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EXPERIMENTS OF INFLUENCE OF DISCHARGE PROCESS ON CHANNEL PATTERN

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ABSTRACT: Based on experimental data and theory, by means of simplified discharge durations in a small flume, the influence of discharge process on channel morphology and channel pattern was analyzed in this paper. It was concluded that on the same original channel, different discharge and channel conditions would end with different river morphology, including thalwegs and radius of bends. Different discharge process resulted in two kinds of change: tiny change in the process of "big-small-big" and distinct change in the process of "small-big-small". Flood discharge duration was verified to be the main cause in the discharge process. Proper discharge process will change the morphologies of river, even can led to channel pattern transformation. The influences based on the relationship between the flow and the channel itself, including slope and riverbed constitution. Although not be a main cause, original channel morphology may influence its final channel pattern. Neglecting the influence of channel itself will hamper the understanding of channel patterns.

KEY WORDS: discharge process, channel pattern, flood duration

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1 INTRODUCTION

Many researchers have worked on formation and transformation of channel pattern by means of flume experiments since FRIEDKIN (1942), and a lot of achievements have been gotten, but some problems still exist. TAN Ri-chang (1964) believed that the constitution of river channel was important to the formation of meandering rivers, especially the inconsistent constitution of riverbank and riverbed. YIN Xue-liang (1965, 1995) suggested that the flow and sediment inflow act prime parts in channel pattern′s formation. They both shaped typical meandering rivers although together with some artificial measures. In the 1970s, SCHUUM and KHAN (1972) successfully realized the formation of different channel patterns by changing the channel slope and sediment discharge. By using of a mixture of diatomaceous earth and kaolinite clay as grain material, SMITH (1998) succeeded in modeling high sinuosity meanders in a relative small flume.

In nature, it is common for the discharge process to reform rivers. One flood can influence the river more than long period of moderate flow; its remainder may exist even after a long period of time. Different discharge processes may induce different channel patterns, such as the rivers in north and south Blue Mountain, Jamaica (QIAN, 1987).

It is well known that the building of reservoirs will influence reaches downstream, even may cause channel pattern′s transformation, such as the change from braided river into meandering river in the lower reaches of the Han River after the building of Danjiangkou Reservoir. That the reducing of sediment discharge is a main cause has been well acknowledged, but the influence caused by change of discharge process is always neglected and still kept unknown.

In the simplified flume experimental study on the transformation of channel pattern downstream reservoirs, some runs were designed to study the influence of the discharge process on channel patterns.

2 EXPERIMENTS

The experiments were performed in a glass flume with

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a changeable slope. The flume was 4m long, 1.2m wide and 0.4m high (Fig. 1). With that installation, discharge, slope and riverbed constitution all are changeable according to the demand of experiments.

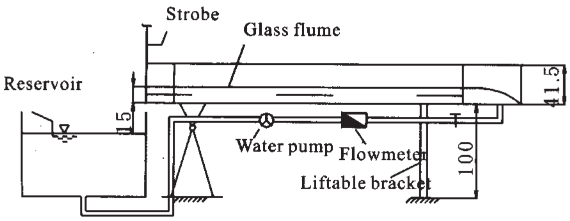

Fig.1 Installations in simplified experiment

In total 8 runs of experiments were performed. Among them, three kinds of grains were adopted, including sands and fine coal particles with the specific gravity of 1.5 t/m^3. The median diameter of different grains was 0.42mm, 0.095mm and 0.15mm in sequence. The discharge process was simplified as three durations. The durations in turn may be one flood discharge duration between two small discharge durations (small-big-small), or one small discharge duration between two flood ones (big-small-big). Three discharges (from 0.5 – 1.5m^3/h) and three slope (from 0.6‰ – 15‰) were adopted. The parameters of the experiments are shown in Table 1.

All channels were shaped by clear water freely. A straight channel with a triangle cross-section was initialized before each run. The time of each discharge process was long enough for the river to reach a state of dynamic equilibrium. The range of Reynolds number was 1500 – 14000 according to the average of all cross-sections.

3 RESULTS AND ANALYSIS

3.1 On Original Channel

According to the experiments, different discharge process may lead to the change of channel pattern, which initially began at duration 1—on the same original channel, different flows may cause variable channel morphologies.

The rivers formed were firstly based on riverbed material. In runs 5, 6 for the coarsest sand, little sinuous river was formed. With the increasing of median diameter of sand, rivers with more sinuous thalweg can be gotten in runs 1, 2. Since the relative small density, coal particle was too light to resist the shaping of flow; rivers with coal particles had few steady bars, and more characteristics of braided rivers were formed in run 7 and 8, duration 1.

The amount of discharge will also influence the channel morphologies. Three couple runs, 1 and 2, 5 and 6,

Table 1 Parameters of experiments

Run	Grain	d_{50} (mm)	Slope (‰)	Duration 1		Duration 2		Duration 3	
				Discharge (m^3/h)	Time (h)	Discharge (m^3/h)	Time (h)	Discharge (m^3/h)	Time (h)
1	Sand	0.095	1.0	0.75	312	1.50	106	0.75	48
2	Sand	0.095	1.0	1.50	218	0.75	239	1.50	214
3	Sand	0.095	0.6	0.75	265	1.50	191	0.75	288
4	Sand	0.095	1.5	0.75	219	1.50	196	0.75	142
5	Sand	0.420	1.0	0.75	198	1.50	203	0.75	201
6	Sand	0.420	1.0	1.50	213	0.75	200	1.50	189
7	Coal particle	0.150	1.0	0.50	200	0.75	198	0.50	200
8	Coal particle	0.150	1.5	0.75	100	0.50	97	0.75	89

7 and 8, had the same experimental conditions except discharge process. According to the appearance, channel made by flood was wider and larger in cross-section area, at the meantime the river′s width-depth-ratio decreased, the river tended to be shallow in the whole. Thalwegs and main flows were more distinct in rivers with little discharge than that with flood discharge. The radius of bends were also different, in rivers with flood discharge, the radius was 17.15% – 31.2% bigger than that with little discharge.

3.2 Influence of Small Discharge Duration

In the three runs (runs 2, 6, 8) with the discharge process of "big-small-big", the change of the river morphology in the end of the first duration and the end of the third duration was very small. It was observed that the bank-lines widened in a very limited extent and tiny change of morphologies in cross-sections was taken place.

The final bank lines in different durations of run 2 were shown in Fig. 2. It was found that the later channels coincided with the original channel in the final of duration 1.

3.3 Influence of Flood Discharge Duration

In the five experiments (runs 1, 3, 4, 5, 7) with the discharge process of "small-big-small", distinct change appeared in the rivers between the first duration and the third duration. As shown in Fig. 2, the average width of channel may increase 41.4% after the flood discharge duration in run 1.

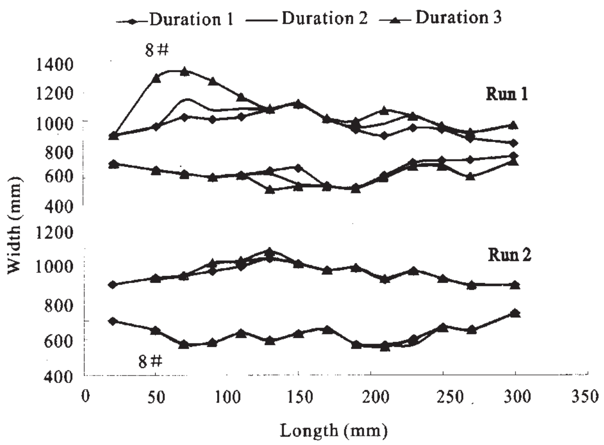

Fig. 2 Final bank line of different durations (runs 1, 2)

The lateral morphology of rivers also changed during the process of "small-big-small". Fig. 3 shows the final cross-section topography in different durations in runs 1, 3 and 4. With the procedure of different discharge process, the channel changed both in width, width-depth-ratio and the position of thalwegs. In cross-section 6#, the position of the bottom transfered to and fro with extend of more than 0.2m. Changes happened both in duration 2 and duration 3, compared to the topography in cross-section 8#, run 1, the channel was extended to more than 200mm in duration 3; and a distinct erosion and deposition can be seen in cross-section 4#, run 4.

Phenomena in Run 1 were typical and end with transformation of channel patterns. Beginning with a relatively small discharge ($0.75m^3/h$) in duration 1, no distinct mainflow was formed when the river had been stabilized; the channel pattern was straight with some characteristics of debauchery. In duration 2, the channel expanded but no distinct thalweg appeared. In the duration 3, when the discharge reduced back to $0.75m^3/h$, the river went through the thalweg formed in duration 2, shoals under water in duration 2 came out of the water. Thalweg and lateral current appeared. With time going on, the phenomenon of deposition in inner bank and erosion in outer bank also became distinct. Sinuosity of the river increased to more than 1.5 especially in the lower river. The curve ratio kept increasing and the river had expanded to the edge of the flume near cross-section 8# in the lower river, experiment one was forced to terminate after 48 hours of duration 3. Fig. 4 was the final morphology after the "small-big-small" discharge process and a roughly meandering river was formed.

3.4 Influence of Channel Conditions

According to the experiments, the influence of discharge process should also be based on the channel conditions especially the riverbed constitution and channel slope.

3.4.1 Riverbed constitution

Because the channel was formed in the uniform experimental sands, the riverbed conditions were mainly decided by which sand we chose. Compared to the 8 experimental rivers in duration 3, with the different river bed constitutes, the relationship between flow and channel may be shown as follows (Fig. 5):

(1) Channels changed minutely in the small discharge duration, and flow was restricted by channel (run 5).

(2) Channels evolved following the original channel, the channel restricted flow, at the mean time reshaped by the flow (run 1).

(3) Rivers evolved far beyond the original channel and were fully reshaped (run 7).

It can be concluded that with the increase of mean diameter of sands, which means a bigger stability, the restrictive acting of channel to flow increases, at the mean time, the reshaping acting of flow to channel decreases correspondingly. Run 5 has the thickest constitution of riverbed, the reshaping of flow to channel in duration 3 was the smallest. But in coal particle, the channel cannot resist the reshaping of flows, and the change was great.

3.4.2 Slope

As shown in Fig. 2, three runs (runs 1, 3, 4), with the channel slopes of 1.0‰, 0.6‰ and 1.5‰ respectively, have different channel topographies after duration 1, and after the full discharge process, the discrepancies enhanced. The change in run 3 was relative small, but in run 1, the change can be distinct, even typical characteristic of meandering river appeared in the lower reach (Fig. 4).

3.5 Flood Duration and Stability of Bars

The influence of discharge process on channel pattern, which mainly means the influence of flood duration in our experiments, may be caused by two main factors: the change in flood duration and the stability of bars.

In runs with the discharge process of "small-big-small", after the flood discharge duration, all rivers changed distinctly. The emergence of flood discharge, whether change the channel's morphology directly, or

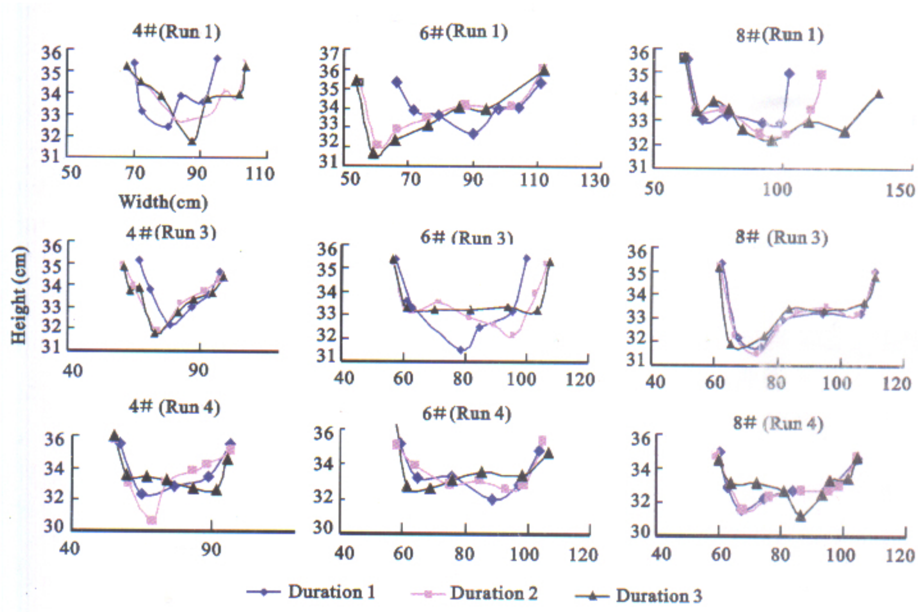

Fig. 3 Final cross-section topography in different durations

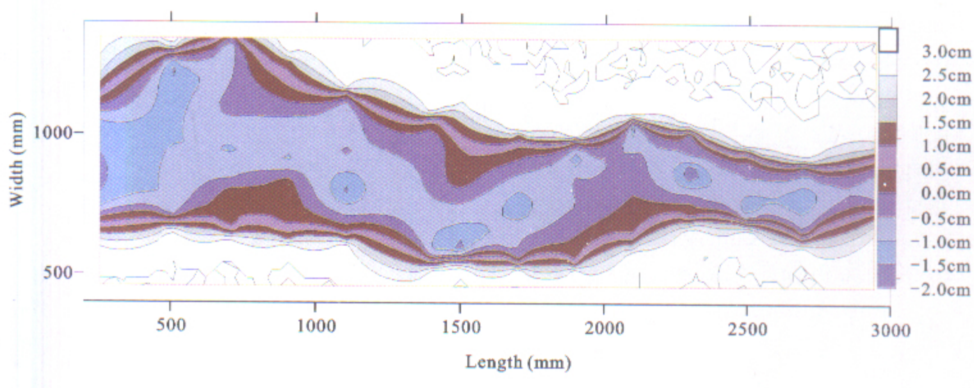

Fig. 4 Final morphology in run 1, duration 3

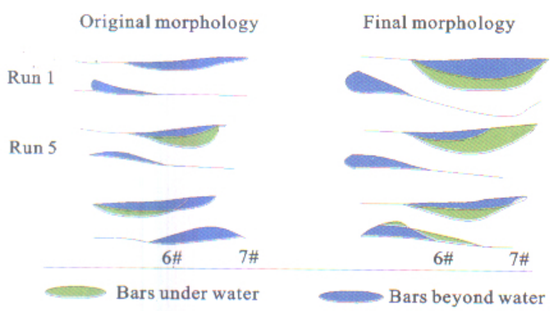

Fig. 5 Sketches of channel change in duration 3

change the physical characteristic or stress structure of channels by means of erosion, moisten, so as to break the equilibrium formed in the small discharge duration.

When the discharge decreased back to small discharge in duration 3, flow and channel had to begin a new process of adjusting from un-equilibrium to equilibrium, and channel pattern transformation may appear during this process.

The key of the influence may lie in the stability of bars formed in the flood duration. According to the experiments, most rivers in flood duration had sinuous thelwags, distinct or not. When the discharge decreased back to be small, flows fall into the thelwags, bars emerged from underwater, and a transitory meandering river formed. The bars were surely to be reshaped by the new small flow, some were distinguished, but because of the different capacities of shaping of flood and small discharge, most of them existed in some extend. When the transitory meandering river can keep meandering, channel pattern transformation emerged, such as the river in run 1.

According to the analysis of experiments, the intrinsic result of discharge process is the same as a reshaped channel to the same flow, which means the influence of original channel morphology on channel patterns. On meandering river, PRUS-CHCINSKI (1966) believed that the existence of a bend is also influenced by the bends in sequence, and YANG (1971) believed that to maintain a bend needs less energy than to form one.

In recent, on the basis of bankfull specific stream, the proposed distinction between meandering and braided river channel patterns was studied, LEWIN (2001) analyzed and rejected this point, and concluded that the use of a single-stage stream power measure and bed material size alone is unlikely to achieve. We believe this may be the result of neglecting the influence of channel itself.

4 CONCLUSIONS

(1) On the same original channel, different discharges and different riverbed materials will end up with different river morphologies, including thalwegs and radius of bends.

(2) Different discharge processes may reshape the river and end up with different river morphologies. The influence of discharge process was mainly laid on the flood discharge. In the discharge process of "big-small-big", the river morphology kept nearly unchanged. After the flood discharge duration in process of "small-big-small", channel shaped by small discharge duration may be fully reformed; even channel pattern can be transformed when the conditions were appropriate.

(3) The extension of this influence is also decided by the river conditions itself including the channel conditions and the channel slope. For different river conditions, this influence may be different.

(4) The key of the influence may lie in the stability of bars formed by the flood duration, which means the influence of original channel morphology on channel patterns. Neglecting the influence of channel itself will hamper the understanding of channel patterns.

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