The Effects of Sediment from a Gas-Oil Well Drilling Accident on Trout in Creeks of the Williamsburg Area, Michigan

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THE EFFECTS OF SEDIMENT FROM A GAS-OIL WELL DRILLING ACCIDENT ON TROUT IN CREEKS OF THE WILLIAMSBURG AREA, MICHIGAN[1]

By Gaylord R. Alexander and Edward A. Hansen[2]

Abstract

A gas-oil well drilling accident caused abnormally large quantities of sediment-laden water to enter trout streams of the Williamsburg area, Michigan. No abnormal concentrations of dissolved solids or dissolved oxygen were noted and stream water temperatures were not elevated. However, sediment concentrations were greatly increased and some sediment deposition occurred on the streambed.

Spring and fall trout populations of Williamsburg Creek, the most affected stream, were reduced for a number of years. No measurable change in the trout stocks of Acme Creek, a lesser affected stream, were detected. No significant change in individual trout growth rate was noted for any of the streams. However, growth of trout biomass was reduced for Williamsburg Creek.

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Introduction

Movement and deposition of sediments in streams is believed to be detrimental to fish populations and stream habitat for many aquatic organisms. Stream morphology is known to be altered by sedimentation (Hansen and Alexander 1976), the degree depending on the quantity of sediment added to the stream, sediment size and stream gradient. Erosion of soil into water courses occurs continuously and to a certain degree, naturally. The magnitude of natural erosion is generally, but not always, small, and depends on many factors: soil type and structure, relief of the land, distribution of annual precipitation, vegetative cover on the land, etc. However, soil erosion and abnormal sediment input into streams are accelerated greatly by the ever increasing activities of man. Activities such as road construction and maintenance, land developments, timber harvesting, farming, mining, and oil and gas drilling, to name a few, can have major erosion problems associated with them.

On April 18, 1973, the drilling of a gas-oil well resulted in an accident that caused substantial quantities of sediment-laden water to enter trout streams of the Williamsburg, Michigan, area. Apparently, uncontrolled natural gas moved up the well shaft from some 5,000 feet and then moved laterally through a limestone formation at about the 1,500-foot depth. The gas then percolated upward to the earth's surface through the porous rock and glacial mantle. As the gas moved upward, it carried groundwater with it and created small geysers where it erupted at the earth's surface. The muddy water discharged from the geysers then flowed into nearby streams. Our objective was to determine the impact of this sedimentation on trout.

Area description

The streams of the Williamsburg area, Grand Traverse County, Michigan (Fig. 1), are small, with discharges of less than 20 cubic feet per second. They flow through sandy glacial drift, thus stream discharge is stable because of little surface runoff and high groundwater yield. This stable supply of cold groundwater, low stream gradient, and relatively low sediment load, is typical of most trout streams of the northern part of the lower peninsula of Michigan. The accident of April 1973, resulted in large increases in both sediment and stream discharge of Williamsburg Creek and to a lesser extent, Acme Creek.

Methods

Substantial amounts of data were collected on stream sediment concentration and dissolved solids concentrations. Very limited measurements were made on stream discharge, water temperature, dissolved oxygen concentration, and particle size distribution of the transported sediments. Over 100 stream cross sections were established and measurements made to determine the extent of streambed sedimentation from the abnormal sediment inputs.

Sediment samples were collected by sampling with a DH-48 suspended sediment sampler in such a manner that the sampler intake traversed the entire vertical profile of flow (Hansen 1974). Samples collected in this manner provide a measure of the total sediment discharge.

Sampling stations for making trout inventories were established in areas affected by sediment in Williamsburg and Acme creeks (Fig. 1) and in areas unaffected by sediment in Williamsburg Creek, Acme Creek, and the nearby Boardman River to the south. Trout were captured by electrofishing. Estimates were calculated by the Petersen mark-and-recapture method as described by Shetter (1957). Representative groups of trout were scale sampled for age and growth analysis. These trout population estimates were conducted in both spring and fall, beginning the spring of 1973 and ending with fall 1976. Nearly all of the salmonid population in Williamsburg Creek and the Boardman River were brown trout. Acme Creek, however, had an array of salmonid species, with rainbow trout and brown trout being predominant and of about equal abundance, but also present were a few brook trout, coho salmon, and chinook salmon. For analysis, all species of salmonids were pooled. We looked for sedimentation-related trends in trout populations by examining the ratio of trout numbers in stream sections exposed to sediments, to those unexposed to sediments.

Results

Sediment data showed: (1) an initially high sediment concentration with a maximum of 4,600 ppm in Williamsburg Creek on April 20, 1973 (Fig. 2),[3] (2) a steady reduction in concentration during the first 2 weeks followed by stabilization at a concentration of generally less than 100 ppm. In contrast, the controls with one exception had concentrations of less than 15 ppm throughout the entire period of study.

The increased sediment concentration depicted in Figure 2 represents a sediment discharge of 1,400 tons for Williamsburg Creek for the April 20-May 4 period, and 50 tons for Acme Creek for April 26-May 4. This compares with an estimated normal range in discharge of 5-20 tons for each stream for the same period.

During the eruption phase, stream sediment concentrations were highest in the zone of eruption activity and decreased in a downstream direction due to sediment deposition on the streambed and dilution by the input of clean groundwater downstream (Fig. 3). As the geyser eruptions subsided sediment input to the stream decreased and sediment concentration began to increase in the downstream direction. This was due to scour and entrainment of sediment that had previously deposited on the streambed. Thus from early June through the remainder of 1973, sediment concentrations increased in the downstream direction along Williamsburg Creek. During the winter and spring of the following year, sediment concentrations were once again higher in the area of the previous geyser activity, presumably from erosion of deposited sediments from both the upland and streambed during periods of high runoff.

Another measure of the effects of geyser activity is a comparison of spring sediment concentrations for each of several years. It is apparent in Figure 4 that concentrations in 1973 were extremely high but had returned to fairly low levels by 1975. However, the 1975 levels averaging 40-60 ppm

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[3] On April 18, 1973, Evans (1974) reported a sediment concentration of 10,320 ppm in Williamsburg Creek at Highway M-72 and 3,600 ppm in the East Branch of Acme Creek at Lautner Road.

are still somewhat above those at the control station less than one-quarter mile upstream where concentrations averaged around 7 ppm during the same period.

Concentrations of total dissolved solids ranged between 170-200 ppm in the affected zone during geyser activity. This was well within the normal range of 140-220 ppm for small streams in northern Michigan. A small increase under 10% apparently occurred during the first 2 months following the initial gas eruption.

On April 20, temperature and dissolved oxygen data were collected in one large geyser and in Williamsburg Creek. The data show: (1) water temperature in one large geyser was 49 F (the same as the regional groundwater temperature). This normal temperature, together with the normal dissolved solids concentrations, indicate that water discharged from geysers originated from local (shallow) groundwater and not from deep strata. (2) Temperature of water discharge from a major geyser was colder than ambient stream water. There was no evidence of abnormal warming of stream temperatures due to geyser discharges. (3) Dissolved oxygen content of geyser-discharged water was essentially zero. However, pickup of dissolved oxygen was rapid, reaching 7.1 ppm with less than 100 yards of overland flow from the geyser. (4) There was no abnormal lowering of dissolved oxygen near the mouth of Williamsburg Creek. However, this does not rule out the possibility of a dissolved oxygen sag in the stream area immediately affected by the geyser discharge, particularly where geysers were located adjacent to the stream.

Stream discharge increased by as much as 50% relative to the control station during the period of high geyser activity and decreased to normal as geyser activity subsided. The increased stream discharge due to geyser activity did not exceed "bank full" conditions and was not of unusual magnitude when compared to seasonal floods on other northern Michigan streams of comparable size. Stream flow in the control section was essentially stable during the entire measurement period.

The major zone of geyser activity on Williamsburg Creek was immediately above Highway M-72. In that zone 500 feet of stream had continuous sediment deposits consisting of silt and clay with two large areas of thick sand caps. The volume of deposited material was 275 cubic yards with depositional depths up to 1.6 feet. Below M-72 sedimentation consisted mostly of a thin coating of fine sediments on logs and rocks, and occasionally thicker deposits along the margins of the stream.

Silt was the predominant sediment size added to the stream and it affected the entire stream below the geysers. Two samples collected at the peak of the geyser activity showed only 0.3 and 1.0% sand size, the rest was predominantly silt. Much of the sand discharged into the stream from the geysers deposited out immediately and formed permanent deposits along a 100-yard section of stream above M-72. This happened because the culvert at M-72 was set high during highway construction, which created a sediment trap. Silt deposits immediately downstream from the sand areas contained only 1-3% sand indicating an abrupt transition from sand to silt bed areas.

No quantitative trout population information was available for the streams of the Williamsburg area prior to the gas eruptions. Since we could not make before and after comparisons, we compared trout populations for several years after the eruptions to see if population ratios of sediment exposed areas to sediment unexposed areas (control) changed or trends developed.

Trout population estimates, expressed as number per acre for Williamsburg Creek, Acme Creek, and the Boardman River are shown in Table 1. The calculated ratios of the trout population per acre of exposed to control areas are given in Table 2.

Table 2 shows that spring population ratios for Williamsburg Creek were generally lowest in 1974 and increased progressively from 1974 to 1976 for all length classes of fish. These trends were evident when the exposed areas were compared to either the Williamsburg Creek or Boardman River controls.

The relatively high spring population levels during the 1973 period of geyser activity probably reflect the near normal densities of trout for these streams prior to sedimentation. We believe this because no evidence was found indicating immediate trout mortality due to factors such as low dissolved oxygen, toxic substances, or gill damage, etc. on trout larger than 3.0 inches (fish 1 year old and older). However, no trout fry were found or examined and it is possible that many of these newly hatched fish died.

The possibility exists that in Williamsburg Creek the 1973 spring trout populations are abnormally high in the upstream control area because of trout movement out of the highly turbid zone. If movement occurred this would explain the relatively low 1973 ratios for trout in Williamsburg Creek exposed to the Williamsburg Creek control, compared to the ratio of Williamsburg Creek exposed to the Boardman River control.

We conclude that the sedimentation in Williamsburg Creek reduced the spring trout population substantially (possibly one-half of normal) by the spring of 1974. Recovery then occurred steadily from 1974 to 1976, but may not be complete by 1976 (Table 2).

Examination of the fall trout population data for Williamsburg Creek exposed areas divided by the Williamsburg control areas generally demonstrates an increasing population trend from fall 1973 through fall 1976. Ratios of Williamsburg Creek exposed to Boardman River control show the same improvement trend for Williamsburg Creek 1973 through 1976. We have no basis to judge whether the fall trout populations have completely recovered because fall trout population levels prior to the gas eruption are unknown.

Based upon the trends evident in both length groupings of trout and for both of the control areas, we conclude that sediment input into Williamsburg Creek was detrimental to the trout population. Relative decrease in the fall trout population ratios was from 48 to 59%, depending on the trout size class. Changes in the spring ratios suggest that the spring trout populations were lowered some 55 to 62%, depending on trout size class.

Ration analysis of trout population densities in sediment exposed and unexposed stream sections of Acme Creek show no measurable trout population reductions related to sedimentation in either the spring or fall estimates. This is also true of the ratio analysis when using the Boardman

River data as a control. The much lower sedimentation loading in Acme Creek compared to Williamsburg Creek caused no measurable decrease in the numbers of trout.

Our analysis of trout growth from an examination of trout scales indicates no significant change in growth rate of individual fish. However, trout production was reduced because fewer fish were present.

Samples of stream macroinvertebrate communities in Williamsburg and Acme creeks did not show detectable degradation when measured on May 2 and 3, 1973, nor on June 26, 1973, some 11 weeks after gas eruptions, according to Evans (1974). However, he stated that net-building caddisfly larvae below the point of sediment input showed signs of stress. Suspended solids at or above the concentrations measured in Williamsburg Creek will usually cause detectable damage to stream biota (Cordone and Kelly 1961).

Acknowledgments

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Table 1.--Estimated average spring and fall trout population numbers per acre, by length group, in sediment-exposed and unexposed sections of Williamsburg Creek, Acme Creek, and Boardman River.

Stream section and year	Spring Length group (inches) 1.0-6.9	Spring Length group (inches) 7.0+	Fall Length group (inches) 1.0-6.9	Fall Length group (inches) 7.0+
Williamsburg Creek				
Unexposed				
1973	2,164	488	2,643	499
1974	834	438	2,237	348
1975	821	374	1,737	585
1976	421	437	2,374	270
Exposed				
1973	925	500	875	276
1974	396	260	1,591	331
1975	701	244	1,919	419
1976	859	350	1,843	392
Acme Creek				
Unexposed				
1973	626	200	1,811	257
1974	1,204	150	1,196	161
1975	698	169	1,889	390
1976	1,471	244	2,746	292
Exposed				
1973	1,659	581	1,627	552
1974	1,329	536	1,656	484
1975	896	434	2,830	373
1976	1,740	292	2,988	373
Boardman River				
Unexposed				
1973	584	197	930	244
1974	611	337	946	305
1975	428	308	587	284
1976	610	170	784	227

Table 2.--Relative numbers of trout per acre, of two length groups, comparing sediment exposed with unexposed sections of Williamsburg Creek (WC), Acme Creek (AC), and Boardman River (BR).

Stream section ratios by year	Spring Length group (inches)		Fall Length group (inches)	
	1.0-6.9	7.0+	1.0-6.9	7.0+
$\frac{\text{WC exposed}}{\text{WC unexposed}}$				
1973	0.43	1.02	0.33	0.55
1974	0.48	0.59	0.71	0.95
1975	0.85	0.65	1.10	0.72
1976	2.04	0.80	0.78	1.45
$\frac{\text{WC exposed}}{\text{BR unexposed}}$				
1973	1.58	2.54	0.94	1.13
1974	0.65	0.77	1.68	1.08
1975	1.64	0.79	3.27	1.48
1976	1.41	1.58	2.35	1.73
$\frac{\text{AC exposed}}{\text{AC unexposed}}$				
1973	2.65	2.90	0.90	2.15
1974	1.10	3.57	1.38	3.01
1975	1.28	2.57	1.50	0.96
1976	1.18	1.20	1.09	1.28
$\frac{\text{AC exposed}}{\text{BR unexposed}}$				
1973	2.84	2.95	1.75	2.26
1974	2.18	1.59	1.75	1.59
1975	2.09	1.41	4.82	1.31
1976	2.85	1.72	3.81	1.64

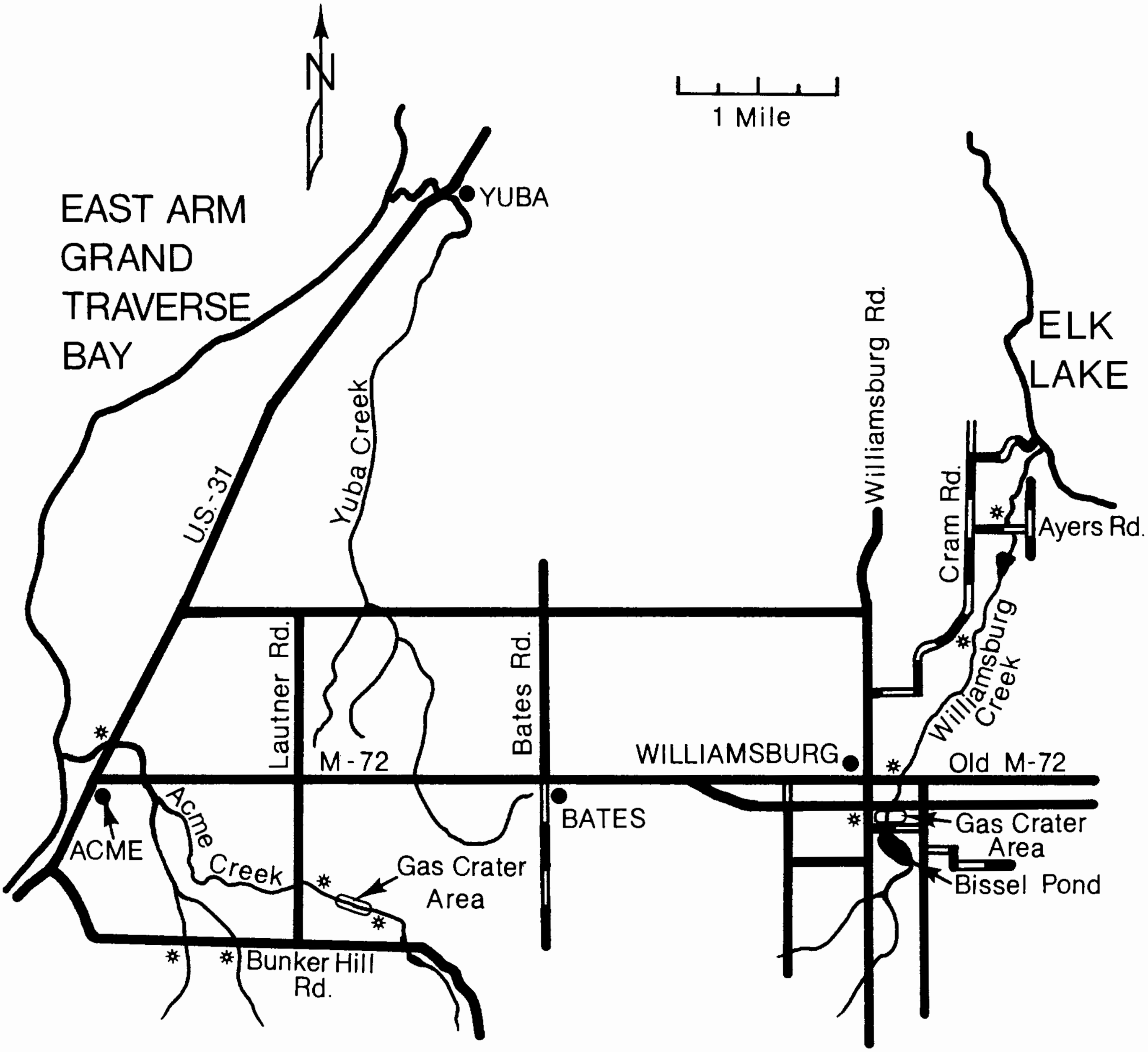

Figure 1.--Location of Williamsburg area creeks, with general gas crater (geyser) areas shown. Asterisks show locations of trout population inventory sections of streams.

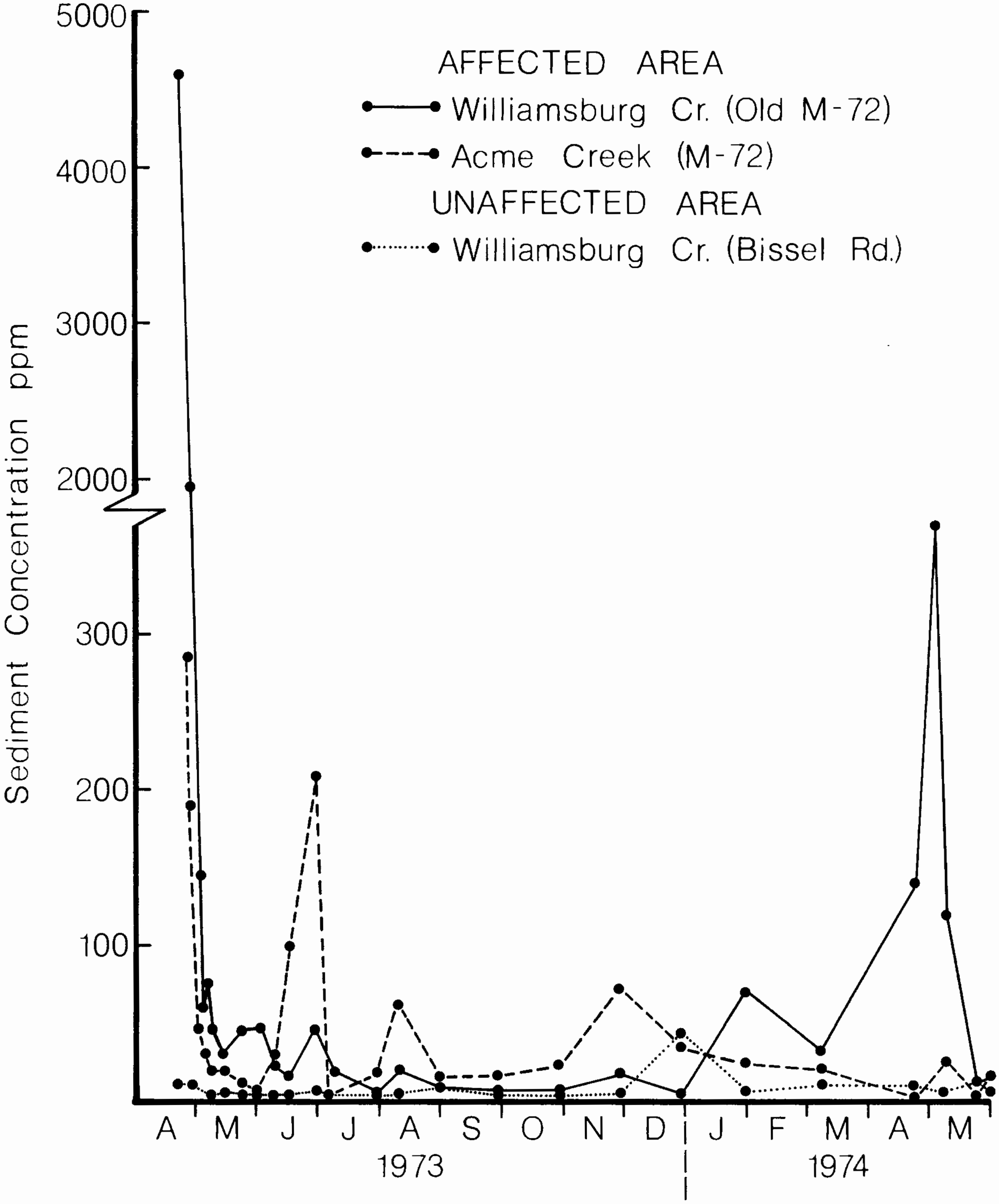

Figure 2. --Sediment concentrations from geyser discharge affected area as compared to unaffected area immediately upstream.

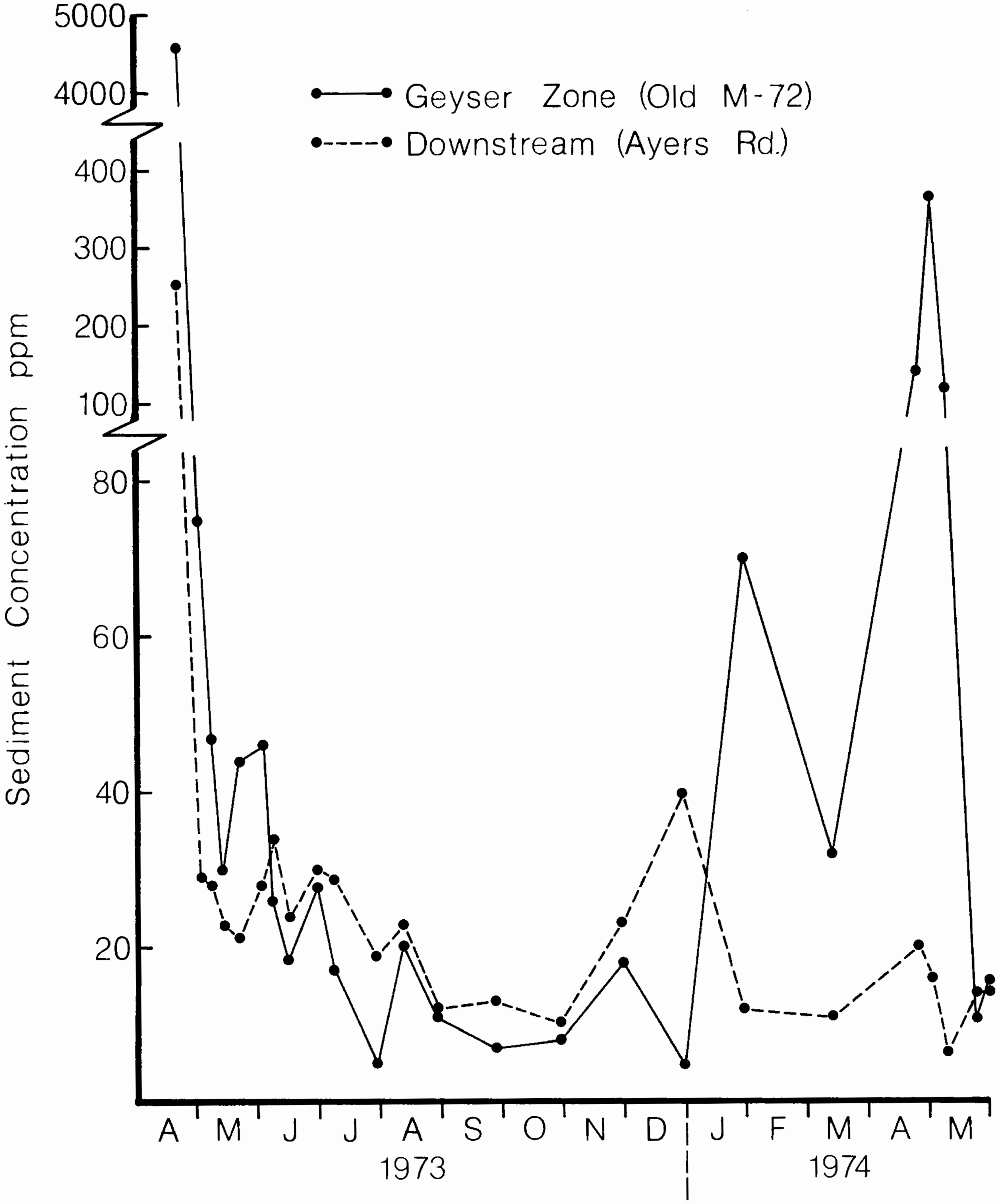

Figure 3.--Sediment concentrations on Williamsburg Creek at geyser zone and downstream near stream mouth.

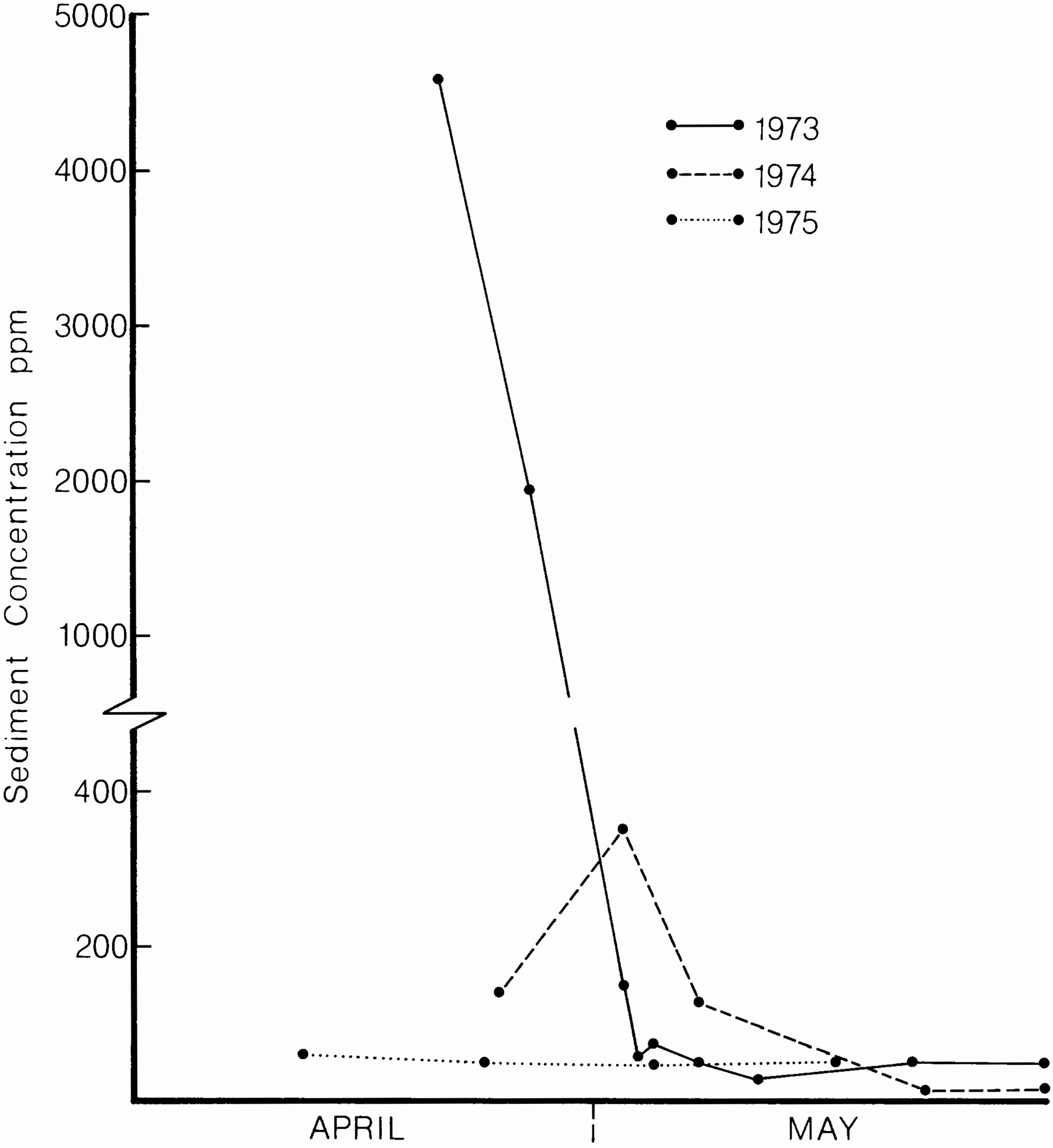

Figure 4.--Spring sediment concentrations 1973-1975 on Williamsburg Creek.

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