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River Channel Change with Time: An Example

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ABSTRACT

Monumented channel cross sections were resurveyed over a period of 20 yrs (1953 to 1972) to determine the amount and kind of change of channel area and position on a 3.7-sq-mi basin, Watts Branch near Rockville, Maryland. For the first 12 yrs, the channel progressively but slowly became smaller as urbanization of the basin gradually proceeded. After 1966, a threshold of change apparently was passed and, probably as a result of an increased rate of land alteration upstream, large amounts of sediment were deposited within the channel and overbank. The number of floods exceeding channel capacity increased dramatically from an average of two to more than ten per year. Simultaneously, the channel area began to increase. Despite the trend toward increasing cross-sectional area, the net result after 20 yrs was a channel smaller by 20 percent than it had been originally. Urbanization did not alter the rate of channel migration.

GENERAL STATEMENT

When one observes the many and great changes that have occurred in some landscapes since the beginning of the Pleistocene, he is inclined to the belief that a longer period of time was involved than he had been led to believe. Death Valley is an example where lakes of great depth once existed in a locality that is now a true desert. Segments of giant fans, some faulted, have been built out on the dried-up lake basin. Some large boulders on the fan surface are so deeply weathered that a hammer blow will reduce them to grus.

We are rapidly learning that certain geomorphic processes are much more rapid than we have been wont to believe. But only recently have geologists attempted to determine by actual measurement process rates formerly the subject of general reasoning or speculation. Such measurement programs have documented the fact that rates of landscape change are greater than had earlier been suspected.

This address is the result of a modest scheme I began two decades ago, in order to observe changes in the channel of a small river, thinking at the outset that the results might become of interest to the generation of my grandchildren, but not to my colleagues. I soon found, however, that the changes being observed occurred far more rapidly than I had expected, and the healing, the hiding, or the obscuration of such changes was much more complete and misleading than I had supposed. The present report

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presents the results of consecutive, repetitive measurement of channel change in a small river in a humid-temperate climate, and some thoughts on the need for more such observations.

OBSERVATION PROGRAM

The river is Watts Branch, a small tributary of the Potomac River, north of Washington, D.C., arising in the rolling topography of the Piedmont which receives an annual precipitation of 44 in. The place of observation is where the small perennial stream meanders in a flat-floored valley. The drainage area is 3.7 sq mi. The purpose of the observational program was to describe the process and rate of lateral migration of the channel, the construction of point bars and flood plain, and the effects of meander curves on the process and rate. That part of the observational program discussed here consisted of 14 monumented cross sections which have been surveyed about every other year for 20 yrs, 1953 through 1972, inclusive. Much was learned on the subjects mentioned as the original purposes, but unexpectedly, the program has yielded some quantitative data on the effects of progressive urbanization in a small river basin.

An outline and location map of the basin is included in Figure 1. Figure 2 presents planimetric maps for 1953, 1959, and 1972, and shows the reach of the stream where the cross sections were established. As can be seen, the sections were located to represent a variety of positions relative to the meander curves and straight reaches of the river. Each cross section was monumented at both ends by ½-in. steel rods or pins usually 2½ ft long driven into the ground so that initially the top was a few inches below the surface. Though this made the rods less easy to relocate, they were not subject to disturbance either by vandals or by the mowing machine which, during the first few years, was used to cut the hay on the valley flat. A few bench marks were also established, usually a large nail or lag screw near the base of a tree. Distances from bench marks to some pins and between pins were measured with tapes. The triangulation network of distances was used to go progressively from exposed bench marks to individual pins and thence from located pins to those still hidden. Two tapes were held at known points and the intersection at recorded distances was the location of an as yet uncovered pin. At that location, a shovel was sliced beneath the sod in attempts to find the subsurface steel.

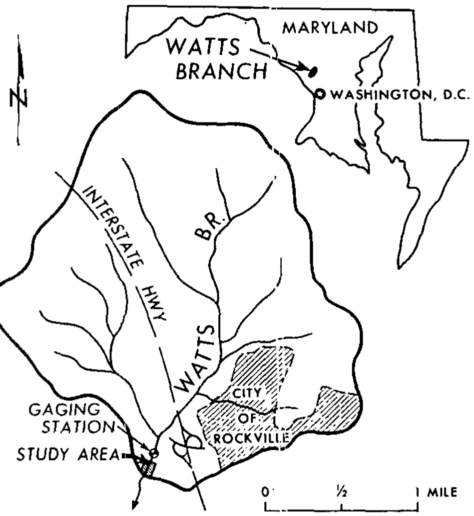


Figure 1. Planimetric and location maps of the basin of Watts Branch near Rockville, Maryland, above the study reach.

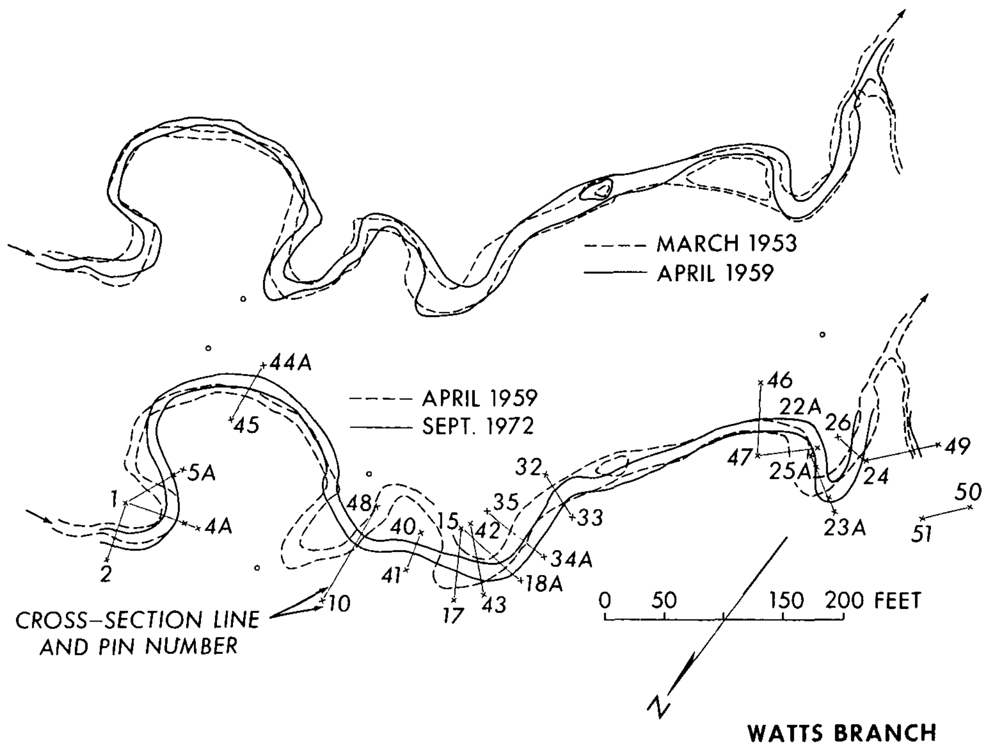


Figure 2. Planimetric maps of the study reach of Watts Branch for successive surveys. Upper, channel configuration in 1953 (dashed line) and 1959 (solid line); lower, 1959 (dashed line), and 1972 (full line) with location of cross sections.

For the first few years, the task of locating the pins was simple. The pastured field was a greensward of grass, and the pins lay only a few inches below the sod. In later years, the farm was sold, stock was removed, brush and weeds became rampant, and silt resulting from upstream development was deposited in quantity. Thus the digging required to find each pin became quite onerous.

Lateral migration of the river eventually exposed and then destroyed certain pins. Usually the cross section was preserved by establishment of a new pin on the same line. As the threat of urbanization became apparent, some new cross sections were added, especially across a small tributary where housing development was likely. This accounts for the fact that some cross sections were established later than others, and have a shorter record.

Because of this research program, I had established a U.S. Geological Survey stream-gaging station on Watts Branch, a few hundred feet upstream of the measurement reach. Thus flow records are available for most of the period of channel observation.

CHARACTERISTICS OF VALLEY AND STREAM

In the study area on the Vier's farm, 900 ft downstream of Maryland Highway 28, the valley floor is nearly flat and is 250 ft wide. The channel is about 25 ft wide at the top, and this is the width of the flow at bankfull stage. At normal low water, the channel is about 12 ft wide. The channel banks are 2 to 4 ft high, and the depth of water at low flow is about 0.5 ft. The mean annual discharge is 3.2 cu ft per second (cfs); and at a straight and natural section, the bankfull discharge was 220 cfs before the effect of urbanization. Since that time, the average channel capacity at bankfull has been somewhat reduced, as will be explained. The gradient through the study reach is 0.0081. The bed alternates in elevation through a series of pools and riffles and is generally composed of gravel having a median size of 16 mm.

Bedrock underlying the valley floor is Wissahickon Schist, the surface of which lies only 6 to 7 ft below the surface and is remarkably flat. In places, gravelly regolith a few feet thick lies on fresh schist, but generally the bedrock is overlain by a foot of gray or mottled coarse gravel which, in turn, is covered with 5 ft of silt or clayey silt. The lower foot of the silt exposed in stream banks is gray, appears clayey in texture, and owing to the reducing environment below the water table, resembles a gley soil. The topography of the bedrock surface was exposed in a trench cut in 1961 for a sanitary sewer down the length of the valley. The design engineers must have sought no geologic information, for the sewer trench was blasted 6 to 7 ft into the bedrock for the full length of the line.

Figure 3. Watts Branch in May 1953, looking upstream toward area where cross sections were established. Staff gage at natural section in right foreground and where bankfull stage was determined.

Figure 4. View downstream in 1959 at section 44A–45 for comparison with Figure 5.

Figure 5. 1971 view of same reach shown in Figure 4. Note greater prominence of blocks of sod falling off left bank. Also growth of willow brush on point bar to right.

Construction of the sewer trench destroyed some of the pins of the original cross sections and necessitated re-establishment of sections in unaltered portions of the reach, thus shortening the repetitive record significantly. The construction also cut off a meander bend between sections 44A–45 and 15–17, shortening the channel length by 130 ft.

The photographs of Figures 3 through 9 show the character of the stream and valley and the visual changes that occurred. Note especially the houses appearing in the background of the later pictures.

PROCESS AND RATE OF CHANNEL MIGRATION

The successive maps (Fig. 2) show that channel movement occurs more or less at all places, greater on the curves than in straight reaches. In two decades, there were several

Figure 6. Downvalley view near section 1–2 in 1953. Compare with Figure 7.

Figure 7. 1971 view near section 1–2. Note flood debris in left foreground, and willow brush. New housing under construction in background.

Figure 8. Closeup of retreating bank near section 44A–45 in 1971. Iron pin originally set well away from bank has been exposed by bank retreat and is now bent over into channel. Sod lumps undercut by bank retreat fall into channel.

Figure 9. Stream bank which had been subject to ice crystal growth and loosening of surface layer. A moderate stream rise has removed this prepared material in lower third of the bank leaving a fresh surface of silt and showing the main mechanism of bank retreat.

places where the lateral migration amounted to more than the width of the channel.

The process by which this motion takes place is twofold, one erosional and one depositional. The erosion of a bank is not the result of erosion by high-velocity water, whether in a concave bank on a curve or in a straight section. Rather, for effective erosion to occur, the material must be loosened—which in this stream, is done by formation of ice crystals in winter. Crystals push soil particles out from a vertical bank of silt. When the ice crystals melt, usually on the day following formation, the grains of silt which cling to the points of growing crystals drop vertically and accumulate as a loosely structured debris cone at the base of the vertical bank. This process has been documented by Wolman (1959). The major floods occur in summer as a result of thunderstorm rain and are not effective in lateral erosion. Small rises in flow, separated by periods of freeze and thaw, are effective agents in channel migration. Details of point bar stratigraphy and its development from small increments of deposited sediments on point bars have been previously published (Leopold and others, 1964, p. 324–326).

CHANGES IN CHANNEL CROSS SECTION

Point bar growth into the channel for the first decade kept pace with recession of the opposite bank, maintaining approximately the same channel width. However, the increase in sediment load associated with urbanization in the later part of the record resulted in building of higher banks, the channel cross section becoming less trapezoidal and more rectangular. This has caused a narrowing of the top width of the channel. This can be seen in the net changes of channel dimensions presented in Table 1. For each channel cross section, the dimensions are given at the time of first survey and in 1972. In interpreting the data in the table, it must be emphasized that there is considerable latitude in choice of the bankfull level of a given cross section, and the choice of this level determines all dimensions except mean bed elevation.

The cross sections presented in Figure 10 were chosen from the 14 available to represent

TABLE 1. CHANNEL OF WATTS BRANCH: DIMENSIONS AND ELEVATIONS AT TIME OF FIRST SURVEY AND IN 1972*

Section	Year established	Bed elevation (ft)		Change in bed elevation (ft)	Channel width (ft)		Channel depth (ft)		Bank elevation (ft)		Change in bank elevation (ft)	Channel cross-sectional area (ft)	
		original	1972		original	1972	original	1972	original	1972		original	1972
1-2	1953	105.3	105.4	+0.1	17.0	19.4	2.7	4.5	108.0	109.9	+1.9	44.5	76.6
1-4	1953	104.0	105.5	+1.5	27.4	19.5	5.0	4.3	109.0	109.8	+0.8	94.4	69.0
1-5	1953	106.4	105.4	-1.0	20.3	19.8	2.2	3.9	108.6	109.3	+0.7	41.6	54.0
44A-45	1961	105.3	105.3	0	25.5	19.6	2.2	4.7	107.5	108.5	+1.0	30.4	48.2
48-10	1962	103.7	104.0	+0.3	17.7	21.9	2.1	3.7	105.8	107.7	+1.9	20.5	51.0
40-41	1962	103.8	103.6	-0.2	16.0	13.6	2.2	3.4	106.0	107.0	+1.0	31.7	38.0
15-17	1953	101.5	102.9	+1.4	35.2	23.1	4.5	3.6	106.0	106.5	+0.5	133.0	59.5
42-43	1962	103.0	104.3	+1.3	55.[illegible]	22.3	3.0	3.1	106.0	107.4	+1.4	100.0	67.4
15-18A	1953	103.0	103.5	+0.5	33.4	17.1	3.3	4.2	106.3	107.2	+1.2	85.0	50.5
33-34A	1958	103.0	103.3	+0.3	37.8	22.4	3.5	3.4	106.5	106.7	+0.2	88.1	55.0
32-33	1956	102.9	103.0	+0.1	25.5	19.6	3.1	4.0	106.0	107.0	+1.0	52.1	63.9
46-47	1961	102.5	102.5	0	34.7	13.6	2.9	3.7	105.4	106.2	+0.8	50.1	43.4
22A-47	1953	102.1	102.5	+0.4	47.9	22.5	2.3	3.4	104.4	105.9	+1.5	55.7	..
26-24	1953	101.4	102.4	+1.0	30.3	17.5	3.1	2.5	104.5	104.9	+0.4	58.2	37.0
Averages					30.2	19.5	3.0	3.7				63.2	55.0
Averages for 20-yr record only					30.[illegible]	19.8	3.3	3.8				73.2	58.0

* *Elevations refer to an arbitrary datum.*

two types of change. Section 44A–45 is on a long gentle curve and shows considerable migration toward the concave bank. Section 1–2 is at the end of a straight reach just upstream of a meander curve. Little lateral migration occurred there. Location of these sections relative to the plan of the study reach can be seen on Figure 2.

In 1953 on the left bank of section 1–2, there was a distinct level or berm at elevation 108. In designating the level of top of channel or bankfull, I followed the general rule that the lowest extensive flat area or definite berm on either bank would be designated. Thus, in section 1–2, the elevation of bankfull stage was in 1953, 108.0; in 1966, 108.4; and 1972, 109.9. In making the choice of top of channel, several successive cross sections were inspected simultaneously and the choices attempted to maintain a continuity in the observed changes through the whole record.

Looking first at the net changes from date of establishment to 1972 for all cross sections, Table 1 shows that the average area of channel decreased 13 percent and for only those sections having the full 20 yrs of data, 21 percent. Channel depth increased one-half foot, but this was due to an increase in the height of the banks, not to deepening of the bed. Without exception, all sections showed an increase in elevation of river banks (Table 1, col. 12). Mean bed elevation rose slightly at 10 of the 14 sections. Because width at top of the channel decreased by about one-third, it can be seen that the sections became more rectangular, smaller, deeper, and narrower. The sections illustrated show these features and demonstrate that deposition occurred less as overbank than as in-channel deposits.

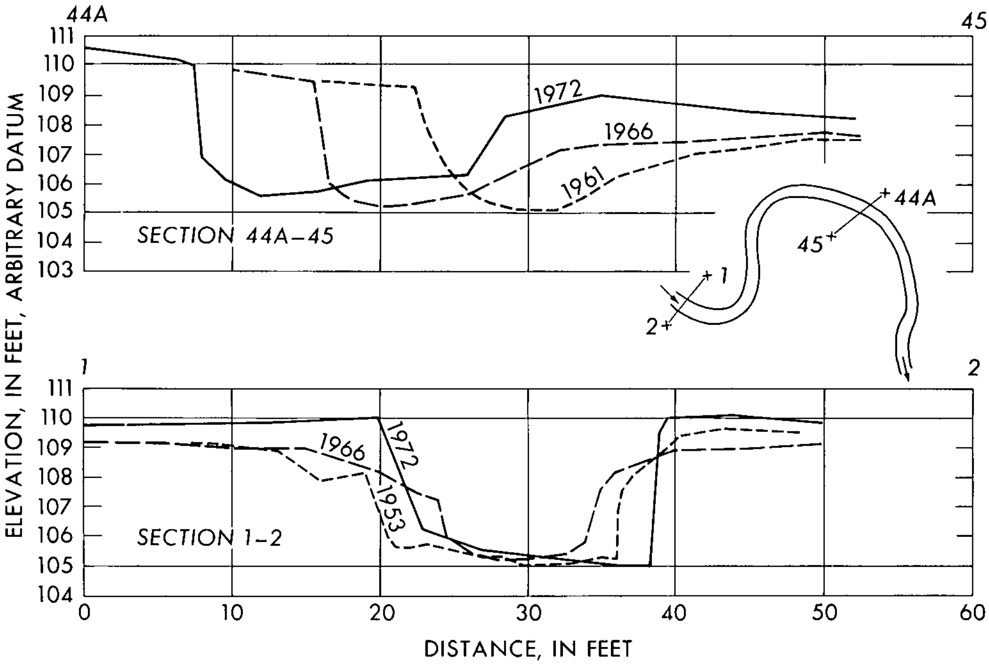


Figure 10. Selected cross sections of the channel of Watts Branch at original date of survey, an intermediate time, and 1972, section 44A–45 (upper) and section 1–2 (lower). Planimetric sketch (center) shows location of sections relative to channel bends.

Deposition in the channel was not confined to point bars convex in plan view. Section 15–17 (Fig. 11), for example progressively built both banks channelward, increasing the steepness at the same time. This occurred despite the fact that the section is located in the upstream part of a meander curve both before and after the artificial cutoff made by the sewer construction upstream in 1961.

To demonstrate that successive small rises, not large floods, account for the progressive alteration of channel, Figure 11 shows two successive surveys of section 1–4A in 1972. The surveys were made in April and September; between those surveys (in August), the largest flood of record occurred, associated with Hurricane Agnes. The section was changed so little that differences are within the usual limit of survey accuracy.

Figure 12 shows an example in section 35–34A of how a locally wide place, formerly a muddy point bar, built up to considerable height as the channel moved laterally. In the same figure, section 46–47 is an example of a place just upstream of a meander bend where the channel migrated not at all but built its banks higher by deposition, decreasing the width/depth ratio of bankfull stage.

EFFECTS OF URBANIZATION

The change in average values obscures some salient details, the most important of which is the marked alteration in stream behavior that began about 1966. Channel cross-

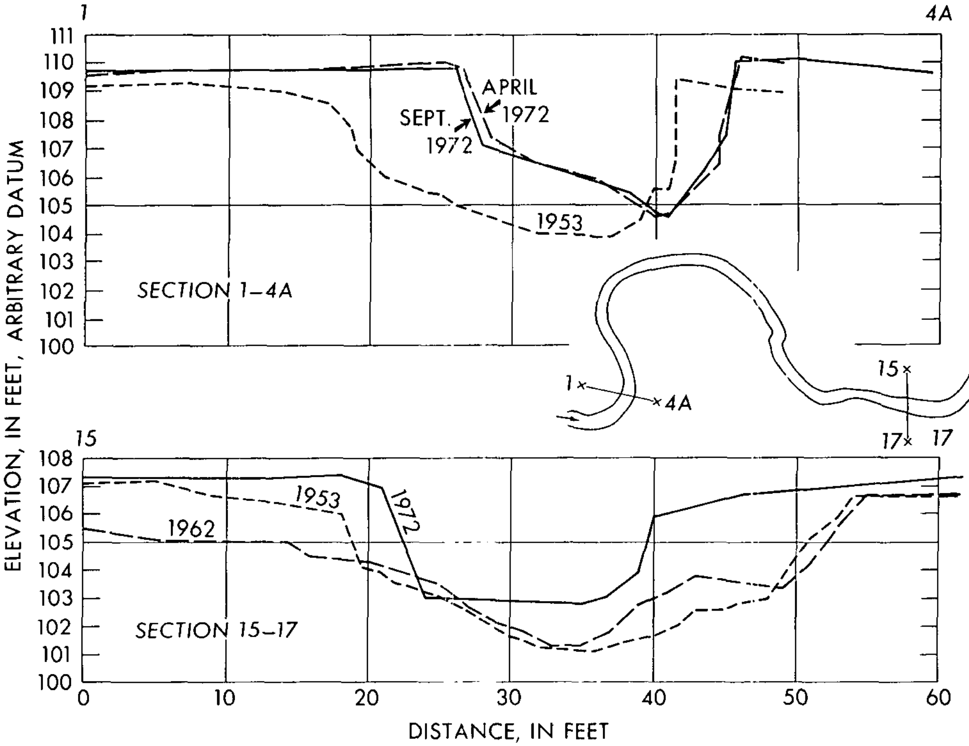


Figure 11. Selected cross sections of the channel of Watts Branch, section 1–4A (upper) and section 15–17 (lower).

sectional area for two sections is plotted against time in the upper graphs of Figure 13. In 1967 at section 44A–45, a large block of turf fell into the channel from the concave bank and caused a temporary decrease in local cross-sectional area and a rise in bed elevation. Otherwise, section 44A–45 shows a tendency for some increase in area in the years prior to 1967, and section 1–2 shows some decrease in area. From 1966 to 1972, the area increased markedly in nearly all sections of which the two depicted are representative. Most sections shared with 1–2 a tendency for some decrease in area prior to 1967.

The amounts of channel erosion and deposition from one survey to another are shown in the lower part of Figure 13 for the same sections. If the channel is migrating laterally, both erosion and deposition are large as in 44A–45. An excess of erosion over deposition in the same period causes an increase in cross-sectional area.

These progressive changes with time can be attributed to the various consequences of progressive urbanization of the basin. Though more sophisticated measures of degree of urbanization may be drawn from study of aerial photos, a simple measure is the number of buildings shown on a 7½′ topographic map published by the U.S. Geological Survey. Three editions of the Rockville, Maryland, sheet were available, and on each the number of buildings shown was counted within the basin of Watts Branch. The results (Fig. 14) show a nearly linear increase from 1954 to 1965. The increase in buildings shown was fivefold. Until 1965, not more than three houses could be seen from that part of the valley

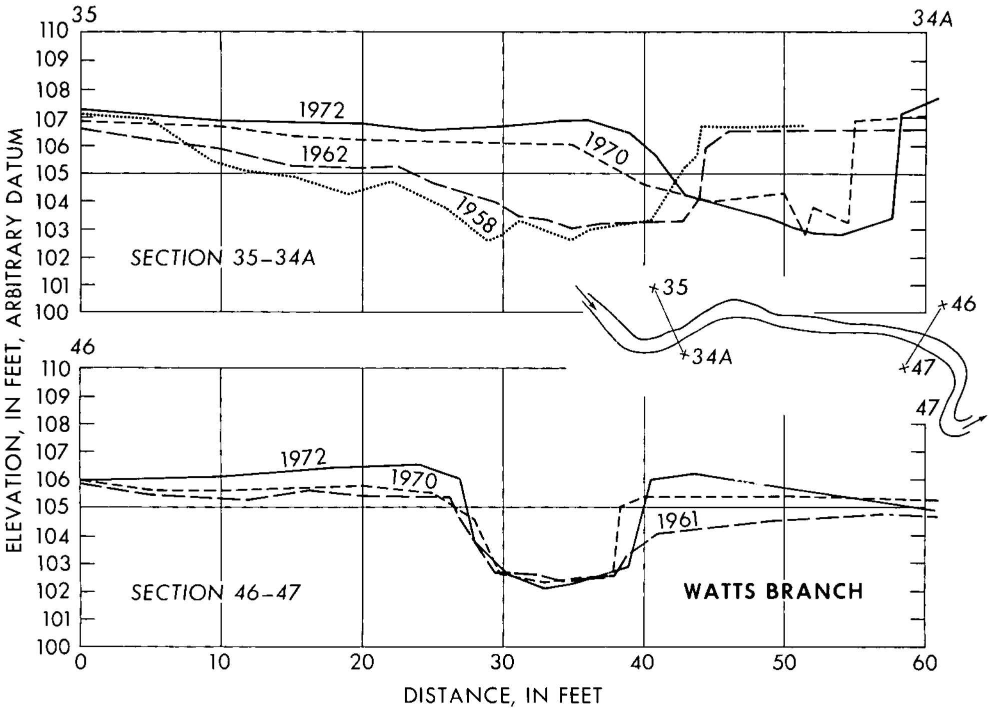


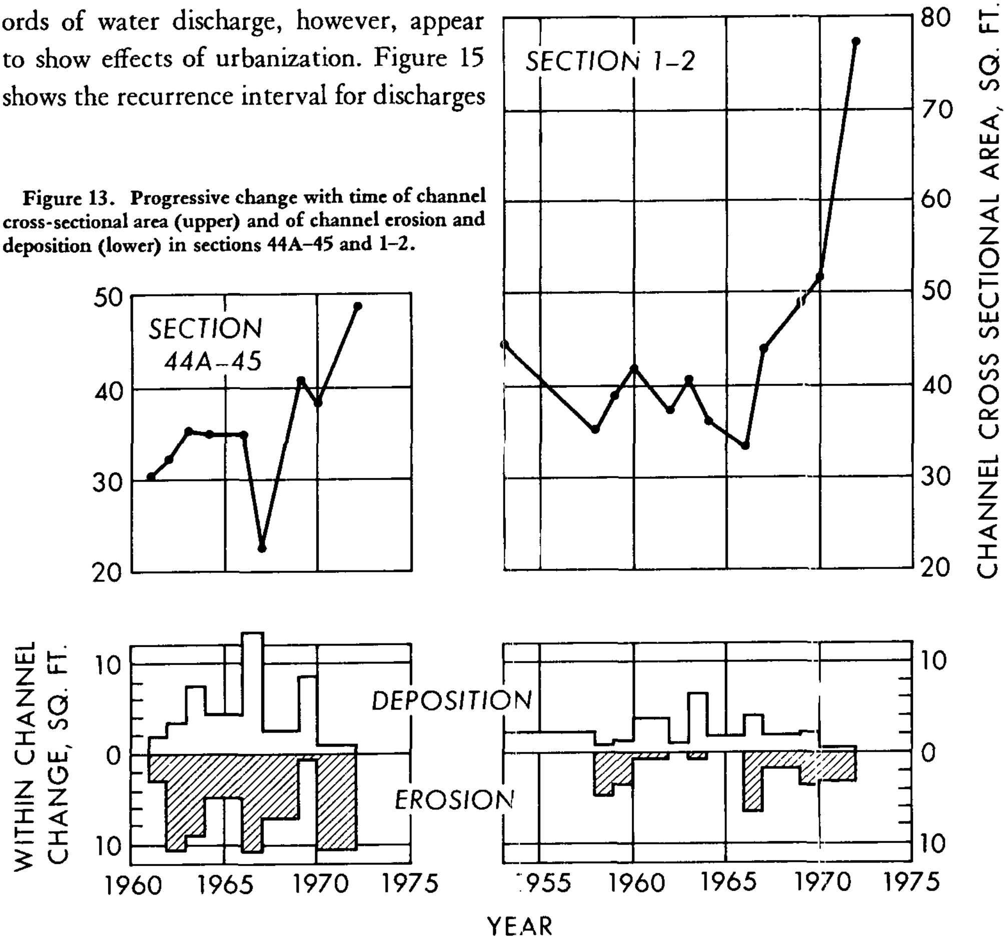
Figure 12. Selected cross sections of channel of Watts Branch, section 35–34A (upper) and section 46–47 (lower).

where the cross sections were established. In 1972, not less than 40 houses can be seen from the same place. When the farm on which the measurements were made was sold for development, grazing ceased and the valley flat became covered with willows near the channel and heavy herbaceous cover elsewhere. This increase in vegetation may have had some tendency to trap sediment during periods of overflow, but the massive deposits within the channel where such vegetation does not exist suggest that a large increase in sediment load rather than vegetation is the major cause of channel and overbank deposits.

During the period of observation, several large building complexes were developed in the upper part of the basin. A junior college and the county school administration headquarters were built, both with large paved parking areas. Much construction occurred within the city of Rockville. An interstate highway was built through the watershed area, including a cloverleaf interchange just upstream of the study reach.

Though I have taken enough suspended load samples in Watts Branch to develop a usable rating curve, the records are not sufficiently complete to show any change in load concentration for a given discharge. Records of water discharge, however, appear to show effects of urbanization. Figure 15 shows the recurrence interval for discharges

Figure 13. Progressive change with time of channel cross-sectional area (upper) and of channel erosion and deposition (lower) in sections 44A–45 and 1–2.



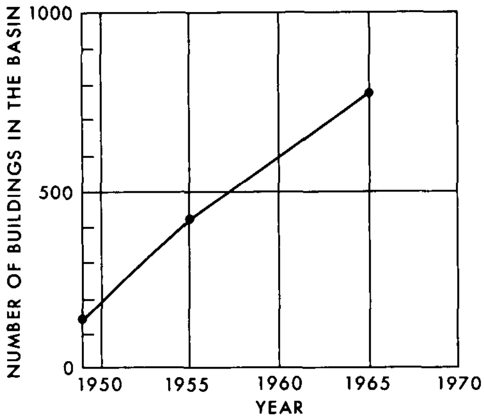


Figure 14. Growth in urbanization in 3.7-sq-mi basin of Watts Branch indicated by the number of individual buildings shown on three successive editions of U.S. Geological Survey topographic maps.

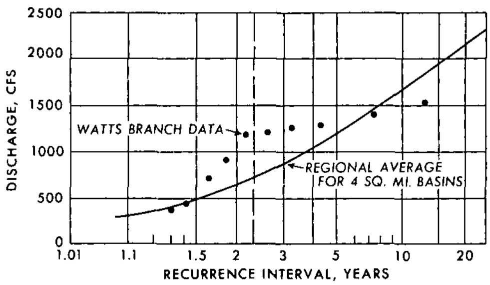


Figure 15. Flood-frequency data for Watts Branch at Rockville; solid line shows the regional average for basins of similar size.

of various sizes. The regional curve representing basins of the same size was taken from the flood frequency study of North Atlantic Slope Basins (Tice, 1968). The Watts Branch data represent annual floods recorded at the U.S. Geological Survey gaging station near the study reach. The highest flows in the short record are commensurate with the regional expectancy, but flows of recurrence intervals of 1.5 to 5 yrs exceed the regional average by more than twofold. The mean annual flood for Watts Branch in the 12 yrs of record was 913 cfs, whereas the regional mean annual flood for basins of the same size is 700 cfs.

The best evidence that the deposition in the channel and on the valley floor and the observed flood experience are interrelated with urbanization is in the coincidence in time that changes took place.

Figure 16 shows the number of flows exceeding two chosen discharge values as a function of time. The figure 220 cfs was used because it represents the bankfull discharge at a straight and natural section when the observations began. As one would expect from previous studies of bankfull stage, this discharge might be expected to be equalled or exceeded about twice each year in a natural channel. Beginning in 1965, this expected number increased dramatically. So also did the number of flows exceeding 1,000 cfs, picked merely as illustrative of flows considerably above bankfull.

The frequency at which a stream overflows its banks is a function both of channel capacity and of frequency of flows of a given size. In the early part of the record, the channel cross-sectional area was slowly but progressively decreasing. In the later part of the record, the number of flows equal to or exceeding a given discharge increased markedly. On the basis of the average net decrease of channel area from the beginning to the end of the record, assuming that velocity at any given discharge did not change, the number of discharges that flowed overbank in the study reach was increased somewhat, as estimated in Table 2.

During this record on this stream, it appears that the effect of urbanization on flow

TABLE 2. NUMBER OF FLOW EVENTS EXCEEDING SPECIFIC LIMITS

Year	Estimated bankfull capacity (cfs)	Number of flows exceeding 220 cfs	Number of flows exceeding channel capacity
1958	220	3	3
1959	220	2	2
1960	215	1	1
1961	215	1	1
1962	210	0	0
1963	210	3	3
1964	205	1	1
1965	205	4	4
1966	200	3	3
1967	200	4	5
1968	195	5	7
1969	190	11	11

TABLE 3. ELEVATION OF GROUND SURFACE AND OF REFERENCE MARKERS LOCATED ON THE FLOOD PLAIN

	1959		1972		
Pin no.	Pin elevation (ft)	Ground surface elevation (ft)	Pin elevation (ft)	Ground surface elevation (ft)	Deposition in 13 years (ft)
1	111.86	111.90	111.82	112.70	0.8 ± 0.1
2	111.45	111.49	111.28	112.52	1.0 ± 0.2
3	111.31	111.35	111.14	111.94	0.6 ± 0.2

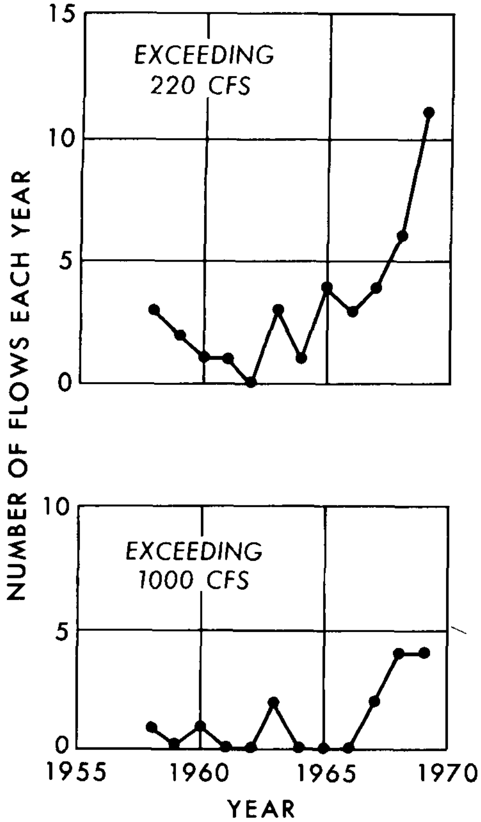


Figure 16. Number of flows equal to or exceeding two discharges, Watts Branch at Rockville, Maryland, as a function of time.

frequency is quantitatively a much more important determinant of frequency of overbank flooding than is the change of channel capacity.

Figure 17 presents data on ground-surface elevation at pins marking the cross sections. Nearly without exception, these are located 10 ft or more away from the channel. The vertical scale of elevation is relative, so that the data are merely separated enough to be read. Data are plotted to the nearest 0.1 ft which is about the random variation resulting from particular placement of the rod during the survey.

Note that there was no overbank deposition accumulating at any pin location in the first 10 to 12 yrs of record. But beginning in 1966, all showed deposition which grew progressively, and even at an increasing rate at some pins. There is, therefore, a coincidence in time of overbank deposition, increase in area of channel cross section, and increase in the number of high flows per year.

The deposition was not confined to the zone immediately next to the channel, but apparently occurred over the whole valley floor. Two types of evidence attest this. There is no obvious or apparent natural levee being developed near the stream margin. Direct evidence is available from the resurvey of three iron pins driven in 1959 and located on a line across the valley floor for the express purpose of determining the importance of overbank deposition away from the channel. These were ½-in. iron rods, 3 ft long, placed respectively 40, 117, and 165 ft from the stream where the river is near one side of the valley. The valley flat is at the place 350 ft wide. The pins were driven so the tops were 0.04 ft (½ in.) below the surface. The local ground surface was determined by laying a 6-in. ruler on the ground and using its elevation as the mean ground elevation at that place.

These pins were relocated and resurveyed for the first time in October 1972. The elevations are shown in Table 3.

For some reason, the pin elevations in 1972 were lower by as much as 0.17 ft than when installed, which probably was the result of a survey error in 1959. Nevertheless, the error is considerably smaller than the amount of deposition. I have listed in Table 3 the net deposition and followed it by a plus-or-minus figure representing the uncertainty. The conclusion is clear, however, that deposition over the valley floor was more than one-half foot in the 13 yrs, and from the cross-section data, most must have occurred since 1966.

In the first decade of observation, the channel area slowly contracted, and the spate of channel enlargement after 1966 had not by 1972 overcome the average decrease in channel area in the whole record. But the reversal from channel contraction to enlargement as the effects of urbanization intensify is what would be expected from the study of Hammer

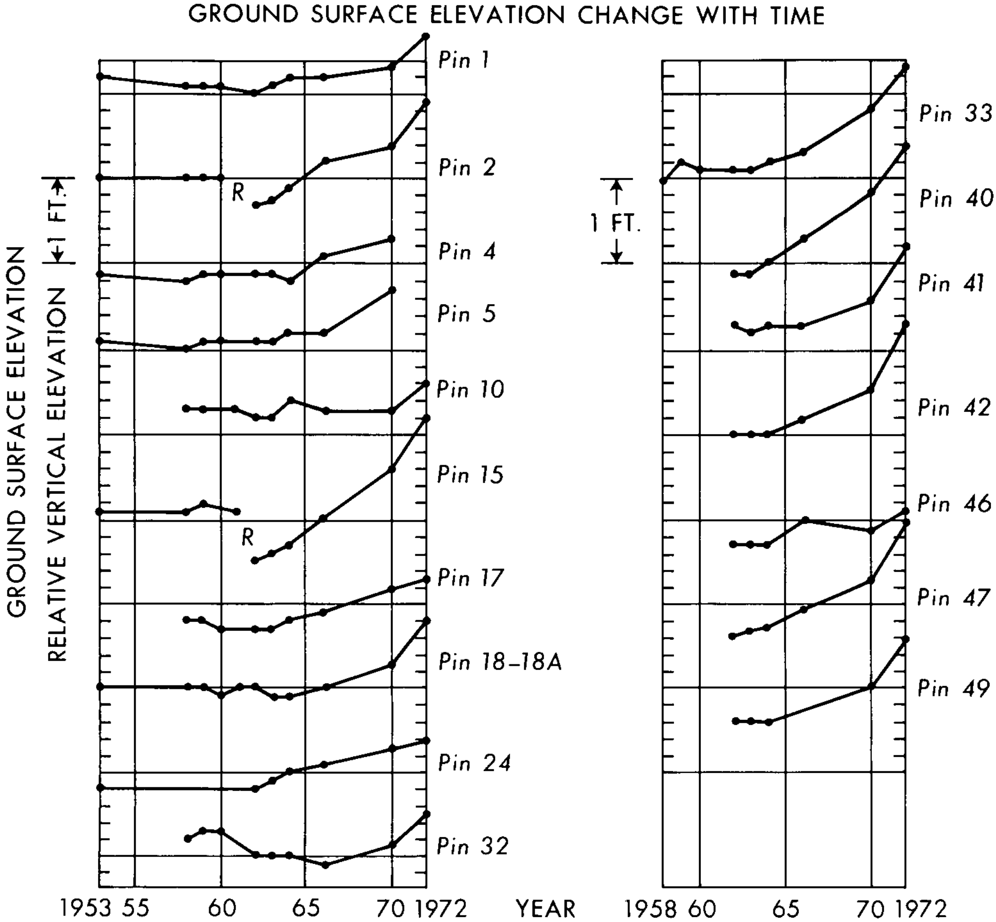


Figure 17. Ground-surface elevation change with time at location of pins monumenting the cross sections.

(1971). He measured channel cross section in 78 basins of 1 to 6 sq mi in area, and showed that channel enlargement is related to the degree of urbanization, the latter being measured by several parameters and in great detail. For a highly urbanized basin, channel area may be approximately double that of a natural basin. Figure 13 suggests that Watts Branch may be expected to continue enlargement of the channel and thus will fit into the pattern demonstrated by Hammer.

Though complete plane table maps of the channel were made only in 1953 and 1959, the progress of lateral channel movement can be traced by comparison of measured cross sections. There is no indication from these data that the rate of channel migration is altered by urbanization.

INTERPRETIVE COMMENT

As suburban growth continues apace, its subtle and delayed effects on the river environment—rate of process, characteristics of channels and flood plains, sediment movement, and aesthetic values—are going to be affecting more areas and more people. In the small basin discussed here, the picnic places where I took my children are now muddy trash heaps. Where we played catch, there is now a shrubby and scrubby jungle. The little stream is littered with bricks, concrete trash, plastic bottles, and old tires. Nearby, new and expensive houses look out on a brown mudhole in a small silt-control basin constructed by the builder.

If we are to devise ways in which urban development may proceed with a minimum of these adverse effects, we must have facts—observations made on the ground documenting effects of particular actions. Our present programs of river observation concentrate primarily on flow records and, much less intensively, on water-quality determinations. But the facts needed in the face of city growth go far beyond these network observations. We must begin to see the river as a whole—or reaches of river as a unit. A river is far more than the water it contains.

The information required is not necessarily complicated or costly. A few days of work a year can sustain a valuable observation program, if continued through a span of years. Yields can be both in theoretical knowledge of process as well as practical knowledge for design. Geologists, more so than most people, know how the natural world operates and what beauty lies in these mechanisms of nature. If some of the beauty of undisturbed processes is to exist within the reach of cities, the present practices of planning, design, and construction must include some geologic knowledge. That knowledge can come only from us.

ACKNOWLEDGMENTS

The work of surveying and shoveling, mixed with the pleasure of good company and interesting conversation, was shared with William W. Emmett, Robert M. Myrick, George Dury, John Troxell, Bruce Lium, Garnett Williams, M. Gordon Wolman, Ran Gerson, and others. Their co-operation through the years has been appreciated.

[*At this point in his oral presentation, Dr. Leopold said that he wished to conclude with a few words about the general problem of environmental degradation (in calypso time).*]

(second verse)

Gotta beat the Russians at the technical race,
The real reason is we're going to run out of space.
We're the only ones who put a man on the moon,
And most of us are planning on moving there soon.
Our industrial capacity never does sleep
So you know what is piling higher and deep,
And so from a logical point of view,
Ya better get the garbage before it gets you.

(third verse)

Da country is bad but science is worse,
A proliferation of words is our curse,
Nobody ask if ya got sometink to say,
Ya gotta write a paper to get your pay.
Scientific laboratories none but the best,
Never see the field so ya just gotta guess.
And so from a logical point of view,
Ya better get the garbage before it gets you.

(fourth verse)

Industry likes to look underground,
But they never tell ya just what they found.
All their reports are classified,
It must mean they got lots of things they must hide.
Their files are so full of junk and of crud,
They never even know when the well was a dud.
And so from a logical point of view,
Ya gotta get the garbage before it gets you.

(fifth verse)

Ground water once was the Survey's pride,
On Meinzer's reputation the whole thing ride,
Now all reports sound just the same,
Geology and ground water some county name.
From Darton and Gilluly they steal all their maps
And then they wonder why ther'e so damn many gaps.
So from a logical point of view,
Ya better get the garbage, ya better get the garbage,
Ya gotta get the garbage before it gets you.

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