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EPHEMERAL FLOW AND WATER QUALITY PROBLEMS: A CASE STUDY OF THE SAN PEDRO RIVER IN SOUTHEASTERN ARIZONA

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INTRODUCTION

Given all the recent federal and state water quality activity and the ephemeral nature of most streamflow in the Southwest, it is surprising that little attention has been paid to water quality problems of ephemeral flow. This paper, through an analysis of water quality data for the ephemeral San Pedro river in southeastern Arizona, illustrates the nature of water quality problems of ephemeral flow and raises some of the issues to be considered when trying to solve these problems.

THE SAN PEDRO RIVER BASIN[1]

The San Pedro river drains a northerly-trending basin of 4,483 sq. miles, of which 696 sq. miles are in Mexico and 3,787 sq. miles are in southeastern Arizona. Situated between the Basin and Range physiographic province to the southwest and the Colorado Plateau province to the northeast, the basin exhibits the classic Mountain Transition Zone province physiography: a long, relatively narrow, alluvial valley surrounded by mountains with relief up to 6000 feet. Climate is semiarid. Vegetation reflects this aridity and is sparse and xerophytic. Temperatures are high. Precipitation is low with much of the basin receiving less than 15 inches per year. Most of this falls during one of the two "rainy" seasons--the summer season of July through September, and the winter season of December through March. Of the two, the summer season is the greatest source of moisture during most years. The characteristics that distinguish these two rainy seasons will be discussed further later.

Most surface flow along the 150-mile length of the San Pedro main channel is ephemeral, in response to rainfall. Consequently, for much of the year most of the main channel is a dry wash. There are some stretches of perennial flow along this channel, one of about 25 miles in the upper part of the basin, and another one of about five miles in the middle section.

Land use is predominantly rural with about 11,000 acres devoted to mostly ground water-irrigated farming and 1,600,000 acres being grazed in the U.S. portion of the basin. There are seven major population centers, most with populations of less than 4000 persons. Growth rates experienced by these towns have ranged from four to 224 percent for the 1970-1975 period. Mining, particularly of copper, has been a major economic activity in the basin and open pits, tailings ponds and smelters are features of the landscape.

WATER QUALITY STANDARDS

Currently in Arizona, the designated primary beneficial uses of water of a given stream determine the water quality parameters and standards applicable to that reach. On the main stream of the San Pedro the primary beneficial uses have been designated as partial body contact, warm water fishery, agricultural, and aquatic life and wildlife. The standards for a particular parameter may vary with the beneficial use the standard protects. When this occurs the strictest standard is the one used.

The water quality parameters and standards applied to the San Pedro main channel are: fecal coliform (FC), 1000 FC/100 ml (geometric mean); pH, 6.5 - 8.6; turbidity, 50 JTU; dissolved oxygen (DO), 6.0 mg/l; temperature, maximum change, 5° F, maximum, 93° F; arsenic, 0.50 mg/l; barium 0.50 mg/l; boron, 1.000 mg/l; cadmium, 0.010mg/l; chromium (hexavalent), 0.050 mg/l; copper, 0.050 mg/l; cyanide, 0.100 mg/l; mercury, 0.005 mg/l; lead, 0.050 mg/l; phenol, 0.001 mg/l; selenium, 0.010 mg/l; silver, 0.050 mg/l and zinc, 0.500 mg/l.

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1. Much of the information presented in this section is taken from DeCook et al, 1977.

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WATER QUALITY STUDIES AND RESULTS

Water quality data of interest to this paper are available for the San Pedro for discontinuous time intervals beginning late 1967. (A summary of the studies and data collected to May, 1976 is presented in ADHS, 1976.) Data have been generated from two types of studies: the intensive survey and the fixed station study. Intensive surveys produce data collected from a number of monitoring stations over the basin during a given time span. These type of data are useful in determining spatial aspects of water pollution. Fixed station studies produce data that are collected at one point over time and are helpful in defining temporal water quality trends. On the San Pedro, the "San Pedro at Winkelman" station (hereafter referred to as Winkelman) has been the locus of these studies. This station is at the northern end of the basin, about 1 mile up from the confluence of the San Pedro with the Gila River near the town of Winkelman.

From November 1967 to October 1968 the first fixed station study at Winkelman was conducted by the Bureau of Water Quality Control (BWQC) of the Arizona Department of Health Services (ADHS). Nine samples were collected and one copper violation was observed. In March and April, 1973, an intensive survey was made by the BWQC over the whole basin in which 226 observations were made and 15 violations were recorded. Of these violations, 11 were recorded for turbidity, one for copper, one for FC, one for pH and one for DO. Between November 1974 and March 1975 the BWQC undertook another fixed station study at Winkelman. One sample was collected each month. Two turbidity violations were recorded. Beginning in October 1974, the U.S. Geological Survey (USGS) began monitoring water quality on a permanent year-round basis at Winkelman. Table A summarizes the violations recorded here from October 1974 to September 1977. In the summer of 1977 another intensive survey of the basin was carried out this time by the Water Resources Research Center (WRRC) at the University of Arizona. Fortynine of the 64 bacteriological samples collected at 19 sites in the basin recorded fecal coliform violations. Seventeen barium violations were recorded over the whole basin. Two lead violations occurred at stations within ten miles of the International border. And 14 copper violations were reported, all but one (at Winkelman) in the upper half of the basin (DeCook et al, 1977).

TABLE A: Summary of Violations Recorded by the USGS at the San Pedro at Winkelman Station, October 1974 to September 1977

(1) Parameter	(2) Number of Violations	(3) Number of Observations	(4) % of Violations Occurring in Summer	(5) % of Summer Flows Sampled That Were in Violation
Turbidity	9	20	73	100
Fecal Coliform	8	13	100	100
Arsenic	5	11	100	100
Barium	4	8	100	100
Boron	1	9	100	20
Cadmium	5	9	100	83
Chromium	5	12	100	100
Copper	7	12	85	100
Lead	8	12	80	100
Silver	1	9	100	20
Zinc	3	5	100	100
Phenols	5	8	40	40

Sources: USGS (1976), (1977), and open file material

An important point to note about these studies concerns the season during which the data were generated. Until the USGS began its year-round monitoring in 1974, all the data generated, between 1967 and 1974, except for that from two samples taken in the first study, were from winter rainy season flows. As such, to a certain extent, they compositely describe the water quality of the winter hydrologic regime. Consider how few in number were the violations recorded over this seven year time span: thirteen turbidity, two copper, one fecal coliform, one pH and one DO. Were there no summer flow analyses made, one could easily maintain that there are few pollution problems in the San Pedro. The data collected by the USGS for winter flow since 1974 certainly supports this contention (USGS, 1976, 1977, and open file material).

However, looking at the USGS data collected at the Winkelman station from October 1974 to September 1977 (Table A) it is apparent that there are water pollution problems here of a greater magnitude than were observed in the previous studies. Whereas the previous studies recorded only five parameters in violation, these data show 12. The most interesting and important point about these violations is the pattern of their distribution, as seen in columns (4) and (5) of Table A. From column (4) we see that eight of the 12 parameters in violation were so only during summer flows. Of the remaining parameters, except for phenols, over seventy percent of the violations occurred in summer. This is not for lack of winter flow analyses: of the 128 observations of parameters in violation, 58 were made during winter flows.

Another important point Table A demonstrates is the relative magnitude of the pollution problem. Column (5) indicates the percentage of summer flows sampled in which a violation for a particular parameter was recorded. For eight of the twelve parameters on this list, every summer flow sampled was in violation. For other parameters, such as silver which was violated during only twenty percent of the summer flows sampled, the problem is not so severe.

All in all, the implications of these data are clear: water pollution problems on the San Pedro are of a distinctly seasonal nature, occurring largely during summer flows.

Why? There is no evidence to indicate that the production of potential pollutants would be greater in summer than winter. The fecal coliform parameter is perhaps the only one that may behave differently according to the season (Velz, 1970). It is hard, though, to attribute a difference of four orders of magnitude between summer and winter fecal coliform counts to a seasonal change in behavior. Instead this seasonality of water pollution problems appears to be the result of the difference between the climatic-hydrologic regimens of the winter and summer rainy seasons.

GEOMORPHIC ASPECTS OF POLLUTION

The summer and winter rainy seasons in the San Pedro valley are the antithesis of each other. The summer season brings highly localized, short-lived, violent thunderstorms. These storms produce short-lived runoff events that peak abruptly (often going from zero discharge to 1000's of cubic feet per second in less than a few hours) and taper off gradually. Winter rainfall tends to be gentle and widespread and to produce runoff events that vary little in discharge over time. Peak discharge will often be in the tens of cubic feet per second.

The erosive power and the volume of runoff per unit of rain in summer are much greater than in winter. For example, generally more than ninety-five percent of annual discharge recorded at the Winkelman station occurs from July through September, although only fifty to sixty percent of the annual rainfall is recorded during this time. Suspended sediment discharge data--an index of the erosive power of the flow and/or rainfall--parallels this trend. At the Winkelman station usually more than ninety-five percent of the total suspended sediment discharged in any year occurs during the months of July through September.

The ability of the summer storm to generate erosion and runoff in far greater magnitudes than the winter storm is probably due to at least three factors. First, there is the very disruptive effect the high winds and intense summer rainfall can have on the soil surface, particularly when it is poorly vegetated, jarring soil particles and potential pollutants loose to be carried away in runoff. Second, the summer storm precipitation rates often exceed the soil infiltration rates. Rainfall that cannot infiltrate into the soil will run off on surfaces with a gradient. In areas where there is sufficient vegetative cover, the rates and volume of runoff can be mitigated. But in most of the San Pedro valley, the sparse vegetative cover can do little to hinder runoff. Finally, this greater volume and rate of runoff means a greater ability to carry away sediment, pollutants, trash--anything that has accumulated in the main and tributary channels.

What does this have to do with water pollution on the San Pedro? Quite simply this: it is the summer storm which provides the mechanisms--erosion and runoff--by which pollutants can be transported from their sources to the stream channel, or, from the stream channel site where they are discharged to the monitoring station. This produces the seasonal aspects of water quality on the San Pedro river. This seasonality is apparent also in the Santa Cruz valley, just to the west of the San Pedro valley, where, at the Rio Rico station all water quality violations for the year of October 1975 to September 1976 were recorded during summer flows (USGS, 1977).

This relationship between summer rainfall and ephemeral flow water quality should not be extrapolated freely to the rest of the Southwest because rainfall conditions vary widely. Nor should it be interpreted to mean that water quality problems will exist only for summer flow in southeastern Arizona. What should be understood is that most water quality problems here occur because of favorable climatic-hydrologic conditions. These conditions are prevalent during the summer but can occur during the winter.

In general, all other things being equal, water pollution problems will tend to be more severe in arid areas than in the more humid zones where rainfall is greater and distributed more uniformly throughout the year and streamflow is perennial. In the first place, the longer time intervals between precipitation events and the even longer intervals between runoff events mean that potential pollutants have a much longer time span over which to accumulate than in humid areas. Additionally, there is much less water available for the dilution of potential pollutants to acceptable levels. So, although surface water pollution problems in arid areas may be nonexistant most of the time because there is no flow in the channel, when there is flow the water quality will tend to be poorer than in more humid areas.

ISSUES

The preceding discussion raises several questions that must be considered if a rational, acceptable water quality management plan is to be developed for the arid lands.

First there is the question of why--why protect the quality of ephemeral flow? Because the channel consists of a dry wash much of the year there is little if any aquatic life or wildlife to protect. And, because when there is flow it is usually in flood condition there is little, direct, intentional use made of it by humans. So what does pollution mean on an ephemeral stream?

Where and if it is decided that ephemeral flow is worth protecting the very practical question arises as to how. The quality of effluent discharged by point sources can be controlled through permits. But it will be difficult economically to control the quality of urban stormwaters and runoff from grazed and mined land and natural sources. In between the extremes of prohibiting (or treating) all runoff and eliminating all sources of pollution, there is little that can be done to control the quality of the ephemeral summer stormflows in southeast Arizona. Yet standards are set for this flow, standards which for the most part are unattainable.

CONCLUSION

It is becoming more imperative that we address the issues of water quality of ephemeral flow. Ephemeral flow, whether it exists in the natural confines of the San Pedro channel or a storm drainage ditch in Tucson, will become more important as the demand for water increases in the Southwest. At the same time that a rapidly growing population increases this demand, it also contributes to the decline in quality of the flow. If, and where, as a culture, we decide the quality of ephemeral flow must be protected, we must realize that the natural geomorphic processes and environment in an arid area put strict constraints on the level of quality that is attainable, at least for summer flows in southeastern Arizona. And, we must also consider that certain practices--such as using stream systems to carry off effluent--that are acceptable in areas with more rainfall and perennial streams are perhaps inappropriate here.

Or, if we determine that the water quality of ephemeral flow really is not a health or environmental hazard, then let us set standards for that flow which recognize the environmental aspects of the problem, rather than standards that are often unattainable.

In any case, it is hoped that the main point of this paper has been appreciated: that water quality problems of ephemeral flow in arid areas are of a different nature than the water quality problems in the humid zone. To deal with these problems effectively and in an acceptable manner we must recognize this.

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