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ESTABLISHING LOCAL WATER QUALITY MANAGEMENT PRIORITIES

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ABSTRACT

A methodology which can be implemented by water resources regulatory authorities to establish local water quality management priorities for urban watersheds is presented. The model utilizes an approach to management which does not require extensive field sampling and investigation, but rather makes use of readily-available data. Indirect indicators of watershed characteristics and land use planning are used to predict overall water quality conditions of the watersheds. The methodology is applied to Allegheny County, Pennsylvania, a region which can be divided into eighty-two separate, independent drainage areas. Indirect indicators are used here to forecast the overall water quality of those watersheds for which no direct measurements exist, to single out problematic watersheds for possible regulatory action, and to identify those watersheds which should receive an in-depth study to characterize water quality conditions. This methodology is currently used by Allegheny County Health Department to establish implementation priorities for the small urban streams in the region.

Introduction

Recent environmental legislation at both federal and state levels has provided strict controls to protect the integrity and quality of the

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nation's watercourses. Specifically relating to water quality, the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) establish the national goal of zero discharge of pollutants by 1985. The act further establishes an interim goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife, as well as the protection of water-based recreation; these interim goals are to be achieved by July 1, 1983 [1].

Previous and many present planning and management efforts have concentrated on achieving the objectives of PL 92-500 in the major rivers within an urban area. Concern for small streams in planning for the protection and upgrading of water quality in urbanized areas has primarily been limited to their influence on the major rivers. This is certainly a valid reason for inputting small streams into a comprehensive watershed planning and management effort. An equally valid reason is that small streams themselves present inherent urban resources. For example, a small stream can provide a setting for local recreation and aesthetic enjoyment, uses which are particularly valued in a densely-populated urban area.

Management Framework for Small Urban Watersheds

An analysis of the characteristics of small urban watersheds is important when considering the framework within which urban watershed management functions. Large federal agencies are primarily concerned with protection and preservation of major rivers within problem areas. Thus, their concern for small urban watersheds is mainly directed to the influence which these watersheds exert on major rivers. Concern for protection of the resources of the watershed itself generally rests with local authorities: state, county, municipal, and private.

The planning and management tools which are used by federal and state agencies in large-scale studies of major river systems do not fill the needs of a local authority. Local authorities generally do not have the data, the facilities, or the financial base to implement these large-scale management models. In addition, present management models provide more detailed information than is needed to establish priorities at the local level. Thus, if an agency were to have available the resources needed to use an existing management model, it is unlikely that this action would be cost-effective.

Use of Indirect Indicators in the Management of Small Urban Watersheds

Often very little information exists on which to base an analysis of small urban watersheds. At best, water quality and streamflow data are typically few in number and were collected discontinuously with little concern for patterns of time. Agency budgets and the urgency of the problem preclude establishing an extensive water quality and stream gaging network and operating it long enough to generate sufficient reliable data.

Assuming that watershed characteristics determine the problems presented by the watershed, an analysis based on readily available measures of watershed activities (e.g., population, land use data, waste disposal activity) can provide a mechanism for establishing priorities without extensive data requirements. This method utilizes readily available measures as indirect indicators of watershed problems in lieu of more expensive and often unobtainable direct measurements (e.g., stream sampling data and streamflow measurements). Local regulatory authorities can implement a method based upon indirect indicators to establish cost-effective priorities in the management of small urban watersheds.

The objective of this study is to provide the local regulatory authority with an alternative mechanism for determining existing overall water quality conditions on the watersheds. Throughout the United States, there are 253 SMSA's which include about 70 per cent of the population [2]. In general, these areas represent high concentrations of urbanization and industrial activity, and as such are candidates for application of the methodology developed here. To illustrate the development and use of the method, a case study of the problems current in a major urbanized area, Allegheny County, Pennsylvania (Pittsburgh SMSA), will be used to formalize the inherent decisionmaking process.

A Case Study: Urban Watershed Management in Allegheny County, Pennsylvania

Allegheny County, 730 square miles of densely-populated and heavily-industrialized area in southwestern Pennsylvania, presents severe managerial problems in the application of water quality legislation. Although the Allegheny County region includes eighty-two separate drainage areas (Figure 1), only sixty-one watersheds were analyzed. The remaining twenty-one intervening areas were excluded from all further analyses, since they lack a well defined stream channel.

Using the Allegheny County region as a case study, a method was developed to predict overall water quality from indirect indicators of watershed characteristics, which are readily available to the local regulatory authority. The method reduces both the need for extensive field sampling and the time required to compile a reliable management database.

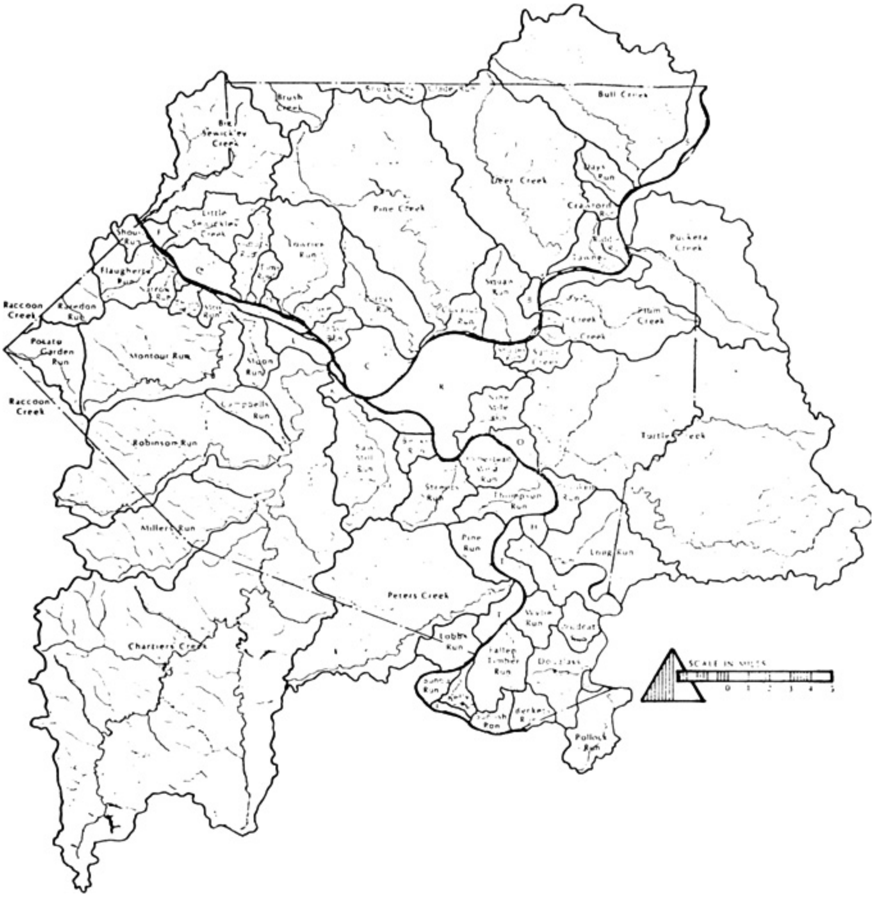

Figure 1. Allegheny County and surrounding watersheds.

METHODOLOGY

A previous study of fifty-two watersheds in Allegheny County collected data to characterize the generally degraded conditions on the County watersheds, and utilized this information to develop a methodology for choosing a small group of streams for field sampling [3, 4]. Samples taken from these streams, representative of water quality conditions likely to be encountered throughout Allegheny County, were incorporated into the original database to provide an extended body of information for this study. Because of the general nature of the information required by the planning and management processes as applied to urban watersheds, the analysis here focuses on determining overall water quality for an entire watershed rather than on the status of individual water quality parameters or on variations in water quality within a single watershed. To accomplish this, a method was sought to determine an integrated rating of the water quality on as many of the sixty-one watersheds as possible.

PERCEIVED WATER QUALITY

A panel of experts was chosen, each having a thorough knowledge of one of the factors which influence an individual's perception of water quality. The panel included twenty-two persons; panel members were selected from representatives of the following agencies:

1. Allegheny County Health Department (ACHD)
2. Allegheny County Department of Waste Systems Management
3. Pennsylvania Department of Environmental Resources
4. Pennsylvania Fish Commission
5. Pennsylvania Soil Conservation Service

The panel members were asked independently and anonymously to rate the overall water quality, as they perceived it, on any of the watersheds with which they were familiar. They were to assign an index number from one to five (perceived water quality increased with the value of the index number). The questionnaire was administered and the results compiled using the Delphi method survey technique as a guideline [5].

Following two survey iterations, responses had converged sufficiently to permit average perceived quality ratings to be calculated for thirty-two of the watersheds. These watersheds, along with the average ratings and the 95 per cent confidence intervals of the averages are listed in Table 1.

Because the perceived quality ratings provide a very general measure of overall water quality, these ratings were used as the basis for determining groups of watersheds with similar perceived water quality. Previous work had attempted both correlation analysis and multiple linear regression analysis to predict actual values of the perceived quality index [4]. These attempts were largely unsuccessful, and a more general determination of perceived quality was sought here. The division into groups was determined by the use of hierarchical clustering analysis, a multivariate statistical technique which establishes several mutually exclusive groups within which watersheds are relatively similar and between which watersheds are relatively different [6]. The technique provides

Table 1. Perceived Quality Ratings for 32 Watersheds

	Perceived quality rating	
Watershed[a]	*Average*	*95% Confidence Interval*
Saw Mill Run	1.38	± 0.46
Plum Creek	1.42	± 0.38
Potato Garden Run	1.43	± 0.49
Girtys Run	1.59	± 0.42
Bunola Run	1.67	± 1.42
Streets Run	1.71	± 0.71
Fallen Timber Run	1.75	± 1.53
Becks Run	1.78	± 0.92
Millers Run	1.83	± 1.03
Thompson Run	2.00	± 1.34
Turtle Creek	2.00	± 0.39
Robinson Run	2.12	± 0.71
Montour Run	2.27	± 0.31
Homestead-West Run	2.29	± 0.88
Chartiers Creek	2.36	± 0.62
Long Run	2.48	± 0.49
Kilbuck Run	2.50	± 0.92
Moon Run	2.50	± 1.59
Sandy Creek	2.50	± 0.78
Peters Creek	2.75	± 0.48
Campbells Run	2.80	± 0.57
Lowries Run	2.83	± 0.80
Jacks Run	3.00	± 0.00
Pucketa Creek	3.00	± 0.90
Deer Creek	3.09	± 0.47
Pine Creek	3.15	± 0.54
Flaugherty Run	3.29	± 0.71
Bull Creek	3.36	± 0.45
Big Sewickley Creek	3.62	± 0.61
Guyasuta Run	4.00	± 0.67
Little Sewickley Creek	4.00	± 0.54
Squaw Run	4.40	± 0.50

[a] Listed in increasing order of Perceived Quality Rating.

thirty-one different configurations of the thirty-two watersheds, with the configurations ranging from one to thirty-one individual groups. After the method outlined by Ball [7], the total error of fit was plotted versus the number of groups in the configuration (Figure 2). Examination of this plot shows that very little reduction in total error of fit occurs by choosing a configuration composed

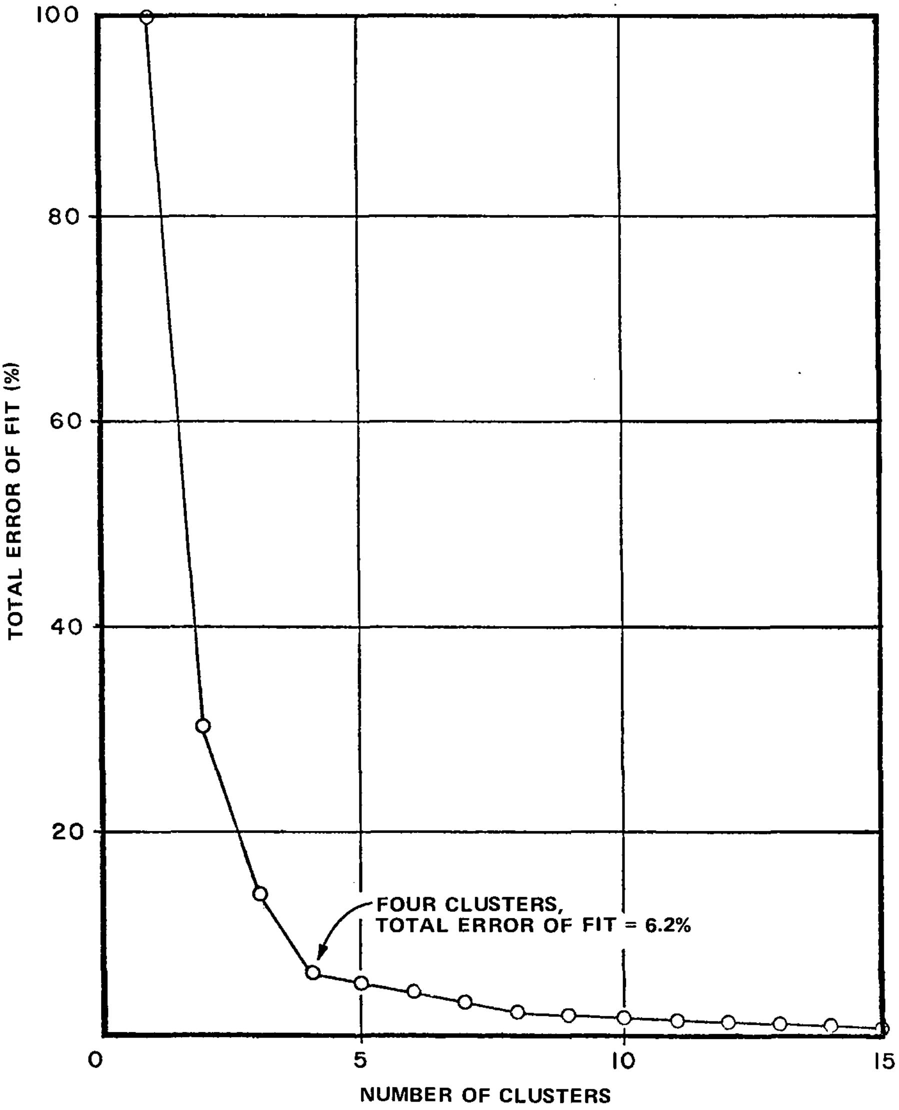

Figure 2.

of more than four groups. In addition, configurations with more than four groups contain singletons (groups composed of a single watershed). The high value of the pseudo-F statistic (Table 2) indicates that most variation is among groups, with very little variation within groups. Hence the optimal clustering of watersheds into four perceived quality groups is shown in Table 2.

Table 2. Optimal Clustering of 32 Watersheds Into
4 Perceived Quality Groups

Group 1 ($\mu = 1.62$, $\sigma = 0.17$
(Worst Perceived Quality)

Saw Mill Run
Plum Creek
Potato Garden Run
Girtys Run
Bunola Run
Streets Run
Fallen Timber Run
Becks Run
Millers Run

Group 2 ($\mu = 2.30$, $\sigma = 0.20$)

Thompson Run
Turtle Creek
Robinson Run
Montour Run
Homestead-West Run
Chartiers Creek
Long Run
Kilbuck Run
Moon Run
Sandy Creek

Group 3 ($\mu = 3.03$, $\sigma = 0.21$)

Peters Creek
Campbells Run
Lowries Run
Jacks Run
Pucketa Creek
Deer Creek
Pine Creek
Flaugherty Run
Bull Creek

Group 4 ($\mu = 4.01$, $\sigma = 0.32$)
(Best Perceived Quality)

Big Sewickley Creek
Guyasuta Run
Little Sewickley Creek
Squaw Run

Note: Overall pseudo-F for Clustering = 105.68; df = (4,28); F_{crit} (0.001; 4,28) = 6.25; μ = group average of watershed values; σ = group standard derivation of watershed values.

Validating the Perceived Quality Rating

An initial task was to establish the panel's water quality ratings (Table 1) as consistent and reliable. To do this, variations in the perceived quality ratings were related to variations in the measured water quality data. Water quality data, as measured at the mouth of the stream, existed for twenty-six of the sixty-one County watersheds.

Each stream in the final sample group has been sampled at least twice, once in the winter and once in the summer in an attempt to represent seasonal variability.

Multiple discriminant analysis was used to predict membership in a perceived water quality group based upon the annual average values of five stream sampling parameters [6, 8] (Table 3). The results of the analysis are shown in Table 3. Examination of the

Table 3. Multiple Discriminant Analysis of Perceived Quality Groups Based on Stream Sampling Parameters

	Standardized classification coefficients			
Sampling Parameter	*Group 1*	*Group 2*	*Group 3*	*Group 4*
Total Dissolved Solids	11.03	9.41	8.40	7.61
pH	11.28	9.90	11.09	10.57
Dissolved Oxygen	2.91	3.42	3.15	3.75
Total Iron	7.00	5.43	5.24	4.95
Total Coliform	1.38	1.60	1.14	1.16

Approximate F = 2.06; F_{crit} (0.05; 15,50) = 1.88.

Comparison of Original Group Membership and Group Membership Determined by Stream Sampling Parameters

	Number of watersheds classified into group				
Original Group	*1*	*2*	*3*	*4*	*Totals*
1	5	3	0	0	8
2	1	5	1	1	8
3	0	1	4	2	7
4	0	0	0	3	3
Totals	6	9	5	6	26

Fraction of watersheds correctly classified = 0.654; Fraction of watersheds correctly classified by chance = 0.256; t-statistic for classification = 4.649; t_{crit} (.001;25) = 3.725.

standardized coefficients shows that high values of total dissolved solids, and total iron are associated with watersheds which belong to the worst perceived quality group, while high values of total coliform are associated with Group 2. Watersheds in the better perceived quality groups tend to have higher dissolved oxygen values as expected. Although the coefficients for pH exhibit considerable variability, they do indicate that watersheds with low pH values are most likely to belong to the "next to worst" perceived quality group. In addition, the value of the approximate F-statistic shows that the five stream sampling parameters do provide a statistically significant basis upon which to assign watersheds to perceived quality groups. On the whole, they predict original group membership about 65.4 per cent of the time. Morrison provides a method for estimating the proportion correctly classified by chance [9], and Frank supplies a test of significance for

Table 4. Twenty-Six Watersheds Classified Into Four Perceived Quality Groups. (Group Membership Based Upon 5 Stream Sampling Parameters

Watershed	*Minimum chi-square*
Group 1	
Saw Mill Run	4.19
Potato Garden Run	6.73
Streets Run	2.54
Fallen Timber Run	8.11
Millers Run	9.81
Chartiers Creek	0.17
Group 2	
Thompson Run	14.78
Turtle Creek	2.61
Robinson Run	3.61
Montour Run	2.11
Moon Run	4.96
Peters Creek	0.97
Plum Creek	3.19
Bunola Run	6.44
Becks Run	2.44
Group 3	
Pucketa Creek	10.58
Deer Creek	1.59
Pine Creek	0.77
Flaugherty Run	2.03
Long Run	2.02
Group 4	
Big Sewickley Creek	1.88
Little Sewickley Creek	0.41
Squaw Run	0.63
Kilbuck Run	0.50
Lowries Run	0.11
Bull Creek	0.23

χ^2 (0.001; 5) = 20.515.

the proportion correctly classified by the discriminant variables [10]. By chance, watersheds would be correctly classified about 25.6 per cent of the time. Based upon this figure, the discriminant functions do provide a significantly better basis for classifying watersheds than pure chance at the 0.001 level.

Table 4 shows the assignment of watersheds into groups based upon the five stream sampling parameters. Assignment was determined by placing a watershed in the perceived quality group for which the chi-square value was a minimum. None of the chi-square values (Table 4) was statistically different from all the groups, indicating that the five stream sampling parameters do characterize the original division into groups. Nine watersheds are classified differently using the division into groups based on stream sampling parameters (Plum Creek, Bunola Run, Becks Run, Chartiers Creek, Long Run, Kilbuck Run, Peters Creek, Lowries Run, and Bull Creek). In every case except that of Kilbuck Run, the difference is merely an interchange between adjacent quality groups. This indicates that, with the exception of Kilbuck Run, the overall water quality groupings based upon the panel's ratings tend to be substantiated by stream sampling data. Thus, the perceived quality groups do provide a consistent and methodical classification of watersheds on the basis of overall water quality, based upon the results and interpretations of the analysis.

Using Activity Indices as Indirect Indicators of Water Quality

Twenty-one watershed activity indicators were used in this analysis, each indicator representing one or more of the six problem areas contributing to the generally degraded water quality conditions existing on the County watersheds [3, 4, 11]. These indicators were normalized to account for watershed area by expressing them as densities, in the units of per cent per square mile, defined as follows:

$$I_{ij} = \frac{100\, x_{ij}}{A_j \sum_{k=1}^{61} x_{ik}} \qquad \begin{array}{l} i = 1, 2, \ldots, 21 \\ j = 1, 2, \ldots, 61 \end{array}$$

where

A_j = area of watershed j, in square miles

I_{ij} = watershed activity indicator value for variable i in watershed j, in per cent per square mile

x_{ij} = raw data values for variable i measured for watershed j

The twenty-one indicators are listed in Table 5.

Discriminant Analysis of Perceived Quality Groups

The discriminant analysis sought to determine if membership in perceived quality groups (Table 2) could be predicted from a

Table 5. Watershed Activity Indicators

Watershed activity	*Indicator*
I. Municipal Waste Disposal	1. Number of sewage treatment plants.
	2. Fraction of existing sewage treatment plant capacity presently utilized.[a]
	3. Biochemical oxygen demand discharged daily in the effluent of sewage treatment plant.
	4. Number of combined sewer overflows.
	5. Number of unsewered residences.
	6. Number of direct discharges of domestic sewage.
II. Solid Waste Disposal	7. Number of solid waste disposal sites.
	8. Number of mine dumps.
III. Urbanization	9. Population.
	10. Fraction of usable land presently developed.[a]
	11. Number of road-stream crossings.
IV. Acid Mine Drainage	12. Number of strip mines.
	13. Number of deep mines.
	14. Number of mine workers.
	15. Length of stream adjacent derelict land.
V. Industrial Waste Disposal	16. Number of industrial waste treatment plants.
	17. Number of direct discharges of industrial waste.
	18. Length of stream adjacent industrial land.
VI. Siltation	19. Area of vacant usable land.
	20. Area of land with slope greater than 25 per cent.
VII. Stream Potential	21. Assimilative capacity.

[a] Dimensionless fraction, not expressed as per cent per square mile.

knowledge of the twenty-one indirect indicators of watershed activity (Table 5). To test this premise, a stepwise discriminant analysis was performed. This procedure ensures that only those variables that are statistically significant will be included. The stepwise procedure produced the classification functions shown in Table 6, based upon eight of the original twenty-one indirect indicators.

The standardized coefficients shown in Table 6 provide information about the general watershed characteristics of each of the

Table 6. Multiple Discriminant Analysis of Perceived Quality Groups Based on Eight Indirect Indicators

	Standardized classification coefficients			
Indirect Indicator	*Group 1*	*Group 2*	*Group 3*	*Group 4*
Biochemical oxygen demand discharged daily in sewage treatment effluent	-7.09	-2.37	-0.30	-0.19
Number of combined sewer overflows	2.53	-0.05	-0.17	-0.35
Number of unsewered residences	3.29	5.21	3.47	2.66
Number of strip mines	5.51	3.45	2.35	1.03
Number of mine workers	1.38	-9.56	-2.87	-3.27
Number of direct discharges of industrial waste	0.64	3.71	1.20	0.85
Number of solid waste disposal sites	7.62	4.03	0.80	0.34
Population	4.81	4.94	3.52	2.37

Approximate F = 2.47; F_{crit} (0.05; 24,62) = 1.79

Comparison of Original Group Membership and Group Membership Determined by Indirect Indicators

	Number of watersheds classified into groups				
Original Group	*1*	*2*	*3*	*4*	*Totals*
1	8	0	1	0	9
2	0	8	1	1	10
3	0	1	6	2	9
4	0	0	1	3	4
Totals	8	9	9	6	32

Fraction of watersheds correctly classified = 0.781; Fraction of watersheds correctly classified by chance = 0.261; t-statistic for classification = 6.707; t_{crit} (0.001, 31) = 3.636.

perceived quality groups. The coefficients show that combined sewer overflows, strip mines, mine workers, and solid waste disposal sites are associated with those watersheds which belong to the worst perceived quality group. Unsewered residences and direct discharges of industrial waste are the main characteristics of the second-to-worst perceived quality group. The coefficients for population indicate that densely populated watersheds tend to belong to the worst two perceived quality groups much more than to the best two groups. Biochemical oxygen demand in sewage treatment plant effluents is associated with the best two water quality groups much more than with the worst two groups. This indicates that the worst two perceived quality groups tend not to have large sewage treatment plants located in the watersheds. This conclusion is confirmed by the fact that the worst water quality group is characterized by combined sewer overflows (associated with interceptor sewers leading to regional sewage treatment facilities), and the second-to-worst group, by residences not served by a municipal wastewater treatment facility.

Note that the eight variables chosen by the stepwise discriminant analysis represent five of the original six problem areas. Siltation has not been included in the set of eight variables because the variables representing that problem area were not statistically significant in discriminating among the four groups. In addition, the assimilative capacity of the stream was not included among the eight variables because it did not add significantly to the discrimination among groups. This is probably due to the fact that assimilative capacity is closely related to watershed area. Since the variables were normalized by dividing by watershed area, differences in assimilative capacity had already been accounted for.

Comparison of Stream Sampling Data and Indirect Indicators

To compare the predictive power of stream sampling data and indirect indicators in determining membership in perceived quality groups, Figure 3 was prepared. This plot shows the number of correct predictions of original group membership as a function of the number of variables included in the discriminant analysis. Points were plotted for one through five stream sampling variables, and one through eight indirect indicator variables. These plots indicate that six indirect indicator variables predict about as well as five stream sampling variables. However, eight indirect indicator variables do somewhat better than the five stream sampling variables in predicting perceived water quality.

A chi-square test was utilized to determine if one through five stream sampling variables predicted group membership significantly better than one through five indirect indicators. In all cases, the null hypothesis (i.e., that no difference in predicting ability exists between the two methods) could not be rejected at the 0.05 level. In addition, the proportions of correct predictions obtained by using seven and eight indirect indicator variables were not significantly different (at the 0.05 level) from that obtained using five stream sampling variables.

Note that for this comparison the term "correct" means agreement with the original division of thirty-two watersheds into four perceived quality groups. (Table 2.) No attempt is made to

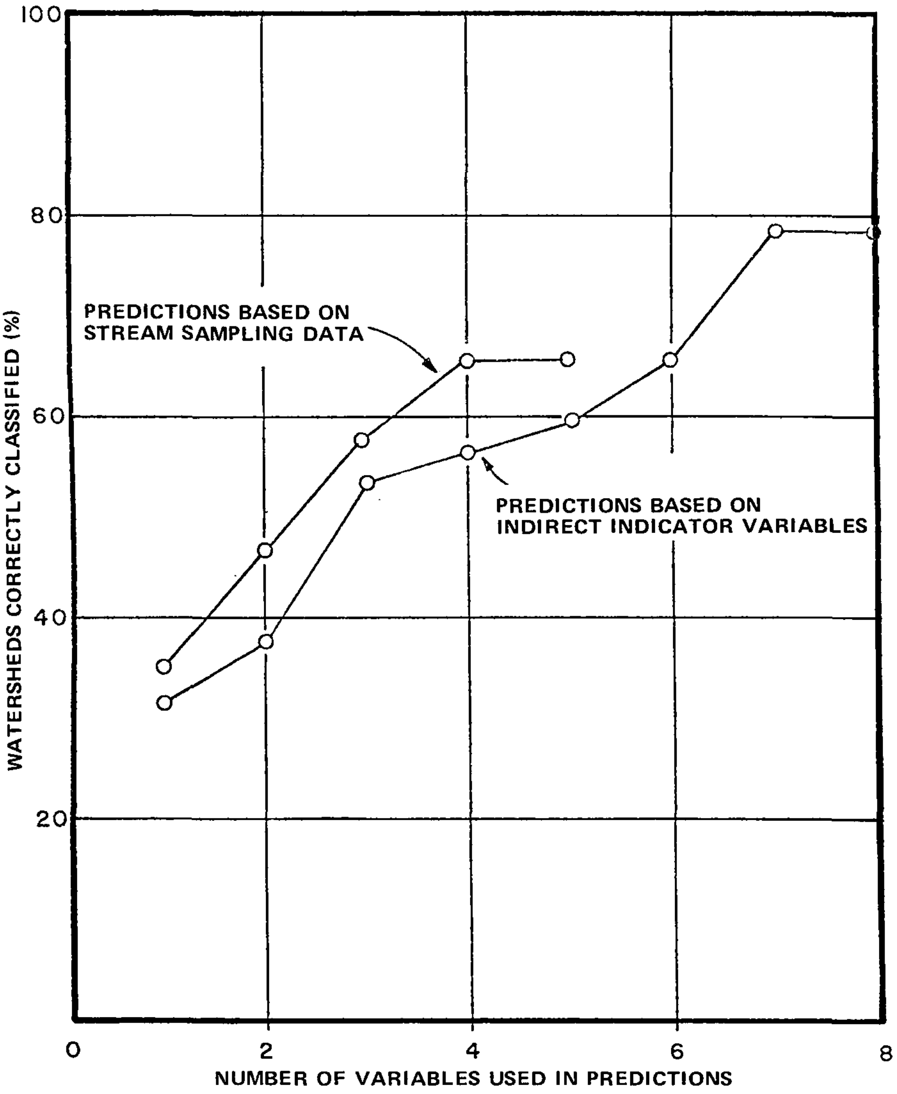

Figure 3.

establish these perceived judgments as an objective absolute. They do, however, represent an integration of knowledge about water quality conditions on the thirty-two watersheds rated. In addition, with few exceptions, these ratings have been duplicated by two sets of objective data: water quality parameters and indirect indicators.

Thus, the perceived water quality groupings and eight indirect indicators provide a reliable basis for water quality management decisions, since they contain at least as much information relating to the overall water quality of the watersheds as the limited stream sampling data presently available to local water pollution control authorities. As priorities are established, and individual watersheds studied in detail, more reliance on stream sampling data to characterize water quality variations with a watershed can be expected to occur.

Classification of Watersheds into Perceived Quality Groups

The discriminant analysis previously described was used to classify the sixty-one watersheds in the study region. Watersheds were classified into a perceived quality group on the basis of the calculated chi-square statistics for group membership. Adjusted chi-square statistics (accounting for prior probabilities of group membership) were calculated for previously unclassified watersheds, following the method described by Tatsuoka [8]. A watershed was assigned to the group for which the adjusted chi-square statistic was minimum. The final assignment of watersheds into perceived quality groups based on the eight indirect indicator variables is shown in Table 7.

Only seven of the watersheds (Girtys Run, Pine Creek, Chartiers Creek, Guyasuta Run, Kilbuck Run, Lowries Run, and Flaugherty Run) are classified differently by the functions than by the panel of experts. In all but two of the cases, the difference amounts to an interchange between adjacent perceived quality groups. The remaining two watersheds (Girtys Run and Kilbuck Run) are classified two perceived quality groups higher by the indirect indicators than by the panel of experts.

Girtys Run has been the subject of an intense study which indicates that the watershed is plagued by flooding problems, but that water quality problems are localized ones associated with combined sewer overflows [12]. It is likely that the low rating assigned by the experts represented an integration of flooding and water quality problems. Although combined sewer overflows are a characteristic of the worst perceived quality group, Girtys Run has no mining activity or strip mines, and no solid waste disposal sites, reducing its similarity to the watersheds in Group 1. Since nearly all the area of Girtys Run lies within the service area of the regional wastewater treatment facility, the Allegheny County Sanitary Authority, and there are no direct discharges of industrial waste, it does not resemble the watersheds in Group 2. Thus,

Table 7. Sixty-One Watersheds Classified Into Four Perceived Quality Groups

Watershed	*Minimum chi-square*
Group 1	
Saw Mill Run	22.56
Plum Creek	15.68
Potato Garden Run	6.21
Bunola Run	9.48
Streets Run	8.70
Fallen Timber Run	6.46
Becks Run	8.11
Millers Run	7.13
Days Run	53.77[a]
Nine Mile Run	47.53[a]
Wylie Run	41.36[a]
Group 2	
Thompson Run	17.63
Turtle Creek	4.02
Robinson Run	6.51
Montour Run	7.23
Homestead-West Run	8.76
Long Run	5.27
Moon Run	9.10
Sandy Creek	9.13
Pine Creek	3.61
Crawford Run	1441.01[a]
Crooked Run	20.23
Indian Creek	16.09
Kelly Run	5.79
Lobbs Run	17.83
McCabe Run	9.27
Pine Run	281.51[a]
Pollock Run	8.42
Quigley Creek	6.44
Thorn Run	7.07
Wildcat Run	5.26
Breakneck Creek	142.95[a]
Brush Creek	31.25[a]
Raccoon Creek	373.11[a]
Group 3	
Peters Creek	12.63
Campbells Run	5.32
Jacks Run	7.95

Table 7. (Cont.)

Watershed	*Minimum chi-square*
Pucketa Creek	4.00
Deer Creek	1.76
Bull Creek	2.74
Girtys Run	3.57
Chartiers Creek	3.06
Guyasuta Run	2.15
Beckets Run	5.02
Douglas Run	4.22
Narrows Run	5.76
Riddle Run	12.82
Shades Run	5.78
Shouse Run	6.35
Spruce Run	7.39
Sunfish Run	6.61
Tawney Run	3.27
Toms Run	7.74
Group 4	
Big Sewickley Creek	2.04
Little Sewickley Creek	0.55
Squaw Run	1.70
Kilbuck Run	0.69
Lowries Run	0.67
Flaugherty Run	1.09
Glade Run	4.59
Raredon Run	6.56

[a] Statistically significant at 0.001 level; χ^2 (0.001, 8) = 26.125.

classification of Girtys Run in the third water quality group does represent a reasonable categorization.

Much less is known about Kilbuck Run, as is indicated by the fact that the perceived quality rating is based upon only four responses. Table 4 indicates that Kilbuck Run was also classified in Group 4 by the stream sampling parameters. This agreement between the stream sampling parameters and the indirect indicators, coupled with the small number of responses upon which the original perceived quality score was based, indicates that Group 4 is probably more representative of the watershed than Group 2.

Because of the nature of the perceived quality ratings, the final assignment of watersheds into perceived quality groups was based upon the classification functions (Table 6). In this way an objective assignment procedure was ensured, eliminating the subjectivity which seems to have influenced the original assignments of the seven watersheds discussed previously.

Implications for Field Investigations

As stated earlier, the final assignment of a watershed to a perceived quality group was determined by calculating chi-square values for the watershed with respect to the centroid of each of the four groups. The watershed was assigned to the group for which the computed chi-square statistic was a minimum. Further, the values of the minimum chi-square statistic shown in Table 7 can be interpreted as a chi-square variable with eight degrees of freedom. In that light, the minimum chi-square statistics for eight of the watersheds (noted in Table 7) are statistically significant at the 0.001 level. Thus, the values of the indirect indicators for these eight watersheds are out of the range of values for which the classification functions provide an adequate characterization of perceived water quality. Hence, the following eight watersheds are prime candidates for special studies and field sampling to provide an adequate characterization with respect to overall water quality:

1. Days Run
2. Nine Mile Run
3. Wylie Run
4. Crawford Run
5. Pine Run
6. Breakneck Creek
7. Brush Creek
8. Raccoon Creek

Because these watersheds all belong to the worst two overall water quality groups, they may represent cases of extreme degradation associated with some particular factor (e.g., combined sewer overflows). They should be investigated to determine if this is the case, and if enforcement action is warranted.

Summary and Conclusions

A mechanism to evaluate the overall water quality of small urban watersheds has been developed. Since very little stream sampling data exist upon which to base the evaluation, the concept of relating perceived water quality to indirect indicators of watershed activity was used.

A panel of experts was selected to provide perceived water quality ratings of as many watersheds as possible. These ratings were used as the basis for defining four groups of perceived water quality. The validity of the four perceived quality groups was established by relating group membership to the limited stream sampling data that were available.

A group of twenty-one indirect indicators of watershed activity was chosen to represent the factors thought to be responsible for the generally degraded conditions of the sixty-one County watersheds. Eight of the twenty-one indirect indicators were chosen as statistically significant in determining membership in perceived quality groups:

1. biochemical oxygen demand discharged daily in sewage treatment plant effluent
2. number of combined sewer overflows
3. number of unsewered residences
4. number of strip mines
5. number of mine workers
6. number of direct discharges of industrial waste
7. number of solid waste disposal sites
8. population

The discriminant functions were used to classify all sixty-one watersheds into the four perceived quality groups, and to identify those watersheds which are not characterized well by the discriminant functions. As such, they represent a choice of watersheds for special studies and field sampling.

The eight indirect indicators achieve a great degree of success in assigning watersheds to overall water quality groups. Thus in establishing initial management priorities, local regulatory agencies may make more reliable decisions based upon indirect indicators than upon the limited and discontinuous stream sampling data usually available for that purpose.

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