Akhtuba (see figure 3-5), but due to the low resolution it is impossible to measure this accurately. Some parts of the river seem inactive; others eroded or accreted about one pixel (30 meters) from 1986 to 2000, which comes down to a rate of about 2 meters per year. The methods used in the field are also rather inaccurate. The yearly bank retreat at a steep bank in the western part of the research is estimated area at about 1-2 meters per year; in areas with lower banks this might be more. Locals however have a different opinion; some of them talk about 30 meters per year, which certainly is not the case. The estimations are made based on the remains of human activities and



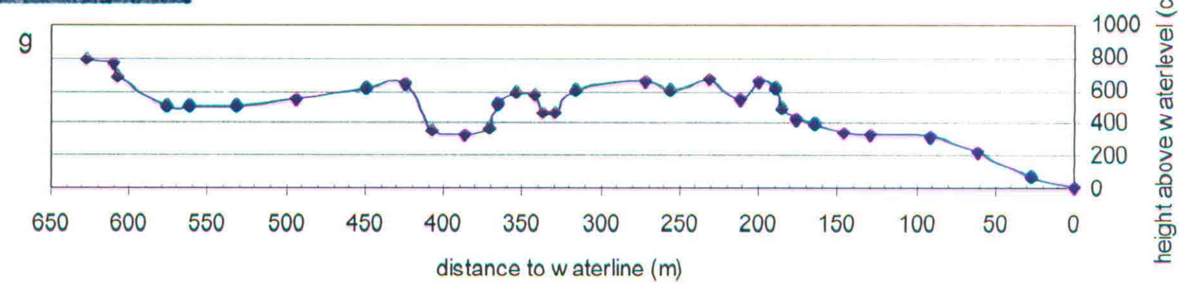


Figure 6-2 An overview of the research area near the camp at Veterok.

a) An overview picture taken from the cliff.
b) Short grass and older trees, grazed.
c) The chute channel with fresh sand and Xanthium.
d) Looking north towards the cliff.
e) Old willow, at least 42 years.
f) Moist high water channel
g) Levelling profile no. 1.

vegetation on the eroding banks, and the amount of recently accreted soil at the opposite bank, which should have the same order of magnitude.

6.2 Vegetation

Vegetation is recorded at two cross-sections in detail (numbers 1 and 4). For an over-all idea of the vegetation in the area photos and sketches are made, see figure 6-2.

6.2.1 Species, location and age of vegetation

Rendering the vegetation in two of the levelled profiles show different stages of development on the point bars: the trees on the older and higher inner bend side are older, and towards the waterline both surface level and vegetation age decrease. The areas near the waterline are sandy, with *Populus nigra* seedlings or *Xanthium*. Farther inland more grasses and herbs are present, as well as *Salix triandra*. Here also some specimen of hardwood (*Fraxinus langustifolia, Tamarix*) are found.

Most of the vegetation found at the Akhtuba is rather dry. Only in the high water channel near the camp at Veterok 'wet' vegetation is encountered. Unlike the Volga research area, no rows of dense willow woods have been found.

6.2.2 Grazing

Some parts of the floodplain are used as pasture land. The effects of this use are clearly visible: the grass is very short and other vegetation –apart from older trees and *Xanthium*- is almost absent, like in a park. Vegetation in non-pastured areas is more diverse; here also pioneering trees are present.

7 Interpretation and discussion : point bar development at the Akhtuba River

For the Akhtuba River there is no field information other than the results of this fieldwork, therefore interpretation is more limited. This chapter first deals with morphological subjects; after that vegetation is interpreted, followed by a discussion in the last paragraph.

7.1 Morphology

7.1.1 Point bar activity

Although the Akhtuba River at first seems little dynamic at the moment, there are several signs of recent morphological activity during floods. The sandy areas with small dunes near the waterline are one of these signs of activity; without a fresh supply of sediment every year they would have been vegetated. Also the chute bar near the camp at Veterok is such a sign: fresh deposits of sand are clearly present, partly bare and partly covered with pioneers (figure 6-2). Of course the erosion of the banks is also a demonstration of its current activity.
The levelling profiles also indicate morphologically active point bars: Starting at the waterline, they become gradually higher towards the oldest part. Lower parts like high water channels show recent sand deposition; higher parts are completely vegetated.

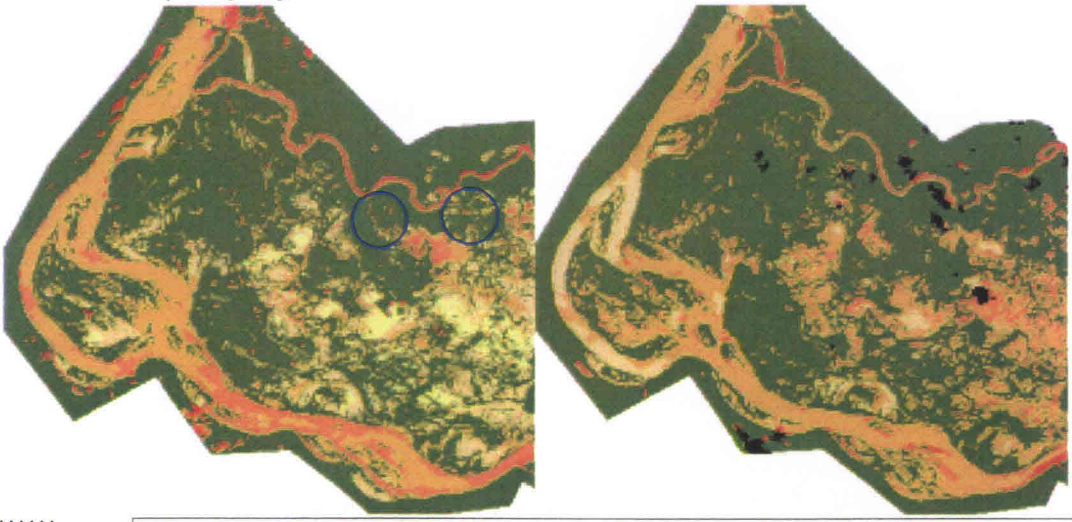


Figure 7-1
Flooded areas in 1985 (left) and 2001 (right). The black spots are clouds. After Van de Ven (2002).

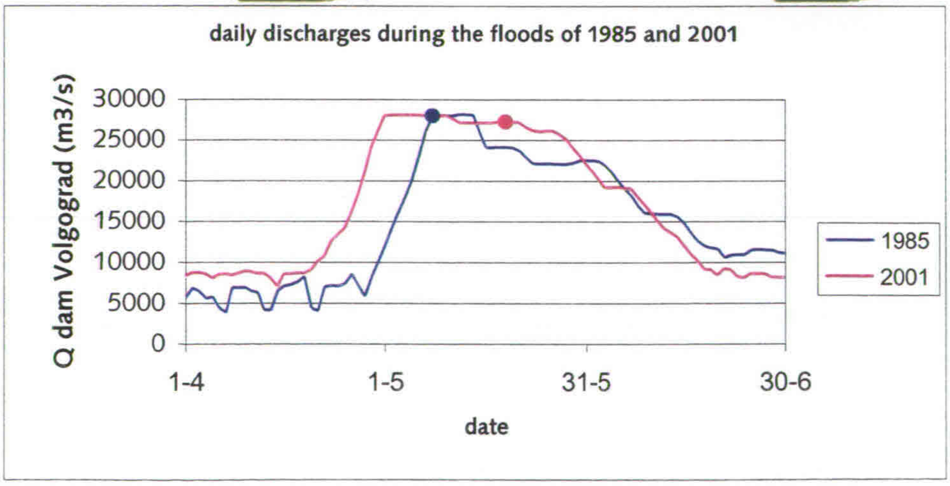


Figure 7-2
The discharges at Volgograd of the floods in 1985 and 2001. The dots indicate the days the images were made.

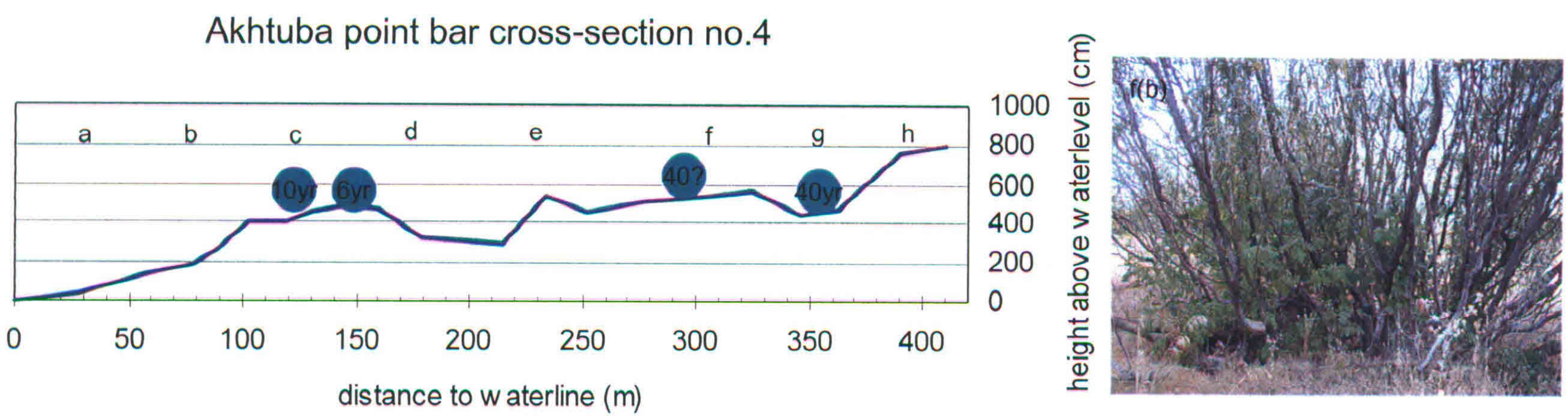


Figure 7-3 Different vegetation ages across a point bar at the Akhtuba River. Picture f(b) shows young hardwood developing between the stems of an old willow (*S.triandra*).

7.1.2 Adaptation to lower discharge

Analysis of the high water images of 1985 and 2001 shows that some small branches in or close to the research area are not flooded in 2001, while they were in 1985; see figure 7-1.

This smaller flooded area could be a sign of incision, but it could be a result of a lower discharge as well: The 1985 image was made at the beginning of the flood peak, with a discharge of 28.000 m3/s, whereas the 2001 image was made after passage of the peak, at 27.000 m3/s (the maximum discharge in 2001 was 28.000 m3/s).

According to Babich (pers.comm.) and the geomorphological map (MSU and RIZA, 2002) however, some of the high areas next to the river belonging to what is called the Volga-Akhtuba Floodplain are not part of the present floodplain anymore: These are Holocene remains that indicate incision on a geological timescale. Besides, these areas are represented on the ecological map (RIZA and the State Committees for Natural Resources of Astrakhan and Volgograd Oblast, 1999) as 'naturally dry'. Therefore the fact that the highest flood traces are found below the level of the adjacent area does not necessarily indicate incision. The use of the term 'floodplain' is a little confusing.

The deep position of the Akhtuba River can also be a result of dredging activities for shipping in the Soviet-period, in combination with incision of the Volga River. Because the much larger Volga River transports more sand, its incision rate close to the dam probably is higher than that of the Akhtuba River. Now dredging has stopped, the incision of the Volga River cannot be followed anymore, thus decreasing the amount of water that is diverted to the Akhtuba River. However, definite signs of incision of the Volga River were not found. Shoubin and Babich (Eds., 2001) explicitly mention that the power station hardly affected the water levels, but at least there is a daily fluctuation. More comprehensive data about water levels, inundated areas and more time might provide more insight in this matter.

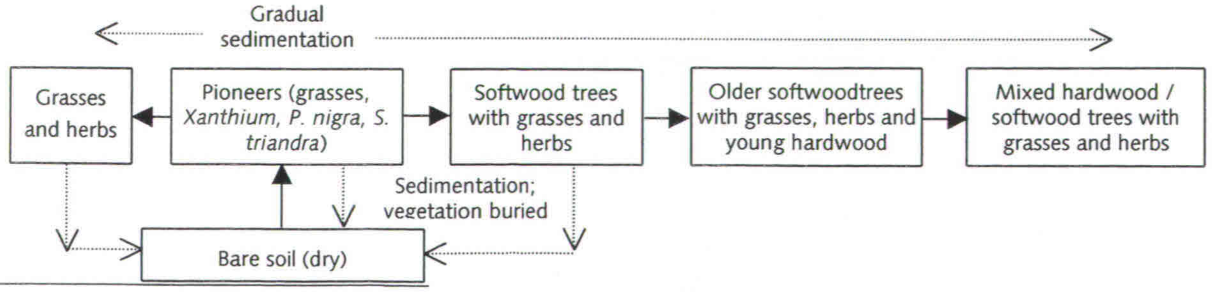
The decreased discharge of the Akhtuba River shows itself in two ways: On the most recent satellite images it shows more meanders on a smaller scale than it did on the oldest one. Smaller meanders indicate a lower discharge. Furthermore, the discharge data of around 1960 show an average discharge of around 180m^3/s, while more recent reports (Shoubin and Babich, Eds., 2001) mention around 100m^3/s.

7.2 Vegetation

As can be seen in the profile in figure 7-3, the vegetation generally becomes older when the distance to the waterline increases. At the lower areas, where the most sediment is deposited, young poplars and other pioneers can be found. Higher areas are covered with grasses and herbs; older trees are present here. Unlike the Zakrutsky area, very little pioneers can be found between this older vegetation; the landscape is more open. This can be due to the fact that there is less sedimentation in these areas, hence pioneers cannot germinate, or by grazing, causing seedlings to be eaten.

The succession scheme at the Akhtuba therefore is a little different from that at the Volga: the rejuvenation by sedimentation mainly happens in the lower areas, the vegetation on the higher areas generally just becomes more mature. Apart from this difference, the succession scheme (figure 7-4) is very similar to that of the higher part of Zakrutsky.

Figure 7-4 Vegetation successioin scheme of the Akhtuba point bars.



It is difficult however to determine the time it takes for a certain stage to develop: the amount of tree-augings is very limited, and the satellite images cannot provide much information on such a small scale due to their resolution.

7.3 Discussion

Lack of discharge data

The absence of discharge data about the Akhtuba River is a major drawback in interpreting and comparing river characteristics. It is certain that the discharge regime has changed the past forty years, but this is not quantifiable. Since the discharge affects morphology and vegetation, interpretation (especially concerning the adaptation of the floodplain to a different discharge) is not complete without it, and comparison with other rivers lacks a hydrological basis.

Accuracy of erosion estimations

The resolution of the satellite images is simply too low to obtain reliable erosion rates from them. Therefore GPS-field measurements or –preferably- aerial photographs are necessary. The possible inaccuracy of GPS-equipment (15 m) can be a problem as well.

History

The information about vegetation (augings) and morphology (pictures) in earlier years is very limited. The time things need to develop therefore cannot be estimated, and thus interpretation is practically limited to a rather static description.

Few trees dated

Since the dendrochonological part of the research concentrated on the Volga River, only very few trees are dated at the Akhtuba River. This is not problematic because patterns of vegetation were studied, but nevertheless more detailed information about tree ages could have added to the results.

Less natural

One of the shortcomings of the Akhtuba River as a natural reference river is that it has quite a lot of man-made structures in its vicinity. Though the research area is selected on the absence of villages, still some holiday parks, irrigation pumps stations and their accompanying bank protections were found. These are all quite small, and therefore they probably cause only local effects. The effect of the dam however cannot be neglected; it seems that its influence is larger in this smaller river than it is on the large Volga River.

Inundation by groundwater flow questionable

Report no. 6 (Van de Ven 2002, p. 9) concludes that large parts of the Volga-Akhtuba floodplain are inundated by seepage water instead of flooding. Indications for this conclusion are the absence of connections between wet areas on the satellite images, and the low turbidity (low flow velocity) in the wetted parts. However, this conclusion is highly questionable: The soil needs to be very permeable to allow the water to travel over distances up to 15 kilometres in only a few days under a very small gradient. Besides, many small channels were seen during the fieldwork. These channels might be too small or hidden away by a vegetation roof to be seen on the images. Many of them are also lined by vegetation, and since they are small and the hydraulic gradient is small as well, stream velocities and therefore turbidity are probably low.

8 Comparison of Volga, Waal and other rivers

In order to make the results of the studies at the Volga and Akhtuba River applicable to the Dutch Waal River, their hydraulic characteristics are compared. Because it is already clear that these rivers are very different and thus a direct comparison is impossible, another river is observed as well: the Allier River in France. Together Volga and Allier Rivers form the borders between which the Waal River might behave.
This physical comparison is made in the first paragraph, followed by a comparison of factors influencing vegetation succession in the second paragraph. Since the planform of a river in the Netherlands not only depends on its physical characteristics but more on the river management, this management is discussed in the third paragraph.

8.1 Physical comparison

8.1.1 Choice of comparison rivers and discharges

Van de Ven (2000) already made a comparison between Volga, Waal and Allier Rivers based on parameters considering sediment transport capability and migration rate. This analysis however is for the entire Lower Volga River. Since the river has a different character in other parts, the average values found are not directly applicable to the Zakrutsky bend and its vicinity. The figures of Schoor and Middelkoop (2001) for the upstream part of the river are already better, even though these are based on rough estimations. The current parameter comparison also includes the Akhtuba River and a side-channel of the Waal River near Gameren –one of the locations where the Waal River is left some room. Also the Waal River of 1800 is used as a historic reference; it indicates the potential of the current Waal River in case of a less normalized situation. Only the northern part of the Allier River is used, because the southern (upstream) part is too much of a gravel-bed river to be comparable: the sediment is much coarser and the gradient is around ten times as high.

Generally, the bank full discharge is considered to be representative for the morphological activity. However, comparing the bank full discharge only would be wrong since especially changes in water levels and discharges are important for morphological and particularly ecological processes.
For the Waal River, its side-channel and the Allier River, the bank full discharge is used. For the Russian rivers an average of the yearly high discharge is used. For all rivers applies that the used discharge occurs about every one or two years. The bankfull discharge that can be calculated for a cross-section of the Russian rivers is not representative since the discharge is regulated: A bankfull discharge is considered to be reached about every two years, but on the Russian rivers it is exceeded for several weeks every year. Van de Ven (2000) estimates $Q_{bankfull}$ at about 12.000 m^3/s using calculations of cross-sections, while normally around 25.000 m^3/s is reached every year.
For the less regulated rivers the bank full discharge is a more extreme event, which may cause a slight overestimation of their dynamics with respect to the Russian rivers. However, since the high discharge used for the Russian rivers is higher than the calculations based on cross-sections indicate, the activity of the Volga and Akhtuba Rivers may be overestimated as well. With a discharge of 24.000 m^3/s for the Volga River probably a usable comparison can be made.
Comparing dynamics parameters

Tables 8-1 to 8-3 compare several representative parameters of the rivers. The first table gives some general parameters. The second and third deal with the circumstances during average and high discharges respectively. The three parameters that measure dynamics are the width/depth-ratio, the stream power and the Shields parameter. These dependent parameters are marked grey in the tables and used for the graphs in figure 8-1. It should be noted that for every river the values of only one location are used. These do represent the order of the parameters, but not the variety along the river; the points in the graphs should be looked at as clouds to see this variety.

Interpreting the tables the following explication should be taken in mind:

- The data about discharges and flood durations are not statistically correct; they are just meant to give an approximation;
- The mean grain size is the mean grain size of the main channel;
- The migration in meters per year means erosion measured at the maximum points of erosion in bends. In hectares per year it displays all erosion in a bend;
- N.a. means not applicable

Table 8-1
General parameters of the comparison rivers.

General	Akhtuba	Volga Zakrutsky	Waal 1800	Waal 2000	Gameren side-channel	Allier North
flood duration (days)	40	40	10	10		
$Q_{high}/Q_{average}$	9	3	1.7	1.7		6.9
gradient (10^{-5})	4	4.5	13	11	12	5.4
mean grain size (mm)	0.4	0.4	0.9	0.9	0.5	4.8
migration (m/year)	2	19		n.a.		
migration (ha/year)		5.7	9.2	n.a.		

Table 8-2
Comparison at average discharge.

$Q_{average}$	Akhtuba	Volga Zakrutsky	Waal 1800	Waal 2000	Gameren side-channel	Allier North
Q (m^3/s)	100	8000	1500	1500	12	130
mean depth (m)	2	8.6	3.2	7.4		
width (m)	145	1200	540	260		
mean width/depth ratio	73	140	169	35		
stream power (W/m^2)	0.27	2.9	3.5	6.2		
Shields parameter	0.12	0.58	0.27	0.52		

Table 8-3
Comparison at high discharge.

Q_{event}	Akhtuba	Volga Zakrutsky	Waal 1800	Waal 2000	Gameren side-channel	Allier North
Q (m^3/s)	900	24000	2600	2600	73	900
mean depth (m)	5	10	4.8	8.4	2.5	3.2
width (m)	280	1680	587	323	65	158
mean width/depth ratio	56	168	124	38	26	49
stream power (W/m^2)	1.3	6.3	5.6	8.7	1.3	3.0
Shields parameter	0.29	0.67	0.41	0.59	0.34	0.022

Data about the Russian rivers result from the fieldwork or literature mentioned earlier. Parameters of the Dutch rivers are taken from Schoor (2003, in prep.). The data about the Allier River are from Wilbers (1997) and Van de Ven (2000).

The figures show that the Volga River is a river with large dimensions, which has high flood discharge, a very low gradient and the sediment grain size is small. The latter results in a high Shields parameter; the sediment is easily transportable. The width/depth ratio of the Volga River is high compared to the Waal River and the Allier River, due to its very large width. A large width/depth ratio means a dynamic river. But also due this large width, in combination with its small gradient, the stream power of the

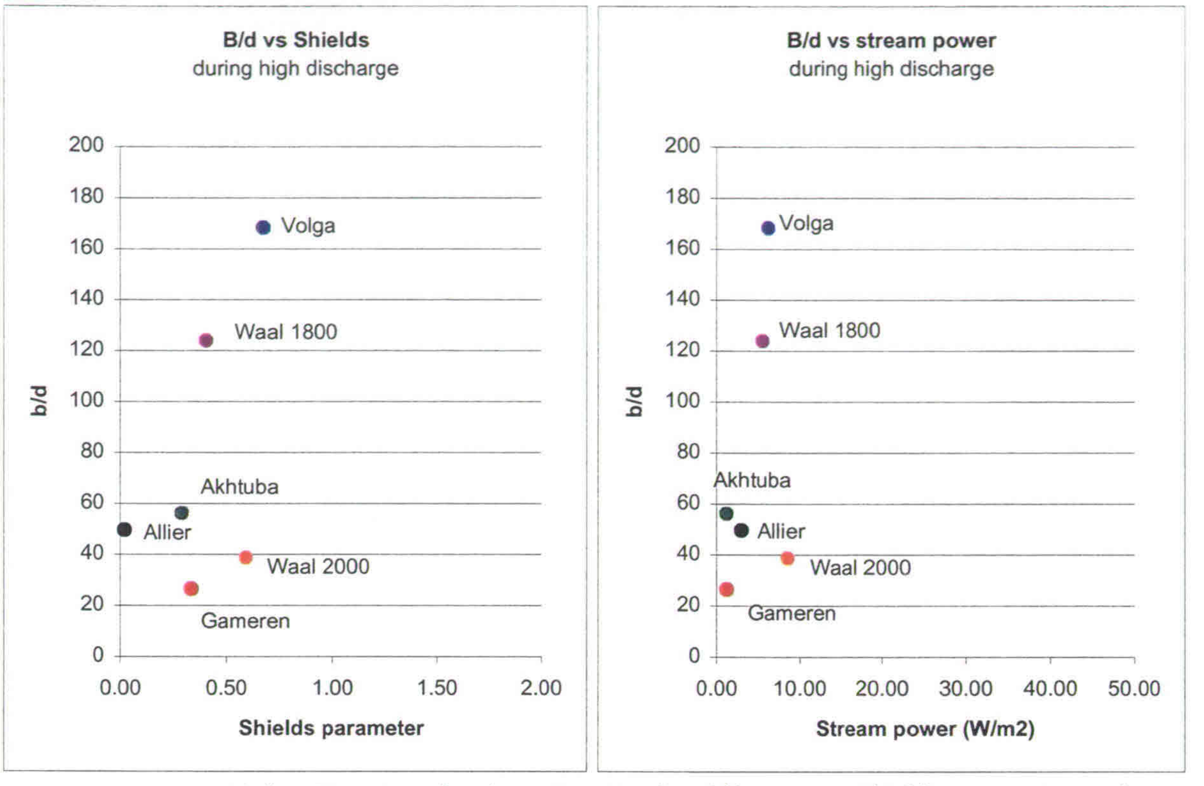


Figure 8-1
Representation of parameters showing the differences and similarities in dynamism of the compariosn rivers.

Volga River is rather low. Despite the difference in Shields parameter and its slightly higher w/d-ratio, the Volga River is very well comparable with the historical Waal River from around 1800. Overall this Waal River from around 1800 fits nicely between the boundaries of Allier and Volga Rivers.
The Akhtuba River is comparable to the current Waal River concerning the width/depth ratio, but it has much lower stream power and Shields parameter. These are more similar to the Gameren side-channel.
An important difference between the Volga River and the Waal River is the discharge regime: the Russian river has a regulated discharge, with every year a high water of more or less equal height and duration. The Waal River is less regulated, and yearly variations are larger. This will have its influence on the rate of morphological processes: the Volga River shows more constant rates, whereas in the Netherlands little may change during several years, followed by a quick change. Averaging rates over several years not completely overcomes this drawback, since morphological and vegetation processes are not linear. What happens in the time between high discharges is also important; pioneer vegetation for example may get the chance to develop in a few quiet years, after which it can stand a tougher year. Obviously this will not happen if the discharge is high every year.

8.2 Vegetation

Since not only water and sand determine how an area might develop, a comparison of the ecotopes present at the different rivers should also be made. A thorough comparison however requires more research and extends beyond this report. Nevertheless some of the factors influencing vegetation development are discussed to give an idea of resemblances and differences.

8.2.1 Climate and flooding

One of the major factors determining vegetation is the climate. The climate varies over the regions: The Netherlands have a sea-climate with moderate temperature differences between summer and winter and rain all year round (750 mm). The Allier River is in the centre of France, the moderating influence of the sea is less and therefore temperature differences are larger, but the overall temperature and precipitation (650 mm) are quite the same. The Volga River is situated in a steppe-zone and has a land climate (with about 360 mm of rain). Summers are very warm and dry, whereas winters are very cold. Thanks to the water in the river, the vegetation on the floodplain does not suffer from drought.

Something the vegetation might suffer from is inundation. This happens on all three floodplains, but for different periods. The inundation duration in the Volga River is rather long (mostly 35-45 days) and continuous, on the Waal River it is shorter but might happen several times a year. Especially hardwood species suffer from inundation, and will not develop if the area is inundated for more than 50 days a year. The longer the inundation time, the more succession is stopped at pioneer level.

Floods do not have only a negative effect on vegetation development: Since it is very difficult for poplars and willows to germinate on already overgrown soil, the fresh sediment deposited during inundation gives them a chance to grow, provided the seeds are deposited by the flood as well. The floods in the Allier and Volga mostly occur in spring, which is the right time for germination. In the Netherlands most floods occur in the winter period. This means that seeds are not deposited on the right location; the most recent deposits may be overgrown already and the river transports seeds to the unfavourable low water bed only. Taking this into account, softwood forest will probably develop slower in the Netherlands.

8.2.2 Species and grazing

The species present in an area are also a key factor. The main species of hard- and softwood trees (e.g. *Salix Alba, Populus Nigra, Quercus spec., Fraxinus excelsior*) can be found in all three regions, like several common species of herbs and grasses. An important difference however is that the Volga floodplain has only one thorny plant: the annual *Xanthium*, which mostly grows on freshly deposited sand. The other two rivers also know other species like blackberry bushes and nettle. Lists of species present in the Volga floodplain can be found in De Kramer (2001) and Schoor & Middelkoop (2001; list is in Dutch).

This is especially important in areas with large grazing animals: these animals avoid the thorny herbs, but eat all they can find in the area around them. Young trees between thorny plants can develop, whereas the development of trees on unprotected areas is stopped. This way a landscape similar to a park originates: groups of dense trees and bushes separated by open spaces with just very short grass. At the Allier River and in some Dutch nature parks nice examples of such a vegetation pattern are visible (see figure 8-2). The area near the camp at the Akhtuba was grazed as well, but

Figure 8-2
Park-like landscape at the Allier River, France.

with a different result due to the absence of protective plants: in the grazed area only older trees from an era before pasture started are present.
In the ungrazed Zakrutsky area a different form of a park landscape is present: Poplars germinate scattered over the area, which leaves open space. The difference however can be found in the undergrowth, which is not eaten away and seedlings can develop without the necessity of protection.
Use of woods for timber is mostly incidental, but especially in the Netherlands some excess vegetation might be removed by man.
Of course the condition and presence of vegetation are also dependent on the quality of the water and the soil type. These factors do not (seem to) differ enough to cause remarkable differences, though part of the sediment deposits at the Allier River are much courser (gravel) and therefore dryer than at the other rivers.

8.3 Management

As every river, the Waal, Volga and Akhtuba Rivers have to serve several functions: economy, safety, nature and society. Which of these is served most however, is determined by the need for these functions in their particular situation. This situation in Russia differs largely from that in the Netherlands.

8.3.1 Management in the Netherlands

In the Netherlands safety is chosen to be the most important function, directly followed by economy (shipping). This choice follows logically from the situation in the surrounding area: this is a low-lying area where many people live and where many economic facilities are found. The importance of the river as a shipping route may also be clear since the port of Rotterdam provides about 2% of the GNP, and the rivers are its main transport route to the hinterland. For these two reasons the rivers have been looked at mainly as a canal with dangerous and troublesome properties that had to be tamed. This leads to very active management of the river, using many restrictive measures. Only more recently the vision came that this management strategy not only disrespects the natural potential of the rivers, but it also gradually increases the danger of a flood: the floods get higher due to increasing discharges (external influence) and the more limited storage capacity of the floodplain. To reduce the flood danger a different strategy is applied: Room for the River. This basically means enlarging the storage capacity of the floodplain by lowering it, by increasing the floodplain area or by side-channel construction. In most cases this is combined with nature restoration to serve multiple functions.

8.3.2 Management in Russia

In Russia the type of management is far less active, due to several reasons. The most important one being the limited need for all functions: the area is not as densely populated as the Netherlands (a flood causes less damage and land is not that valuable), the amount of shipping is far less, and natural areas are present in plenty other parts of this enormous country. All these factors, combined with the more limited budget, resulted in a more passive management strategy.
This is especially the case since the Soviet-imperium collapsed. During the Soviet-time in particular the economic pressure was much higher: many dams were build for hydropower, navigation purposes and large irrigation works. Also the rivers were dredged to maintain shipping routes. Due to the current economic depression many large farms are not working anymore, and no money is available for dredging. Nature protection is a more recent development, urged by both regional and international organisations like the WWF, but also by economic factors like the caviar production.

8.3.3 Consequences for rejuvenation

The passive management in Russia allowed large parts of the river and its surroundings to stay in a more or less natural state; only recently a more active way of nature preservation is adopted. In the Netherlands the other functions of the river are far too important to let the river free. Nature restoration is therefore only allowed at relatively small areas and under strict regulations.

This is of consequence for the applicability in the Netherlands of results obtained in Russia: The spatial scale of processes observed differs largely; 'free movement' of the river can only be allowed in side-channels, which have a scale of not more than a few hundred meters in length and tens of meters in cross-direction. The timescale also differs: In Russia developments can continue for decades and longer, hence the river can rejuvenate its floodplain itself, whereas in the Netherlands the more developed vegetation regularly has to be removed by man to reduce flow resistance in order to keep safety levels guaranteed. Rejuvenation by the river itself is not possible since this is not allowed to move for navigational reasons.

9 Conclusions and recommendations

9.1 Conclusions

Many of the objectives of the fieldwork and the project are met, which means more insight is gained in the relation between morphology and vegetation succession in natural rivers and in how this can be related to rivers in the Netherlands.

Judging its parameters alone, the Lower Volga River does not seem to be a very dynamic river. It has a large width/depth-ratio, but a low gradient. However, due to its sheer size and freedom to move, morphological changes at the scale of a point bar or smaller happen rather fast. Average outer bank erosion for example amounts 19 meters per year, and sediment deposition on the point bar can be several meters thick locally.

The effects of morphology on vegetation succession are clearly visible in the Volga River. Without morphological activity the terrain level and other circumstances would remain the same through the years, as a result of which existing vegetation would become gradually older without changing much. The morphological activity at Zakrutsky raises the terrain level, thus decreasing inundation time, soil moisture and flow velocities, which asks for other species. Furthermore, the morphological changes give pioneering vegetation the chance to develop almost every year after a flood because existing vegetation becomes covered with sand and dies, or because new land like the scroll bar is created. This means rejuvenation takes place gradually.
The height of the terrain is found to be a determining factor for which species are present: On low and moist areas dense willow (*Salix alba*) woods can be found, as well as moist herbage and grasses. On higher and therefore dryer areas sedimentation and germination occur more spread out, which creates a more open landscape consisting of trees (mainly *Populus nigra*) of different ages along with dry grasses and herbs. After about 20 years also hardwood (*Fraxinus Langustifolia*) can be found on the higher areas. Generally the difference between moist and dry lies around 4 meters above water level.

Morphology influences vegetation development, but there are indications for vegetation influencing morphology as well. The resistance caused by vegetation can alter flow patterns, and therefore accretion and erosion processes. Several illustrations of such an influence are found at Zakrutsky: The high water channel is eroding since the point bar has become more vegetated, the outer bank erosion has become more severe and a scroll bar has formed. These changes could be a direct result of point bar accretion as well, but since the point bar is largely vegetated they occur faster. Point bar accretion itself can also be accelerated by the vegetation, but this cannot be verified because there is no reliable information about point bar levels from before the fieldwork.

The scale of the Akhtuba River is much smaller than that of the Volga and Waal Rivers. The same applies for its morphological activity with respect to the Volga River, but not with respect to the Waal River since the latter is strongly restricted in its activity. The Waal River shows activity similar to the Akhtuba River, but more limited: morphological changes occur close to the low water

bed. This follows from both the parameter comparison and the things observed in the field and on satellite images. Nowadays the sedimentation on the point bars occurs very gradually, only in the lower areas bare sand and pioneer vegetation is found. This means there is less rejuvenation, which is confirmed by the smaller number of young trees among older ones. The height of older ridges farther from the river however indicate a more dynamic situation from before the dam was built, when discharges where higher.
Very little moist vegetation is found here. Grasses, herbs and *P. nigra* are very common, and also hardwood (*Fraxinus, Tamarix*) is present. Another difference with the Zakrutsky area is that some areas are grazed. These areas show a park-like landscape with older trees, very short grass and *Xanthium*, a thorny herb. On both the Akhtuba and Volga research areas some examples are found of hardwood trees developing between probably old softwood trees.

Except from the river parameters, little can be said about the dynamism of the Akhtuba River in a quantitative way because there is only limited historical information, which moreover is at a scale too large to see short-time processes. Nevertheless, the current state of morphology and vegetation at the Akhtuba River may act as an example for how Dutch side-channels can become after a while when they would have room to move. The spatial scale of these channels is even smaller and their lower width/depth ratio means they are less dynamic, but stream power and sediment transport capability are comparable, and they have a large difference between high and low discharge like the Akhtuba River.

The dynamism of the Lower Volga River at the Zakrutsky bend is very well comparable to the dynamism of the Waal River in 1800, except for the shields parameter. The morphological and vegetation changes observed at Zakrutsky cannot be applied to the present Waal River however. Apart from small difference in climate, flooding time and vegetation species, the paramount factor is the difference in river management. For the Waal River economy and safety are much more important than nature. This means that the river is not allowed to move freely, and woods may not develop to warrant the flood conveyance capacity. Also the 'Room for the River' concept does not solve this: The river is still very limited in its dynamism, and therefore sedimentation rates and stream velocities are too low to ensure natural rejuvenation. Applying an artificial form of rejuvenation may give similar ecotopes as observed at the Volga River, provided the management understands the relations between morphology, vegetation and flow.

9.2 Recommendations and further research

As mentioned in the conclusions, the Lower Volga River is an interesting reference river. The information available about the river however still has some deficits that seem useful to fill up in case similar research is undertaken again. This goes for both hydrological data and local field data.

- Concerning hydrology, discharges and water levels during the year at the research area locations are useful complements. This applies specifically for the water levels at the time of the fieldworks and the days the satellite images were made.
- Other useful complements are aerial photographs on a scale that shows more detail than the satellite images, e.g. 1:25.000. This does not mean buying more satellite images is useless; analysing a new satellite image every three to five years may yield a lot of information about further developments concerning both morphology and vegetation.

- To get a better understanding of what a flood does to vegetation it would be interesting to study the area just before and just after a flood. Visiting the area during a flood can provide information about flow directions and velocities. Such information can be used to calibrate models. The same applies for water level recordings, which also could be used to refine the classification of satellite images. Nevertheless the value of further visits to the area is very limited unless measurements are really necessary for research.
- Dating trees on more locations gives a better idea of when trees started to grow where. This provides more information about the morphological history of the locations. Especially dating young vegetation on recent deposits can tell more about how quickly vegetation is established.

Also two recommendations are made that concern biogeomorphology and rivers in general instead of the research areas specifically:

- The question remains to what extend morphology determines vegetation or vegetation determines morphology. A qualitative interaction certainly exists, but quantitative relations are necessary when computational models are used to predict developments.
- Translating observations from one river to another is difficult due to many factors, both physical and human. Research on more rivers combined with historical reference situations could add to the understanding of the potential dynamics of present-day rivers.

Annexes 4 and 5 provide some background information about further research not directly related to this project: Annex 4 summarizes the NWO project Volga-Rhine; a co-operation between Moscow State University and Utrecht University, and annex 5 makes some remarks about management and research in the Volga-Akhtuba floodplain.

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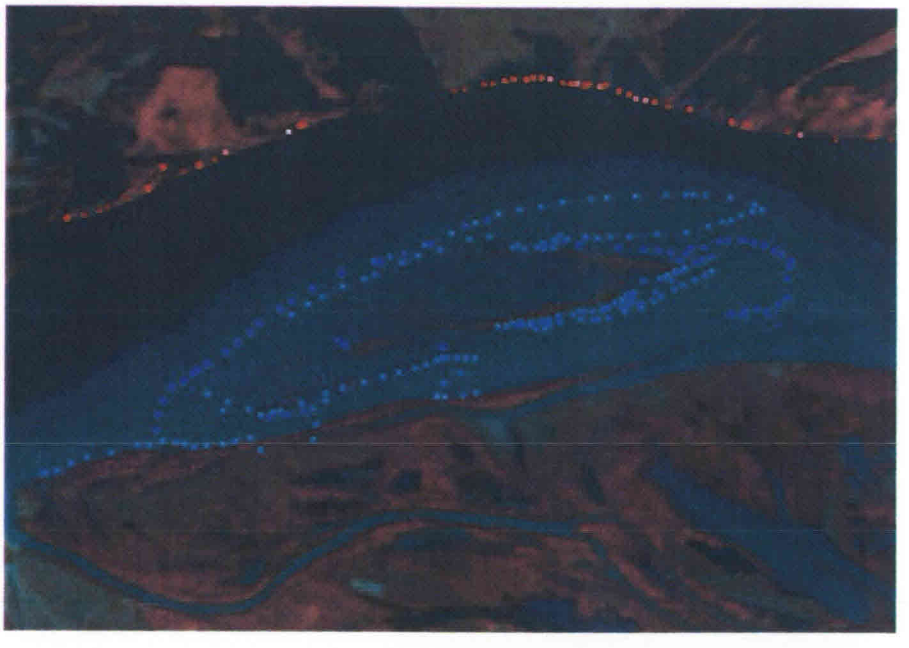
Annex 1a Landsat images of the Zakrutsky area (Volga River)

Pictures taken during summer discharge (1986, 1996, 1999, 2000) can be found in figure 5-3.
High water: 1985 and 2001

1985

2001



Annex 1b Landsat images of the Veterok area (Akhtuba River)

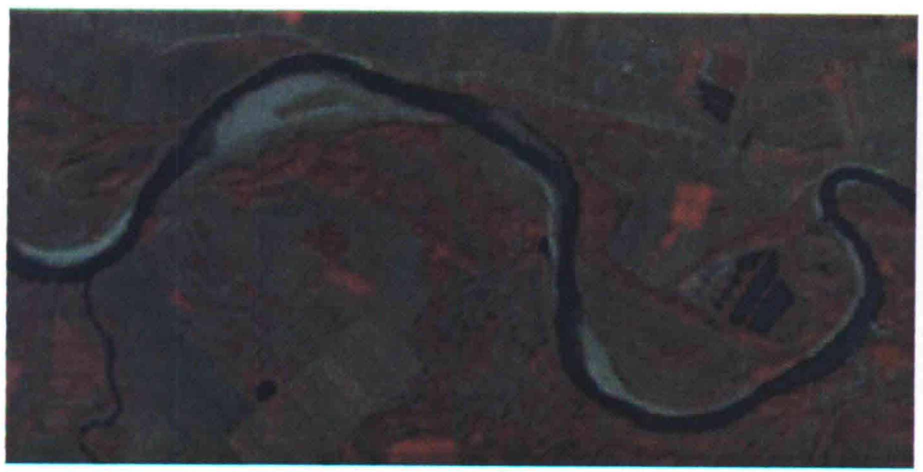
High water: 1985 and 2001
Summer discharge: 1986, 1996, 1999, 2000 (other side)

1985

2001

1986

1996



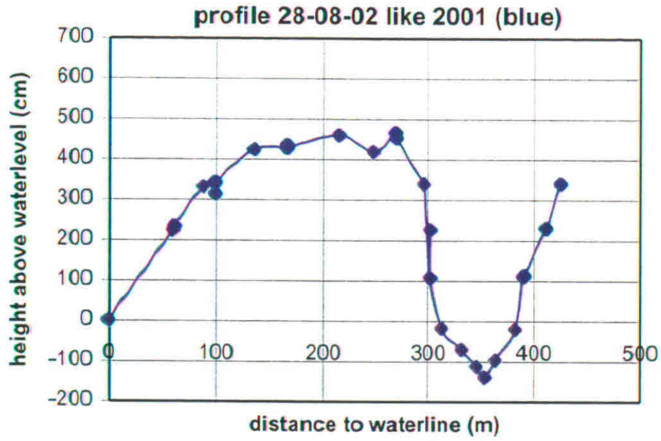
1999

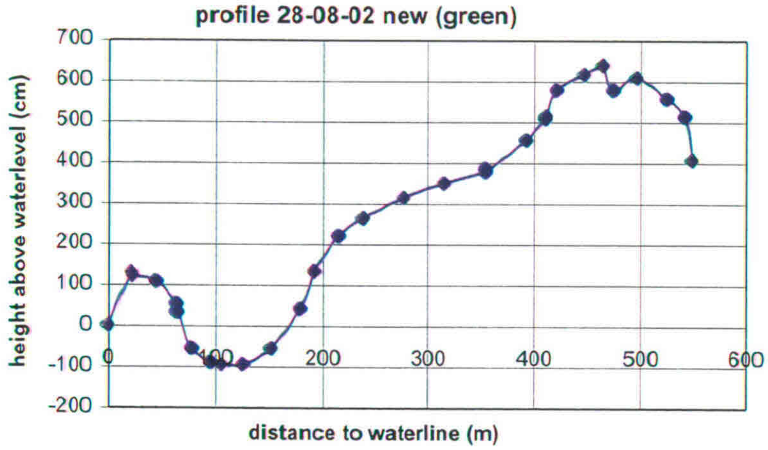
2000

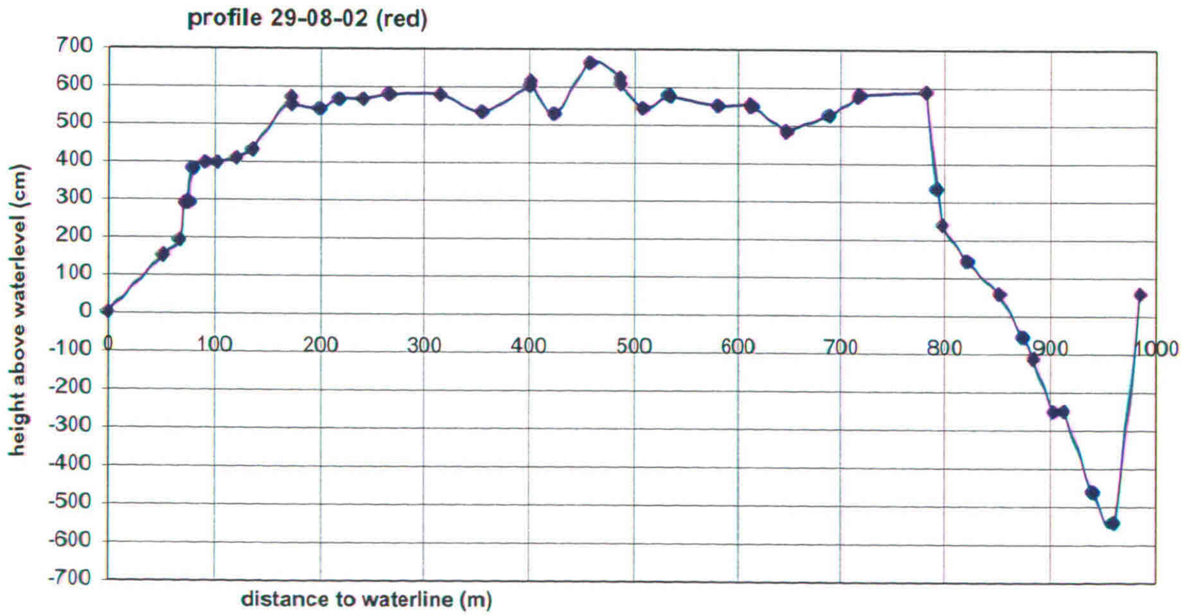
Annex 2 Levelling profiles

Volga River
Akhtuba River

Volga levelling profiles 2002

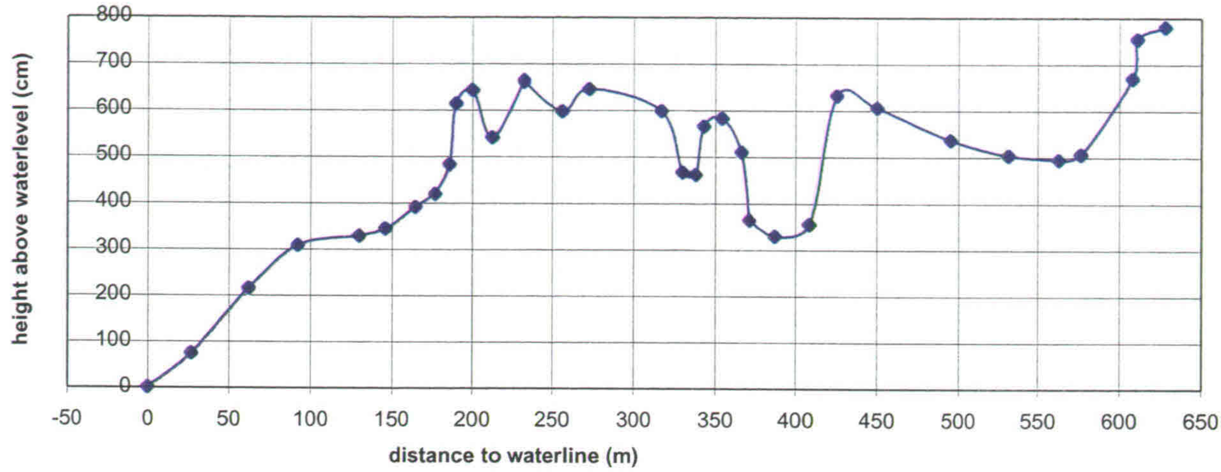




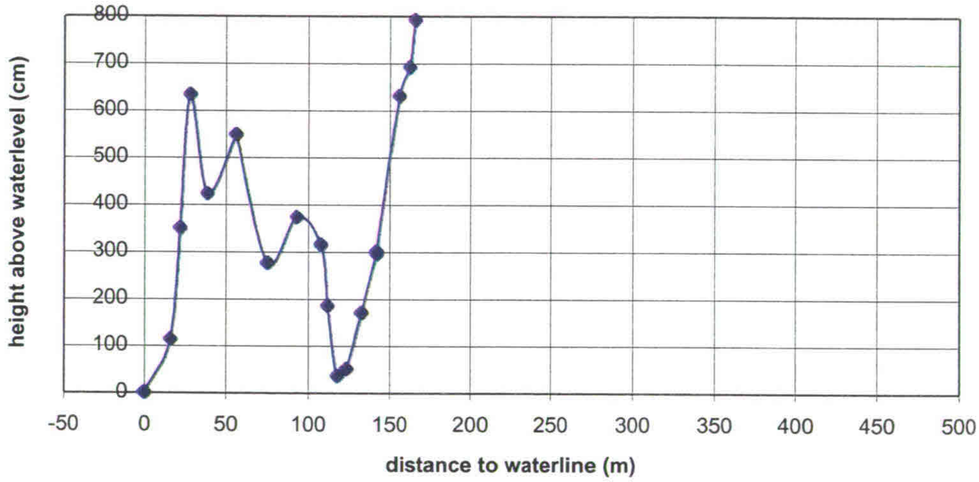


Akhuba levelling profiles 2002 1/3

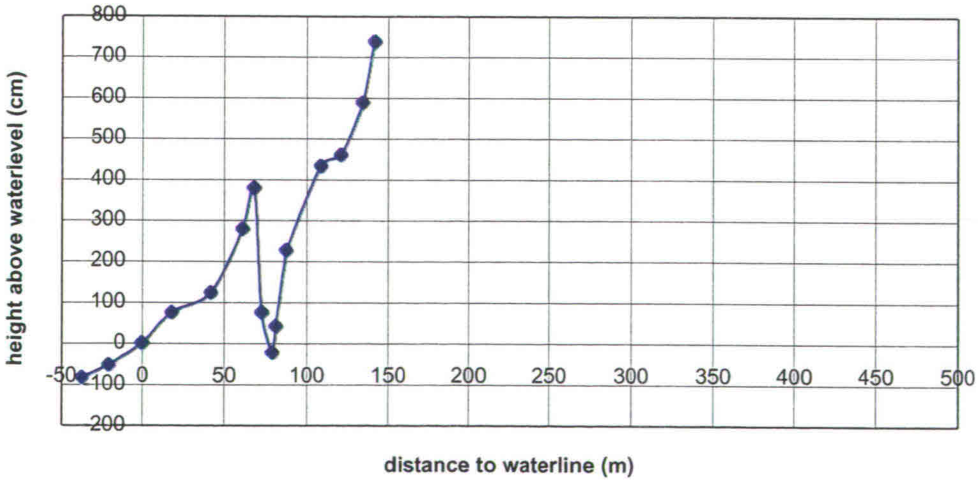
profile 1



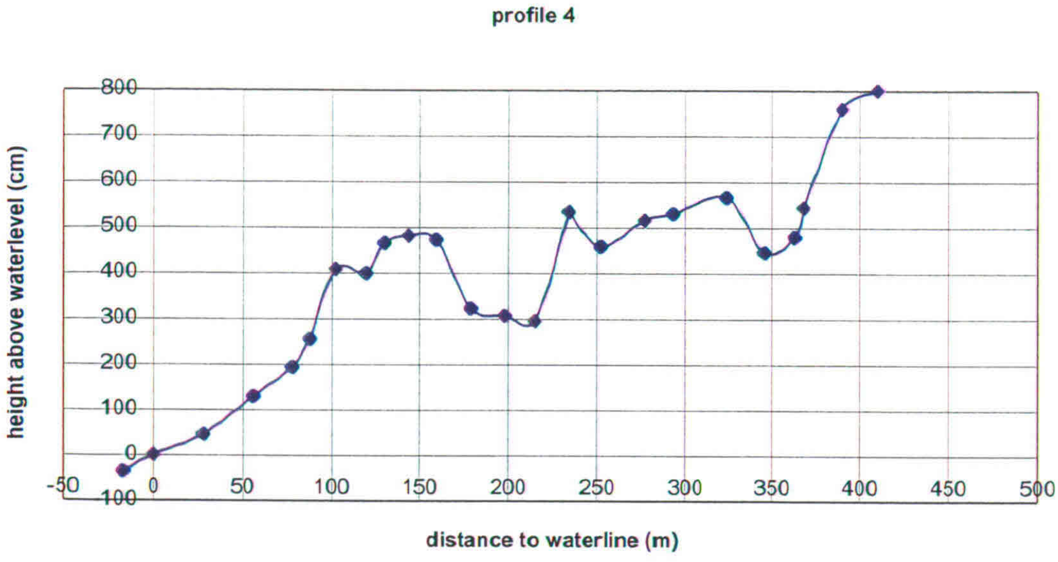
profile 2

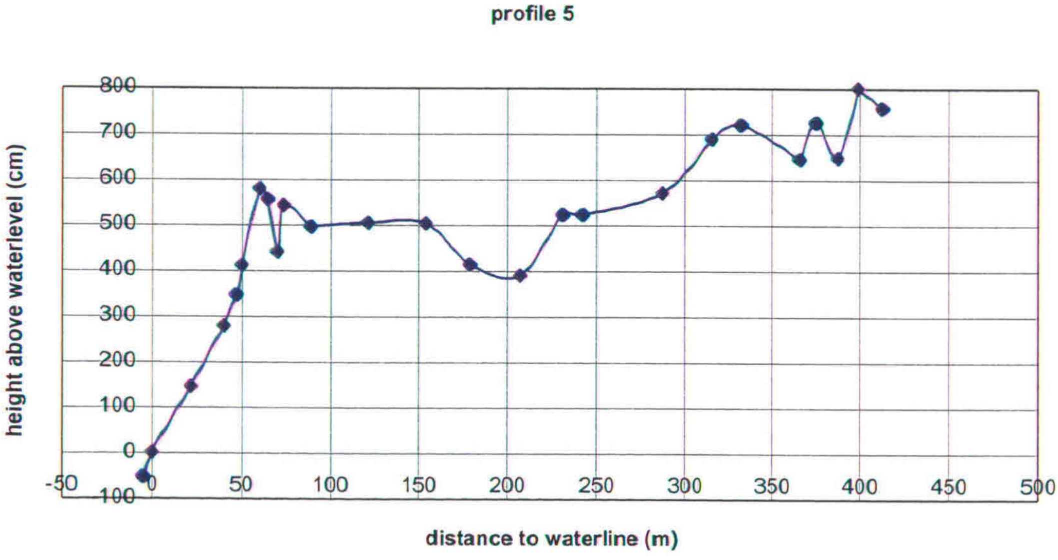


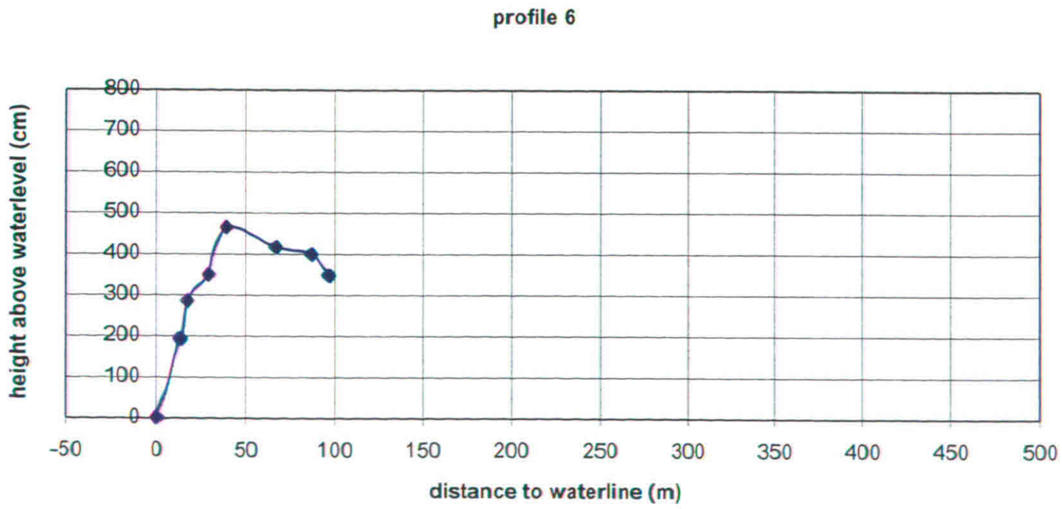
profile 3



Akhuba levelling profiles 2002 2/3

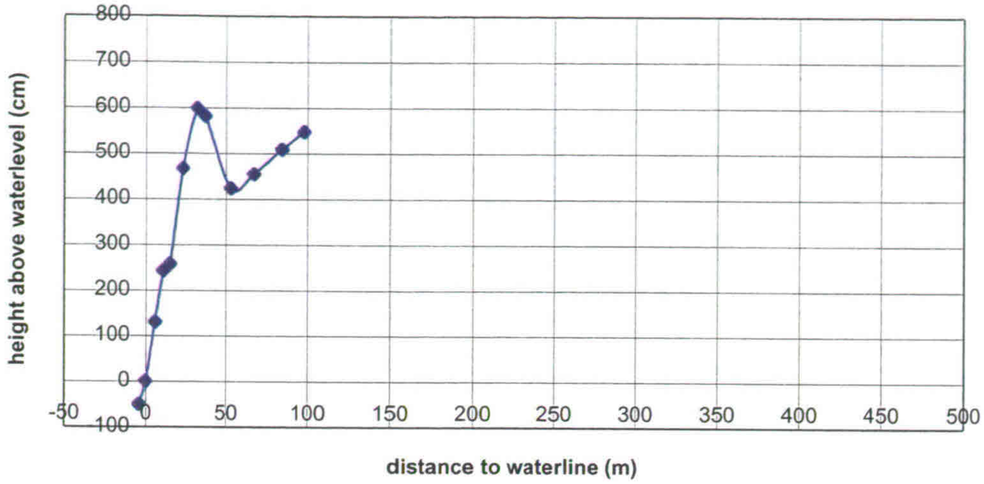




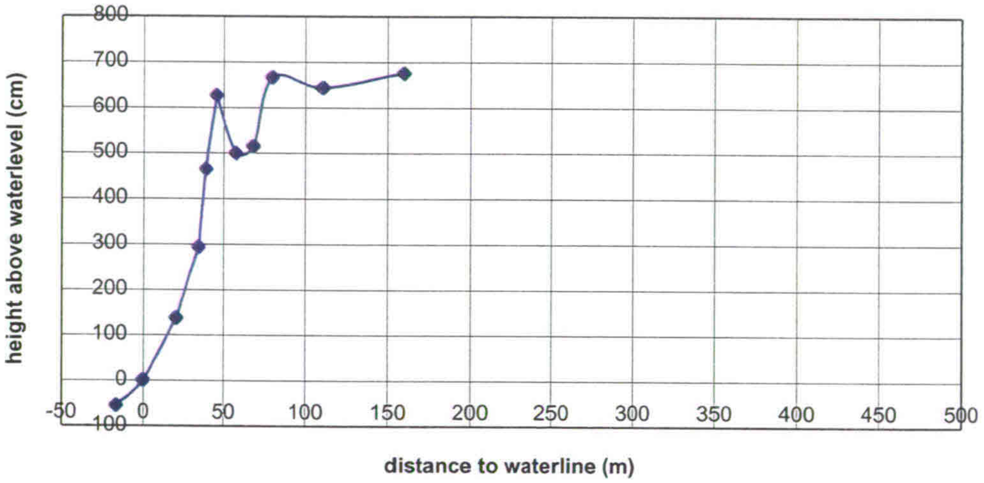


Akhuba levelling profiles 2002 3/3

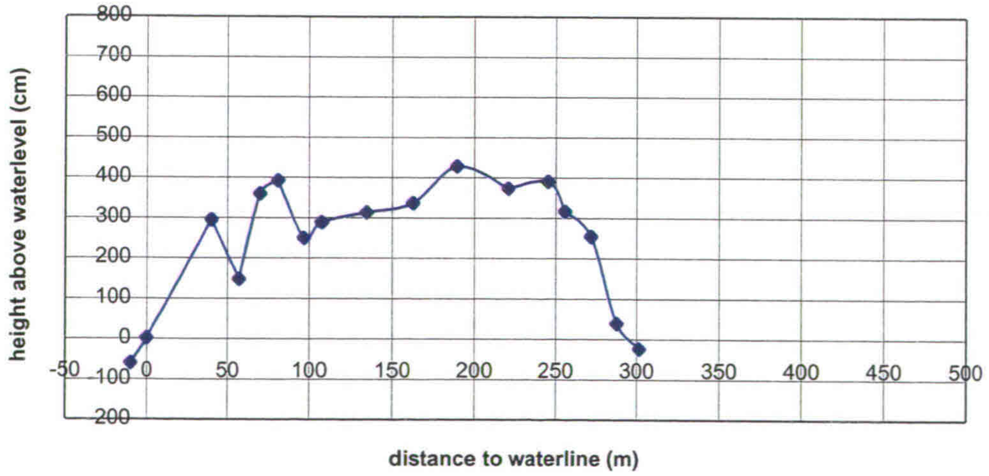
profile 7



profile 8



profile 9



Annex 3 Log and participants of the 2002 Volga fieldwork

The following people participated in the fieldwork:
Mrs. Drs. M.M. Schoor (RIZA, project leader)
Mr. Dr. J.H. van den Berg (Utrecht University, senior researcher)
Mr. Dr. D. Babich (Moscow State University, senior researcher)
Mr. Dr. A. Alabyan (Moscow State University, senior researcher)
Mrs. T. Baluk MSc. (Regional Centre for Study and Conservation of Biodiversity, Institute of Water Problems of the Russian Academy of Sciences Moscow)
Mr. M. Samohin (Moscow State University, student)
Mr. S. Moreido (Moscow State University, student)
Mr. J.T. Dijkstra (Delft University of Technology, student)

Others that took part in the organisation are:
Mrs. N. Lopantseva (Management of the Volga-Akhtuba Floodplain Nature Park)
Mrs. A. Kartunov (Management of the Volga-Akhtuba Floodplain Nature Park)
Mr. Ir. H. Leummens (RIZA)

25-08, Sunday: Flight from Amsterdam to Moscow.
26-08, Monday: Flight from Moscow to Volgograd together with Dmitry. Transport by car to the camp near the Zakrutsky research area near Bulgakov at the Volga. Accompanied by the management of the Nature Park, a quick stop is made at a school in the floodplain with which the Nature Park organisation co-operates in providing ecological education.
27-08, Tuesday: The morning is used to test the equipment brought. In the afternoon the erosive left bank downstream of the camp is scouted; location and height are measured. Traces of sand deposited during the most recent flood are clearly visible. This flood has been lower than it is normally, and this year there is also little rain; it has been dry the last three months. Late afternoon Andrei, Misha and Seva arrive. They have come from Moscow by car and were meant to arrive yesterday, but have been delayed by a minor accident.
28-08, Wednesday: The first of three days the boat is available. Due to its draught (1.10m) navigation in shallow water is difficult. The team goes ashore at the Eastern part of Zakrutsky. Margriet and Tania measure trees, Janrik maps contours and scouts the area, while Misha and Seva level last year's profile over the scroll bar again and a new one across the high water channel. Andrei, Dmitry and Seva stay on the boat to sound the main channel, but the software is not working yet.
29-08, Thursday: The West part of Zakrutsky is visited. Misha, Seva and Jasper level a long profile and map some contours. Janrik also maps contours and studies sediment structures. Margriet and Tania look for the oldest and thickest trees, which should be found in this area. The others sound the main channel for about 15 km. Again the draught of the ship is problematic.
30-08, Friday: On the last day the boat is available, a television crew from Volgograd is present. They film Margriet, Tania and Misha auging trees at the Eastern part of Zakrutsky. Janrik maps more morphological phenomena, whereas Jasper measures the vegetation density at several places. The boat team measures flow velocities in the main channel.

31-08, Saturday: In the morning Andrei, Janrik, Jasper, Misha and Seva go by car to the upstream part of the left bank to measure its location and height. The afternoon is used to elaborate data.

01-09, Sunday: Tania leaves for Volgograd, the others move to the camp at the Akhtuba near Veterok (close to Sredjana Akhtuba). The area is briefly scouted.

02-09, Monday: Andrei returns to Moscow with his car. Margriet and Seva use the morning to visit the ceremony for the opening of the new school year at the ecological school. The children are happy to go to school again since this means they do not have to work on the fields anymore. Janrik, Misha and Jasper scout the area upstream of the camp. Discussion arises about probable incision of the river after the dam construction in 1959 because terraces are found 1 to 2 meters higher than the young floodplain.

03-09, Tuesday: A small and fast motorboat is available the next three days. First it is used to get on the 30-40 meters high cliff near the camp, to get an overview of the area. After this, Margriet and Janrik use it to scout the river downstream. The decision is made to make soundings for about 10 km in downstream direction, level a profile every kilometre and make 2 detailed eco-morphological descriptions of point bar profiles. This is started in the afternoon.

04-09, Wednesday: Dmitry and Seva complete the soundings, while the others finish the profiles on the downstream point bar. This point bar shows a nice sequence of ridges and swales, which are older (both morphological and in vegetation succession) and less active the farther they are away from the river. Also the heights of the upstream outer banks are measured. All tree kernel transport tubes are full now. One of the GPS-handhelds was used with a wrong setting for the XY-coordinates, but fortunately this could be reversed without data loss.

05-09, Thursday: On this last day in the field Janrik and Seva go to Leninsk by boat to study the area where the river inundates the floodplain. Unfortunately they have to return because the boat cannot pass a pontoon bridge somewhere halfway. On their way back they measure the outer bank heights, which are lower than those upstream. The others use the day to process data. In the evening the team toasts to the productive and pleasant co-operation.

06-09, Friday: Back to Volgograd, where finance matters are dealt with after dinner.

07-09, Saturday: First a flight from Volgograd to Moscow, then, after a brief visit to the city, the Dutch members fly back to Amsterdam.

Annex 4 The NWO project Volga-Rhine

Main participants of this project, which is fully called 'Large European river system responses to global change and local human activities-The Volga and Rhine Rivers', are Moscow State University and Utrecht University. RIZA supports the project with satellite images and information obtained during previous fieldworks. The project start date is April 1 2002, the duration is 36 months.

The project goals and content are summarized below (from: research proposal Russian-Dutch research co-operation 2001):
The project aims to assess the potential impacts of changes in climate, land use and large-scale water management measures on the discharge regime and flow and channel pattern of the Volga and Rhine Rivers at the historical timescale (from decennia to a century). Analysis and comparison of both river systems will improve the understanding of natural hydro-meteorological relations and their implications for river dynamics and water management. For a complete understanding of processes in the deltas and lower reaches of these rivers, detailed investigation of the whole river basin is of vital importance. The project therefore focuses on three issues: hydrological impacts, channel morphodynamics and the response of the delta to sea level change. Impacts on the Volga River will be investigated at the Upper Volga (Protva River), Middle Volga (Oka River), Lower Volga River and the Volga Delta. Impacts on the Rhine River will be assessed using models (RHINEFLOW) and results from previous impact analyses, which are already available at Utrecht University. With the Rivers of Russia Information System of Moscow State University, a water balance model for the Volga basin (VOLGAFLOW) will be developed. Subsequently, scenarios will be established concerning future climate (based on global climate change models), land use, water demand, reservoir management and nature development in the Rhine and Volga basins. The impacts of these scenarios will be determined using the models. The implications for flow dynamics, sediment load and channel patterns will be investigated by using existing information, complemented with fieldwork, analyses of old river maps and computer modelling. This part will focus on key areas along the Lower Volga River and in the Volga Delta. The results will be compared with those derived from previous studies for the Rhine. Finally, the relations between hydrological changes in the entire basin, sea level rise and morphological response of the lower river reaches will be determined.

Annex 5 Remarks about management and research in the Volga-Akhtuba floodplain

As mentioned in the conclusions, the Lower Volga River is an interesting natural reference river. Besides this, the Volga-Akhtuba floodplain is a very valuable area in both environmental and economic respect. Like any other valuable area it has its problems, and for both Russian researchers and managers as well as their foreign counterparts it seems useful to mention some of these briefly and make some suggestions for management and further research of the Volga and Akhtuba Rivers and the Nature Park. Some of these will be sensed as stating the obvious, but are nevertheless mentioned for the sake of completeness.

While visiting the Volga-Akhtuba Floodplain Nature Park some things concerning management of the area attracted the attention. The first was the bridge under construction near Volgograd, which makes it much easier to reach the Nature Park. After completion, the pressure on the Park for recreation and living will be much larger than it is now, and even now the first few kilometres do not seem to be a nature park concerning the amount of villages, roads, traffic and pollution. Even though the bridge has been designed before the Nature Park was founded, the Nature Park management has managed to negotiate fewer approaches and exits, and the new road is a replacement of the existing one instead of an addition. According to the Nature Park management new residents will not be allowed in the Park.

The second is the amount of plastic bottles and old fishing equipment found everywhere. Many (summer) houses in the remote parts do not have a controlled way of garbage disposal. It is either burnt or left to be washed away. Controlling this, possibly linked to fishing permit control and withdrawal in case of offence, could improve this situation, provided that there is a good disposal facility and regulation. The Nature Park management is well aware of this, and are trying to find a solution in co-operation with Het Utrechts Landschap as a part of the PIN-Matra project. The PIN-Matra project is a co-operation between the Lower Volga Basin Management Authority, RIZA and Het Utrechts Landschap with the objectives of providing information and establishing a visitor's centre in the floodplain. The PIN-Matra project also supports the Regional Centre for Conservation & Study of Biodiversity; a NGO that makes teaching programmes and brochures.

The third point of attention is the good co-operation between the Nature Park management and the ecological school. Making the children -and maybe via them their parents- aware of ecological matters will be of good influence on the future of the floodplain.

The most serious threats for the Volga River as a natural river however is the economic pressure. Presently the economy in the region is not really flourishing, but this may change in the future, maybe resulting in more shipping (dredging), more industry (pollution) and more people (housing, traffic, bank protection). The Dutch rivers may act as an example for what can happen if economy and safety needs determine the management of the river.

Irrigation also requires concern. The Lower Volga River is the most important source of fresh water in a very dry area. On many places at its banks –and also at the Akhtuba River- irrigation pumps can be seen, although currently there is less irrigation than a decade ago. Irrigation not only taps water from the river, thus decreasing the discharge and (ground)water level, but it also might lead to brackish fields if it is not applied well. In this way it may not only endanger nature, but also the economic situation of the farmers. Therefore irrigation should be part of a plan for integrated water management. An attempt to make such a plan is undertaken by RIZA and the Lower Volga Basin Management Authority.

Restoring the Akhtuba discharges to what they were before the dam was built could be beneficiary for the water management around the Akhtuba River. More water can be used for irrigation in dry periods and during floods more water reaches more parts of the floodplain, thus providing a larger storage capacity for the summer period.
Dividing more water to the Akhtuba River can be done in two ways: By regularly dredging the upstream connection to the Volga River –which is only useful if the Volga River has not incised much more than the Akhtuba River-, or by making a controllable inlet directly at the dam. Many plans have been made so far, but a lack of funds has delayed their execution. Whether such activities are still necessary, and what option is most favourable in a financial and hydraulic perspective might be cause for research. See also the text below about a hydrological model.

Since the Akhtuba River shows signs of incision (see 6.3.2), this will have its influence on the hydrology in the floodplain. At the moment however it is still unsure whether the river actually is incising, and –if so- how fast this happens and what the causes and effects are. This asks for an investigation using data from hydrological stations, and maps, descriptions and aerial photographs of the floodplain from before and after the building of the dam.
For good management of the Nature Park a hydrological model is useful to study the effects of further incision and activities like dredging, irrigation and dike or dam building or removal. This model should be both simple enough to use as a basis of a Decision Support System (DSS), and advanced enough to represent realistic values. Such a model requires detailed topographic and hydrological data, and flow velocities and water levels measured at several places for calibration, also during flood and on the floodplain. Of course good knowledge of modelling and co-operation with organisations that have access to information that has been acquired already are necessary as well.
Making of such a DSS and hydrological model should start with an inventory among the parties involved about what they expected from a model, what effort they will contribute to the creation and maintenance of it, and in to what extent they will deal with the results it produces. The Lower Volga Basin Management Authority is interested in making a hydrological model and a DSS. The Volgograd Oblast Administration offers the hydrological research as a contribution to the PIN-Matra project, and RIZA is willing to support the DSS, but the Basin Management Authority need permission from the Ministry in Moscow for this participation.
The investigation, modelling and use of the model will only succeed if such problems and the need for actions are felt at a high administrative level too. Probably a lot of the studies and information mentioned above is already carried out or gathered, but for some reason unavailable.

During the fieldwork also some suggestions for further research arose:

As one of the issues of the NWO project, Moscow State University is interested in modelling the Zakrutsky bend area using Delft3D, in order to predict morphological changes on bank scale for several years. However, several modelling aspects require attention:

- Thorough knowledge about Delft3D is absolutely necessary; a course is recommended.
- On this scale of modelling much more detailed information about the area is needed: detailed soundings, measuring terrain height using DGPS, determination of ecotopes and their hydraulic roughness; this all could be done if more time and the right equipment are available.
- Images and maybe additional fieldwork are necessary to verify the predicted changes; the available satellite images do not really have sufficient resolution for this, which makes aerial photographs on a 1:25.000 scale advisable.

Apart from this, a model is more interesting to study hypotheses rather than just trying to predict what will happen.

The comparison between the rivers Volga, Waal and Allier has been mainly focussed on morphology due to the people involved in the project. Comparing vegetation succession and the influence of pasture on it in the different floodplains is also interesting. Arrangements for a Russian ecologist with good knowledge of the Volga floodplain to visit the Allier and some Dutch experimental areas are made.

Annex 6 Biomorphological glossary

The aim of this glossary is not to provide a complete overview of ecological and morphological definitions, but it is meant to explain the most important terms used in this report.

Secondary flow
In a river there is not only flow in downstream direction (called main flow), but also in lateral direction, called secondary or spiral flow. This secondary flow is a result of water head differences that occur in bends due to the centripetal force. River bend erosion and -accretion processes, which are largely lateral, are determined mainly by this secondary flow.

Island
An island or detached bank in a river can be formed in relatively wide rivers only. In narrow rivers the spiral flow can develop only one large enough spiral, i.e. one channel. In wider rivers more of these spirals (also called 'cells') can develop, resulting in more channels, separated by islands or banks.

Point bar
Area at the inner bend of a meandering river. In a natural river the point bar gradually accretes towards the outer bank, and migrates downstream. The lateral accretion is more or less in equilibrium with the erosion of the outer bank, keeping the channel width constant.

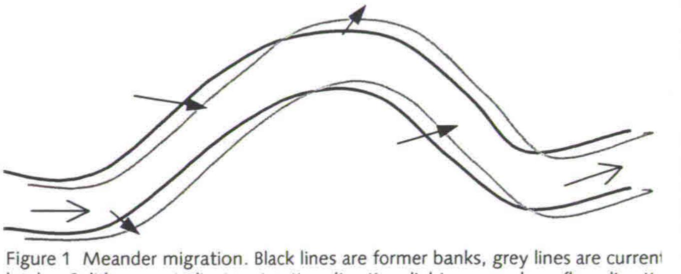


Figure 1 Meander migration. Black lines are former banks, grey lines are current banks. Solid arrows indicate migration direction, light arrows show flow direction

Scroll bar
A scroll bar is the most recent extension of the point bar. The formation of a scroll bar is considered to be a result of a time lag between outer bank erosion and inner bend accretion, which results in a channel width change that is too large to be restored gradually. Therefore the downstream end of the scroll bar is detached from the point bar.
The channel at the point bar side is gradually filled with river deposits until it is completely attached to the point bar. The traces of this process can be seen in the field as (a series of) ridges and swales perpendicular to the stream direction.

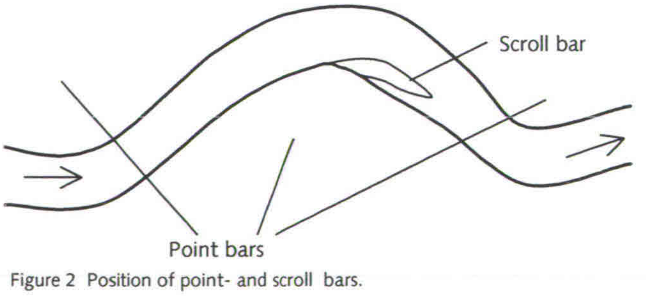


Figure 2 Position of point- and scroll bars.

High water channel

A high water channel carries no or only very little water during normal discharges, while during floods a lot of water may pass. This of course depends largely on the geometry and the position of the bed level, especially at the upstream connection with the main channel.

Due to these large variations in discharges, processes different from those in the main channel occur. For example, vegetation has a better chance to develop, since it is less flooded. In the Netherlands this is problematic since vegetation increases the hydraulic roughness, hence decreases flood conveyance capacity.

Chute channel

Chute channels in meander bends are formed if the meander width (i.e. the main channel length) becomes very large. During a flood the flow takes a short cut across the point bar, thus creating a new, much shorter channel.

Chute bar

A chute bar can develop at the downstream end of a high water channel or a chute channel. In such channels flow velocities can be high because they are relatively small and have a larger gradient than the longer main channel. These flow velocities may cause erosion in the small channel. When the water reaches the large main channel again, flow velocities drop suddenly and so does the sediment transport capacity, resulting in accretion. The chute bar formed in this way moves downstream, because the flow accelerates at its upstream side and erodes the material deposited there earlier. Accretion of the bar takes place at the downstream side.

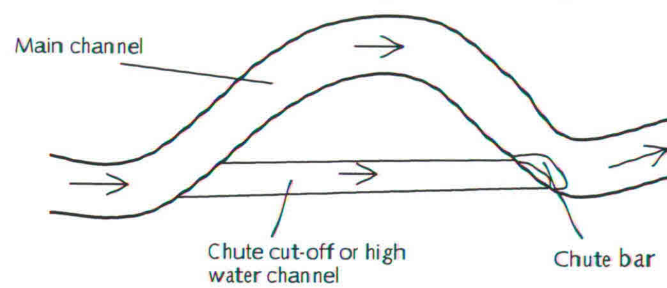


Figure 3 Position of chute channel and chute bar.

Pioneer vegetation

Pioneer vegetation is the first vegetation to germinate on bare, freshly deposited soil. Examples are herbs and grasses, but also softwood trees like poplars and willows. Which of these will germinate and develop further depends on circumstances like moist, additional sand deposition, stream velocities, grazing, etc. After a while non-pioneering vegetation (e.g. hardwood) can develop under protection of these species.

Succession

Vegetation changes over the years. This change is partly influenced by internal factors like growing and dying, partly by external factors like floods, moist, accretion and grazing. If a pioneering vegetation pattern is gradually replaced by a more mature one, this is called succession. Examples of succession are a softwood forest where hardwood starts to develop, or an area with only grasses and herbs on which softwood starts to grow.

Rejuvenation

Rejuvenation is a special form of succession, but instead of replacing a younger vegetation stage with an older one, the older one is removed and succession can start again in an earlier phase. In a river this can happen in two ways: The soil on which for example a mature forest grows can be eroded and deposited elsewhere, where it becomes grown with pioneer vegetation. The other way is that vegetation in some stage of development becomes covered with sediment and dies, which gives pioneers a chance on the fresh soil.

Floodplain

The floodplain of a river comprises the surrounding land that can be flooded by the river at a high discharge. Its borders are determined by higher grounds like terraces or dikes.

Bank full discharge

The bank full discharge is the discharge at which the water reaches a level where the riverbed becomes much wider, i.e. where it starts to flood the floodplain. This discharge is often used for comparison of rivers because it disregards differences in the floodplain that hamper analysis, and it has shown to be a reliable parameter for morphological processes.