The W.A.T.E.R. System: Computer Programs For Stream Network Analysis

D. M. Coffman
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W. N. Melhorn

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THE W.A.T.E.R. SYSTEM:

COMPUTER PROGRAMS

FOR STREAM NETWORK ANALYSIS

BY D.M. COFFMAN
A.K. TURNER
W.N. MELHORN

JUNE 1971

PURDUE UNIVERSITY
WATER RESOURCES RESEARCH CENTER
WEST LAFAYETTE, INDIANA
THE W.A.T.E.R. SYSTEM: COMPUTER PROGRAMS FOR STREAM NETWORK ANALYSIS

BY

D. M. Coffman
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Principal Investigator: Dr. W. N. Melhorn
Project A-007-IND

Purdue University
Department of Geosciences
Lafayette, Indiana

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+ 

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<td>Drainage Basin Area</td>
</tr>
<tr>
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<td>-</td>
<td>Area Drained by Segment of Order U</td>
</tr>
<tr>
<td>A_1</td>
<td>-</td>
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<td>B_w</td>
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<tr>
<td>C</td>
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</tr>
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<td>D</td>
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<td>Fall of Segment of Order U</td>
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<td>-</td>
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<td>Basin Length (Diameter)</td>
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<td>-</td>
<td>Length of Link of Magnitude M</td>
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<td>-</td>
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<tr>
<td>L'_u</td>
<td>-</td>
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<td>NUMSEGM</td>
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ACKNOWLEDGMENTS

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ABSTRACT

The development and importance of quantitative fluvial research has been closely tied with the classification of stream networks. Historically, both qualitative and quantitative systems of stream classification have evolved in response to ever-changing needs and scientific environment. Today, many quantitative descriptions of streams are available, ranging from simple listing techniques to taxonomic hierarchies. All current classifications, however, are based solely on the channel network topology whereas the geometry, hydrology, water budget, form, and fabric of the drainage basin are ignored. Another problem with current methods of stream description is the amount of computation necessary to ascertain the characteristics of streams of any given class. Thus, these advanced research systems are rarely used in applied stream studies.

The WATER System is herein presented as a computer augmented method for collection, storage, and analysis of real river networks. Its purpose is to facilitate the application of advanced fluvial analysis to actual problems of water management and river control. Data are collected so that geometry as well as topology of a stream is preserved, permitting calculation of all common drainage basin statistics such as area, shape, orientation, and texture. Classification of segments and statistical comparisons of the properties
of the various classes are automatically performed. The ability of the WATER System to classify the river network according to any existing topologic system and place numerical values on descriptive terms makes it a first generation attempt at an integrated automated system of stream classification and analysis.
CHAPTER 1
STREAM CLASSIFICATION AND THE WATER SYSTEM

Introduction

Man has been interested in rivers and their drainage basins for centuries. He was thankful for their contributions as means of transportation and sources of food, frustrated by their interference with communication and national expansion, and fearful of their violence in times of flood. Man's interest in rivers has evolved from passive observation and acceptance of river behavior, through thoughtful statements of empirical fluvial laws, to active studies of river processes and form, and eventually to dynamic projects which harness river power and moderate river behavior. Closely tied to this evolution is the history of man's attempts to classify river systems.

Purpose and Scope

It is the purpose of this report to: 1) review and analyze existing methods of stream classification and their historical development, 2) summarize the parameters proposed to describe stream networks and drainage basins, and 3) introduce a new computer augmented system for the collection, storage and integrated description of drainage basins. This report documents and demonstrates also the capabilities
of the Watershed And Terrain Evaluation Research (WATER) System of computer programs. The WATER System offers fluvial researchers and hydrologic planners an economical and speedy method of collecting and analyzing large amounts of drainage basin data such as has never before been possible.

**Stream Network Classification**

Many types of stream classification have been proposed, but a truly ideal classification of a river system should take into account both properties of the channel network and of the drainage basin. Channel properties consist of the hydrologic, geometric, and topologic characteristics of the river itself. Basin properties measure the water budget, form, and fabric of the area drained by the river. Unfortunately, most attempts to categorize streams have been based solely on those features derived from their orderly branching pattern, that is, classifications are based on network topology. Thus five of the six river system properties are ignored in present systems of classification.

Because present stream classifications are topologic, the basic units of a branching network (nodes, links, segments, and nets) should be familiar. Nodes are points indicating the location of either a stream tip or the junction of two tributaries. Links are lengths of stream channel between two consecutive nodes. Segments are collections of a uniquely defined series of consecutive links.
The net is the sum of all the links contained in a portion of the river system under consideration.

The manner in which one or more of these topologic units is described forms the basis of the many systems of stream classification which have been proposed. Interestingly, not all these descriptions meet the criteria of a taxonomic classification which implies hierarchy of sets, subsets, and samples resulting in the ability to predict the position of a sample in the set through the identification of its characteristic properties. Instead, descriptions of a stream's topologic units fall into four categories (lists, labels, groups, and hierarchies) of which only a hierarchical description has the attributes of a system of taxonomic classification.

A list description is simply a listing of topologic units such as nodes or links, generally in an orderly sequence, along with the properties of the unit (i.e. location, length, elevation). Thus the list provides a complete inventory of the nature of every member of the net, but has the disadvantage of bulk and lack of organization. The label description is also a listing of topologic units in some defined sequence, but labels are used to describe selected properties. Labels facilitate improved data handling and thus provide better organization, but the bulk of the list is still a major fault and some information is lost in the substitution of labels for actual values. Group description involves collection of all topologic units with similar
properties into the same class. Grouping introduces significant order into the sampled data but results in reducing accuracy by generalizing the parameter values. Furthermore, no structure exists between individual groups. Hierarchical descriptions are produced when groups can be subordinated. Fig. 1.1 shows the type of description and topologic unit used for the various systems of stream classification.

From the previous discussion, two major problems in stream classification should be apparent. First, current forms of stream classification ignore all properties of the river system except topology. Although valuable relationships between topology and other river properties have been demonstrated, the authors believe a more comprehensive system of classification is a preferable alternative. Secondly, classifications differ in their degree of subordination of elements from simple lists to hierarchies. Although the list contains detailed information on river properties, its lack of organization prevents easy comparison of two basins which is the purpose of a system of classification. On the other hand, although hierarchies facilitate comparisons they generalize actual properties through grouping. Thus the detail needed for quantitative studies into river processes may be lost.

The WATER System represents an integration between these extremes of present topologic stream classification.
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<td>Hierarchy</td>
</tr>
<tr>
<td>Ambilateral Class</td>
<td>Smart</td>
<td>1969</td>
<td>Link</td>
<td>Group</td>
</tr>
<tr>
<td>Quantitative</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**FIG. 1.1** TOPOLOGIC SYSTEMS OF STREAM CLASSIFICATION
Data are collected in the form of a list and permanently stored on computer cards. With the aid of a computer's speed, this list description can be instantly transformed into the major hierarchical classifications, meanwhile maintaining detailed descriptions of any link or segment. In addition, most drainage basin statistics are automatically calculated and the total picture of a river system which can be so easily provided may stimulate development of more comprehensive systems of stream classification in the future.
CHAPTER 2
A HISTORY OF THE DESCRIPTION OF RIVER SYSTEMS

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All rivers run into the sea, yet the sea is not full: unto the place from whence the rivers came, thither they return again.

Ecclesiastes I:7

Introduction

From ancient times Man has used riverine systems in communications, commerce, transportation, as fisheries, and as a source of power. Unfortunately his thinking about streams did not extend beyond their utility; in essence, they were simply there! Streams were formed, the ancients thought, in response to convulsive forces within the bowels of the Earth that rent and distorted the surface, providing a convenient channel through which coursed the waters derived from the interior in response to these same convulsions. The importance of streams in sculpturing landscape forms, in denuding the continents of sediment and transporting it to the sea, or as a necessary element in the chain of the hydrologic cycle—despite the teaching in Ecclesiastes—is, with few exceptions, the product of scientific investigation of the past two centuries of human history.

The rather obvious concept that the planform pattern of any river system on the Earth's surface is the result of
multiple bifurcation that assumes definite order, and that this branching is in constant repetition from stream to stream, does not require formal education. Rather, it required only the keen observation of unlettered pioneers and explorers, as documented by their names for streams in recognition of the fact that stream patterns were branched. For example, in our own local area of Indiana, Wildcat Creek, a tributary of the Wabash River, divides into North, South, and Middle Forks. In other areas—and perhaps from subjective understanding of the nature of streams rather than lack of imagination in assigning place names—forks, in turn, pass into "branches" bearing the same name as the forks and the master stream.

Early Descriptions of Stream Nets (1752-1900)

Perhaps the earliest fluvial erosionist was the Italian scholar Giovanni Targioni-Tozzetti (1712-1784) who, in analyzing the work of the Frenchman Buffon decided that the origin of valleys must be ascribed to the rivers that presently occupy them rather than to some catastrophic force creating depressions and rifts in the Earth's surface. He noted as conclusive evidence of this hypothesis the orderly and systematic pattern of the river network.

"Then it was that the mountain streams, arranged in a network, began to erode and have continued to
deepen their channels until, on approaching the level of the modern sea, they lose their velocity and the force of their impact." (57).

James Hutton, in his first important work on fluvial processes, appears to have anticipated the concept of stream ordering and Horton's Law of Stream Numbers.

"... it is these channels, increasing in their size and diminished in number by the uniting of their waters, that give so clear a prospect of the operations of time past and prove the theory of the land being in a continual state of decay."

(22, II, 446).

John Playfair, protagonist and illustrator of the cardinal uniformitarian principals enunciated by Hutton, apparently was the first to observe that a river was not a chance feature on the landscape but a finely ordered organism, each tributary being perfectly adjusted in height at its junction with the main trunk of the river and each branch joining in the common task of eliminating all irregularities (34, p. 61). In his Illustrations of the Huttonian Theory Playfair stated a basic concept of drainage networks:

"... Every river appears to consist of a main trunk, fed from a variety of branches, each running in a valley proportioned to its size, and all of them together forming a system of valleys, communicating
with one another, and having such a nice adjustment of their declivities, that none of them joins the principal valley, either on too high or too low a level; a circumstance which would be infinitely improbable, if each of these valleys were not the work of the stream that flows in it." (34, p. 102).

In describing the structure of valleys among mountains, the communication between valleys, the uniform declivities of these valleys, and their branching, Playfair further stated:

"These secondary valleys have others of a smaller size opening into them; and, among mountains of the first order, where all is laid out on the greatest scale, these ramifications are continued to a fourth, and even a fifth, each diminishing in size as it increases in elevation, and as its supply of water is less." (34, p. 114).

A wealth of 18th-century mathematically based hydraulic research included a quite remarkable work by Comte Louis Gabriel Du Buat who wrote a treatise on hydraulic principles based on experimentation with factors controlling and influencing the flow and channel sinuosity of rivers. It appears, rather strangely, that his advanced ideas and general observations were either unknown to or ignored by geologists of his own and later times. Writing more than a century before William Morris Davis, the founder of the
modern era of stream studies and originator of the concept of the fluvial erosion cycle, Du Buat clearly preempts Davis' ideas and terminology. There is no evidence, however, that Davis had any knowledge of Du Buat's hydraulic treatise which went through a succession of printings from 1779 to 1816.

"A river, from its source to the sea, depicts the different ages of man. Its BEGINNING is a mere nothing; it rises from the earth but originates in heaven. Its INFANCY is frolicsome and capricious; it turns mills and eddies playfully beneath the flowers. Its YOUTH is impetuous and hasty; it buffets, uproots and overturns. Its MIDDLE COURSE is serious and wise; it makes detours and yields to circumstances. In OLD AGE its step is measured, peaceful, majestic and silent; its tranquil waters roll softly and soon lose themselves in the immense ocean (11, 1786, pp. 32-33).

Charles Lyell was concerned with chemical and physical principles applied to geology, and more specifically with fluvial hydraulics in relation to the amount of sediment undergoing stream transport. He reasoned that changes in width, depth, and general geometry of channels below a tributary junction was accommodated by adjustments of several parameters rather than width alone:
"... when several rivers unite into one, the superficial area of the fluid mass is far less than that previously occupied by the separate streams. The collective waters, instead of spreading themselves out over a larger horizontal space, contract themselves into a column of which the height is greater relatively to its breadth ... By this beautiful adjustment, the water... is made continually to occupy less room...

(25, 1830, pp. 170-171).

During a mid-19th century revival of the doctrine of marine erosion and denudation as the principal agent of landscape sculpture, Colonel George Greenwood remained one of the few and ardent supporters of the fluvial hypothesis. He noted that both valley and slopes are integral features of a drainage system and are intimately connected in such a way that all material of denudation is smoothly carried away without any interruption of the process (5, p. 378).

"Every valley, indeed, is a valley of denudation;...
For it is an essential characteristic of valleys, trunk or branch, that however infinite the tracery, and however countless the number of their ramifying upper inlets, each and every valley can have but one lower outlet (16, 1857, p. 35).

Greenwood also understood clearly the modern concepts of base level, of structural and lithologic control of stream
forms in the denudation process, and the principles of stream abstraction, as for example:

"Every valley is always lengthening at the upper end or decreasing in height there; and all intermediate parts are perpetually in process of being planed down, or built up, to one uniform gradient from the head of the valley to its mouth... (16, 1857, pp. 52-53).

The explorations of the American West in the latter third of the 19th-century permitted examination of large regions of terrain quite different in climatic and structural settings from those accessible to the western European geologists. The explorer-naturalist J. W. Powell and his contemporary G. K. Gilbert are commonly credited with development of the first modern generic system of classification of valleys and streams. Powell established formally the term "base level" and other terms related to structural and lithologic controls affecting stream distributions and patterns; for example, "superimposed valleys", "anticlinal valleys", "consequent valleys", and other structurally and lithogically-derived forms that are still accepted in principle. It is rather startling, however, to discover in careful review of the original writings of these men an almost total preoccupation with this systematic classification based on structure and rock type, the importance of geologic time in fluvial mechanics, and the role of sediment transport in the denudation process. Perhaps this was conditioned
response to the obvious magnitude of these forces, either past or present, in the canyon country. Rarely do they comment on the planform pattern or network of the actual fluvial systems; and where mentioned, the allusion is generally in alliterative descriptive terms relating to scenic impact. This stands in striking contrast to their rather methodical, basically quantitative approach to hydraulic and geologic controls. Such alliteration is nicely illustrated by the following description by C. E. Dutton of the Vermilion Cliffs north of the Grand Canyon; it is one of the rare recognitions of stream nets:

"... the Triassic terrace ending in the Vermilion Cliffs... is literally sawed to pieces with caños. There are dozens of these chasms... Every one of them ramifies again and again until they become an intricate net-work, like the fibres of a leaf (12, p. 62)."

The eminent physiographer, William Morris Davis, synthesized much of the earlier knowledge of fluvial systems and incorporated it into his general terrain model described in his three classic papers of early geomorphology (1889, 1890, 1899). Undoubtedly he was greatly influenced by the Western explorer-scientists, as noted by his assertion that Structure, Process, and Stage (i.e. Time) were the principal components in the sculpture of landscape. Davis clearly recognized, however, how little was yet known about stream systems in a paper written in 1900 (10, pp. 78-81):
"The most ardent uniformitarian would, in the middle of the (19th) century, go no further than to admit that rain and rivers could roughen a region by carving valleys in it...the explorations and surveys of our western territories were undertaken, and a flood of physiographic light came from them. One of the earliest and most important of the many lessons of the West was that Playfair's Law obtained even in the case of the Grand canyon of the Colorado, which was visited by the Ives expedition in 1858... Thus far, while most attention had been given to the work of rivers, little or no attention had been given to the arrangement of their courses. It seems to have been tacitly assumed that the courses of all streams were consequent upon the slope of the initial land surface."

Davis embellished the fundamental observations and ideas of Dutton, Powell, and Gilbert. He added his own ideas and, using the Appalachian Mountains as a testing ground, established a new generic classification of landforms as part of his "Geographical Cycle" which has remained the descriptive model and keystone for many landform studies of the past half-century. Davis recognized clearly that his qualitative, or at best semi-quantitative classification, provided only a general model subject to modification and intrusion of variation through special cases of the model.
He provided a framework which he hoped would stimulate discussion and further refinement of the classification of landforms, particularly those derived from fluvial processes.

"...My object has been primarily to secure a just and accurate recognition of facts, and only secondarily to attach words to the facts as convenient handles by which to bring the facts forward...There can be no question that adoption of a suitable term as the name for a fact is a great aid to the general recognition of the fact itself... It is admittedly difficult always to use terms in a manner that is perfectly consistent with their definitions... Further discussion may therefore be advisedly directed to a settlement of open questions... The future meanings of these words will depend much less on the preference of the older geologists and geographers of to-day than on that of their younger successors."

Davis' request for open discourse and modification of his system unfortunately was ignored for nearly four decades. Geographers and geologists eagerly leaped to accept his system and model, and it was so blindly accepted that the invited dialogue and questioning has generally not come until the last two decades.

Modern texts in geomorphology and introductory physical geology commonly describe in sections pertaining to fluvial processes, yet another system; a "pattern" classification of streams. This classification is in normal usage in
regional or areal descriptions of terrain in geologic reports. Although Davis (9) used terms such as "rectangular" and "centripetal" in describing Appalachian stream networks, it is interesting to note that he never again used these or other pattern appellations in his early essays. Even the name given to the commonest of all stream patterns in nature, the "dendritic" pattern, was apparently not used until 1898 by I. C. Russell, although it was forecast somewhat earlier by Dutton (1882) in the quotation already cited. Additional pattern terminology such as "radial", "annular", "angular", and "trellis" started to come into use at various times between 1895 and 1901. Most apparently were never defined nor proposed in a formal sense. They simply appeared, were repeated, and were gradually adopted into texts and other writings and have become an integral part of the descriptive nomenclature of stream networks without having ever undergone scrutiny and open debate. As a final note, it is interesting to observe that geomorphic texts of the 1930's fail to use or define many of these planform pattern terms, but all are included in modern texts (58, 13).

The "Modern" Era (1900-1976)

A 1932 paper by Zernitz (63) represents the first collation of the planform classification terms and may mark the beginning of modern stream network description, from which later quantitative classifications have developed. In Europe, however, H. Grevelius (17) had attempted in 1914 to classify streams based on their bifurcation. In
his system the largest, most branched (master) trunk stream was assigned a stream order of one. Smaller tributaries were given higher stream order. This system had the disadvantage that unbranched fingertip channels, which are much alike in any drainage basin, had different stream orders. A second disadvantage arose in picking the trunk stream that provides a fixed base for the system; expansion of the system to include larger streams was thus precluded unless the enlarged drainage basin was completely reordered.

**Horton Stream Order**

The German study of Grevelius seems to have been largely ignored until Horton (20, p. 281) resurrected the former's idea of ordering streams on a basis of their bifurcation. Horton (20, p. 281) believed, however, that unbranched tributary streams having generally similar characteristics should be designated by the same ordinal. Therefore he introduced a classification system for order that was the inverse of that formulated by Grevelius. In this system unbranched tributaries were assigned the order one, whereas the largest channel in a basin was assigned the highest stream order. Horton defined second-order streams as those whose tributaries are only of first-order, whereas third-order streams receive both first and second-order tributaries, etc.

The Horton system, also, faced problems in practice. The major difficulty was that at every junction the parent
stream had to be distinguished from the tributary. Choice was made using the following rules:

"1. Starting below the junction, extend the parent stream upstream from the bifurcation in the same direction. The stream joining the parent stream at the greatest angle is of the lower order.

2. If both streams are at about the same angle to the parent stream at the junction, the shorter is usually taken as the lower order."

a system which is cumbersome and open to error of judgment in choice. The chief importance of Horton's work lies in introduction of quantitative measures of a drainage basin derived by his method of stream ordering. He demonstrated graphically that several properties of streams relate to order according to a geometrical series. These relations were subsequently presented as Horton's empirical "Laws of Drainage Composition", including The Law of Stream Numbers, The Law of Stream Lengths, and The Law of Stream Slopes. All of these "laws" may be expressed mathematically.

Although Horton's stream ordering system held promise for advancement of a quantitative investigation of streams, it was difficult to use in a practical sense. Too much time was required to order a basin of any size, and different workers were likely to produce differently ordered maps of the same basin because of choice and interpretation.
Strahler Stream Order

Strahler (54, p. 1120) chose to work with channel segments, rather than with Playfair's concept of a trunk stream and its branches as was followed by Horton. Strahler redefined a given stream order as a channel segment formed by merger of two segments of the next lower order, and ending in merger with segments of equal or higher order. Thus, the necessity of choice required by the Horton system could reduce to a single simple and mandatory rule for defining the process of ordering a drainage basin. The rule became

\[ U \# U = U + 1 \]

where \( U \) represents the stream order of any channel segment, \( \# \) is the operation of joining any two segments, and every unbranched fingertip segment is assigned a stream order of one.

The Strahler system changes the basic concept of a river as described by Playfair. No longer is there a major trunk river which "branches" into smaller tributaries; rather, there are now channel segments that "combine" to form larger segments whose accumulation forms a drainage system. For the study of stream properties such as discharge this concept of a stream has proved valuable. However, streams grow by headward erosion (abstraction) and bifurcation, the antithesis of the idea that the addition of two small segments produces one large segment.
Because the stream ordering methodology was changed by Strahler, it was reasonable to question the validity of the "laws" of drainage composition defined by Horton.

This problem was examined therefore by numerous investigators. Strahler (55, p. 914), Maxwell (27, p. 23), Melton (29, p. 345), Shreve (41, p. 44; 42, p. 50), and Bowden and Wallis (1, p. 769) examined the Horton Law of Stream Numbers and essentially concluded that it is unaffected by Strahler ordering.

Strahler, as cited by Schumm (40, p. 13), Maxwell (27, p. 23), Melton (29), Broscoe (2), and Bowden and Wallis (1, p. 770) independently examined the Law of Stream Lengths and in general concurred in the belief that, by one or more slight mathematical restatements, this law is valid.

Morisawa (33, p. 9) has been critical of the Law of Stream Slopes. However, Broscoe (2) and Bowden and Wallis (1) suggested that replacement of average values with cumulative values, again with slight mathematical restatement, produces a true geometric series of stream slopes.

More recent study led to the development of additional empirical "laws" to add to the Horton set. Horton (20, p. 294) inferred that drainage basin areas of various orders should form a geometric series, but Schumm (40, p. 14) introduced the Law of Stream Areas. This law states that the mean drainage basin areas of streams of each order tend closely to approximate a direct geometric series in which
the first term is the mean area of the first order basins. Schumm adopted the Strahler ordering system and again showed that the mean area of a drainage basin of given stream segment is actually a cumulative value. As with the modified Horton laws, the law of stream areas is reducible to a simple mathematical statement.

Maxwell (27, p. 23) postulated two additional empirical laws of drainage composition. The first, the Law of Basin Relief, states that the mean relief of basins of each order in a watershed tend closely to approximate a direct geometric series in which the first term is the mean relief of the first-order basins. The second, the Law of Basin Diameters, states that the mean diameter of basins of each order in a watershed tend to closely approximate a direct geometric series in which the first term is the mean diameter of the first-order basins. There is some contradiction of these laws with results of other workers, particularly of Broscoe (2), and there is question whether either law is independent of the Law of Stream Slopes or the Law of Stream Areas. Assuredly, neither law has been sufficiently scrutinized as to permit reduction to a simple mathematical statement as has happened with the more time-tested ones.

In summary, it can be said that some half-dozen "laws" of stream composition have been proposed between 1945 and 1960. Some have been rather rigorously studied, tested, and modified and appear to have general applicability. Others are subject to equal treatment but their general worth and applicability is still undetermined.
Other Systems of Stream Ordering

Consistent Stream Order

Horton and Strahler ordering systems both ignore the contribution to a drainage system by lower order tributaries that directly join higher order streams. This has been referred to as the problem of "lost stream segments" by Scheidegger (38, p. 788) and is reflected in the conventional Horton and Strahler systems by failure to increase stream order despite numerous junctions of a stream segment with lower order tributaries. A good deal of recent work in the field of stream ordering has been directed to this problem. Rzhanitsyn (36, p. 3) believed that characteristics of any river segment depend on both order and position along the length of the river. He theorizes that because characteristics of a stream of given order increase the numerical value of the same characteristic for a stream with the next higher order with which it joins, it may change the order of that stream; for example, if two third-order segments each carrying half of the discharge of a fourth-order segment join, in turn, another fourth-order segment the result is equivalent to junction of two fourth-order segments and stream order should be raised to five.

Following Rzhanitsyn's premises, Scheidegger (37, p. B188) postulated a Consistent System of Stream Order. He algebraically derived two mathematical statements, assuming that order can be raised by two types of junctions rather than one.
Absolute Stream Order

Mackin (26) first proposed the concept of a river as a system which always tends toward equilibrium. This concept became generally accepted by geomorphologists who then began to study rivers in terms of open systems. Strahler (53, p. 676) stated that the concept of a steady state in open systems requires attention to the relation between dynamics and morphology which, in a graded drainage system, is manifested by certain topographic characteristics which achieve a time-independent condition. Using the thesis that distribution of energy in a river system tends toward the most probable state, Leopold and Langbein (23, p. A2) concluded that landscape evolution occurs under dynamic equilibrium. Chorley (4) and Howard (21) have supported the value of the open system approach to geomorphology in emphasizing the adjustment between process and form. The growth of rivers, which is acceptable in open system theory, has been considered a stochastic process by Scheidegger (38).

Woldenberg (59, p. 431) showed that if two parts of an open system are related allometrically to the entire system then they are related to each other by a power function of the form \( y = ax^b \) and yield a straight line when plotted on a log-log graph. Horton's laws, as already described, yield straight lines on a semi-log plot. Assuming that streams are indeed steady state or allometrically growing systems, Woldenberg concluded that Strahler stream orders
are themselves logarithmic, each order beginning a new cycle on the logarithmic scale. He then proposed that an absolute stream order exists, this being simply the bifurcation ratio raised to the power of the Strahler stream order, or

\[ U_A = R_e^{U-1} \]

Stream Magnitude

The concept of stream magnitude as introduced by Shreve (44) in a study of random channel networks is founded on the premise that links rather than segments are the primary units of importance in a stream network. All exterior links (considered to be the building blocks of a river system and also the reaches identical to first order Strahler segments) are assigned a magnitude of one. Thereafter, the junction of any two links increases the magnitude of the resulting downstream link according to the formula:

\[ M_1 \# M_2 = M_1 + M_2 \]

It has been demonstrated by Shreve that stream magnitude is simply related to Scheidegger's Consistant Order by the equation:

\[ M = \log_2 2U_c \]

Ranalli and Scheidegger (35) point out that stream magnitude is identical to Scheidegger's equivalent integer associated with consistent order. Digital Stream Order, developed independently in 1968 by the authors of this report before becoming aware
of Shreve's work, is identical to the concept of link magnitude and as an integral part of a stream growth study further suggests the future importance of this system of stream classification.

Proportional Stream Order

An attempt to modify the Horton-Strahler system of stream order to take into account the effect of "lost" stream segments was made by Stal and Fok (51). Their Proportional System of Stream Order altered normal Strahler order to include both integer and fractional numbers. The Proportional order \( U_p \) as defined for any link of a Strahler Segment \( U \) is given as:

\[
U_p = U + U_x
\]

where \( U_x \) is a decimal figure relating to the development of first order segments above the link under consideration.

Mixed Hexagonal Hierarchies

Based on the premise that the hexagon is the space filling figure which results in maximum economy of channeled flow versus overland flow, Woldenberg (69) has proposed a mixed hexagonal hierarchical stream classification. Important in the development of Woldenberg's model is the fact that any hexagonal area may be subdivided into smaller, equal hexagonal areas in three ways, resulting in area ratios between the large and subdivided hexagons of 3, 4, and 7. These hexagonal hierarchies may then be mixed
which is done by rearranging the geometric progressions of
3, 4, and 7 in consecutive order. By selecting groups of
numbers from this consecutive listing whose convergent means
are equal to the observed numbers of stream segments of
each order a unique classification of any stream net may be
produced.

Other Types of Stream Descriptions

Milton-Ollier Codes

Not all recently proposed systems of stream descriptions
have been hierarchical. An early attempt at improving the
Strahler system of stream order by Milton and Ollier (32)
is an example of a label description. Starting from the
stream mouth the first tributary of a given order which is
encountered is labelled a, the second b, and the process is
continued for all orders along the length of the highest
order segment. This same procedure is then repeated for
progressively smaller tributaries until every segment is
uniquely labelled. A typical level such as 1a · 2d · 3b
denotes the first, first-order tributary on the fourth,
second-order tributary of the second, third-order tributary
from the mouth of the mainstream. It is a fine distinction,
but although this coding system is founded on a hierarchical
system of classification whose structure is never lost, the
usefulness of this system is derived from a listing of
stream segments whose coding serves as a replacement for
the parameters of position, thus permitting reconstitution
of the original net.
The Storet System

Another proposed labeling description of streams is the Storet System (15). For its purpose the United States has been subdivided into major and minor drainage basins, and codes are assigned to major river tributaries according to stream level and mileage from the junction of the mouth or next level stream. Stream levels are the same as stream orders as proposed by Grevelius with each major stream being a level one, thus level does not have the hydrologic significance of Strahler or other stream orders. Again, the value of the system is a listing of stream segments, wherein the label replaces absolute parameters of position in order to facilitate computer handling of associated stream segment parameters such as water chemistry and quality.

Binary Strings

A number of binary string methods for describing the topology of stream networks have been proposed by Scheidegger (39), Shreve (44), Liao and Scheidegger (24), and Smart (49). These strings are simply lists of either nodes or links where the position of a link in the list and an indication of its internal or external position in the net serve to permit reconstruction of the topology of a river system.

Ambilateral Class

Smart (48) introduced a method for describing the topology of channel networks consisting of equal numbers of links which he called "ambilateral". The basic rule of this
classification scheme is that two topologically distinct networks belong to the same group if one can be converted to the other by reversal of the right-left order at one or more junctions. Smart suggests that this system of stream description is more closely correlated with geomorphic and hydrologic properties than is the usual stream number classification.

Summary

Throughout the historical development of the description of river systems both qualitative and quantitative methods have been employed. However, rather than an orderly evolution from qualitative to quantitative, as might be expected, we find that each method has been used in a time and place where its particular advantages were suited to the problems encountered.

The early fluvialists were philosophers and therefore held little interest in measurement of real phenomena; thus, all early work was descriptive. The first quantitative fluvial measurements were done by engineers in the early 18th century as a result of military and economic pressures to control Europe's river systems. More or less concurrently with these engineering hydraulic studies, geologists revived their interest in the grand-scale processes operating to produce the gross features of the Earth's surface. The very nature of such complex discourse necessitated the use of qualitative models.
For some reason, between the early 18th century and mid-19th century, very little was done to advance either qualitative or quantitative aspects of fluvial studies. Possibly the cause lies in the renewal of debate between proponents of the concept of dominance of marine denudation and the fluvial erosionists, an argument in which the neodiluvialists dominated in sheer numbers, even if not in logic or observational powers. In any event, this controversy seems to have preoccupied the thinking of the best geological minds of the time.

Renewal of observation of river systems, because of the opening of the American West to exploration by a band of talented naturalists, stimulated interest in fluvial systems and led to the most significant advances in understanding of quantitative processes since the early 18th century. Also, much of the descriptive terminology in current usage derives from this period, although the descriptors are generic and reflect an emphasis on geologic process rather than observations of actual fluvial networks.

Generic description of fluvial processes dominated until 1945, when Horton, Strahler and others began to investigate the geometry and topology of networks in an attempt to quantitatively describe and classify river systems. Within the past 10 years, coding and labeling systems have been proposed as a mechanism for describing and identifying streams. Meanwhile, no new descriptive classifications have been developed.
The study of river systems has historically been either descriptive or quantitative with little or no interaction possible between these two extremes. The advent of coding and labeling systems marks a preliminary attempt to fill the middle ground or semi-quantitative need for a usable description of stream networks. The WATER System represents an improvement in bridging the descriptive-quantitative classification gap. This system assigns numerical values to descriptive terms as well as producing hierarchical stream classifications of the net, thus making it a first generation attempt at an integrated classification system.
CHAPTER 3

DESCRIPTION OF FLUVIAL MORPHOMETRIC MEASURES

Introduction

As the quantitative study of stream networks evolved from its introduction by Horton, the number of parameters used to define and test the complicated interrelationships in drainage basins grew steadily. Most of these fluvial morphometric measures have been reviewed and classified by Strahler (56) as: 1) properties measured or counted solely from the channel network and basin outline reduced to a horizontal plane, 2) properties requiring areal measurement, and 3) properties involving elevation differences. This general classification has been used in the WATER System.

Many more properties of drainage networks have been proposed than are calculated by the WATER System. Only those measures believed by the authors to be generally valuable or particularly promising have been included. The following discussion of these parameters attempts to identify their original source, comment on their purpose, and discuss their method of calculation within the computer programs.

We have diligently attempted to retrieve from the literature any significant contribution bearing on the development of the fluvial parameters discussed in the sections to
follow. Any omissions or failure to properly identify and credit the individual initially responsible for any of these suggested parameters is inadvertent and not the result of bias by the authors.

Part 1

Properties measured or counted solely from the channel network and basin outline reduced to a horizontal plane.

Strahler Stream Order and Basin Order

Stream order, as discussed previously, was introduced by Horton (20) and modified by Strahler (54). Strahler's method of ordering possesses the advantages of a simple classification procedure and non-fractional class values. The order of a basin is defined as the order of the largest segment which it contains. The order of a Strahler stream segment is roughly proportional to its length, channel size, discharge, and area drained. Thus increase in order is reflected by an increase in these other features.

The Strahler order of each stream reach is computed in subroutine LINKER and the reaches are connected to form ordered Strahler segments in subroutine ORD1. The ordered drainage maps produced by the WATER System are totally accurate for the data provided, however, it should be emphasized that the blue lines of small scale maps do not accurately depict the actual drainage network.
Number of Strahler Stream Segments and the Bifurcation Ratio

The first law of drainage composition as introduced by Horton (20) states that the numbers of streams of different orders in a given basin tend to approximate an inverse geometric series in which the first term is unity such that:

\[ N_u = R_B O^U \]

where \( N_u \) is the number of streams of order \( U \) and \( O \) is the basin order. \( R_B \) is a constant called the bifurcation ratio.

Because the method of ordering streams has been changed by Strahler, it is reasonable to question the continued validity of the Laws of Drainage Composition as defined by Horton. It has been demonstrated by Strahler (55, p. 914) and Maxwell (27, p. 23) that the Law of Stream Numbers is still valid. Melton (29, p. 345) suggested that the very definition of Strahler's ordering system results in an inverse geometric series. Shreve (42, p. 50) found segment ordering gave a better fit to this law than Horton ordering and had suggested (Shreve, 41, p. 44) that this is due to a statistical relationship of random development. Bowden and Wallis (1, p. 769) concluded that the Law of Stream Numbers is unaffected by Strahler ordering and is a statistical relationship resulting from the definition of stream order.

The Bifurcation Ratio supposedly provides some measure of a stream segment's tendency to divide. However, studies of this ratio have indicated it is not terribly consistent, and recently Scheidegger (38) has suggested that "lost"
stream segments make it inherently impossible for the bifurcation ratio to remain constant between consecutive orders in a basin.

The bifurcation ratio (BIRAT) is calculated in subroutine ORD1 as suggested by Melton (28) such that

\[ R_B = \frac{N_u}{N_{u+1}} \]

thus permitting easy comparison of its consistency between orders. The number of segments (NUM) of each Strahler order are counted as well as the total number of Strahler stream segments in the entire basin (NUMSEG).

**Average Length of a Strahler Stream Segment**

Horton's (20) Law of Stream Lengths states that the average lengths of streams of each of the different orders tend to approximate a direct geometric series in which the first term is \( L_1 \) such that:

\[ L_u = L_1 R_L^{u-1} \]

where \( L_1 \) is the average length of first-order streams, \( L_u \) is the average length of streams of order \( u \), and \( R_L \) is a constant called the stream length ratio.

The validity of the Law of Stream Lengths when Strahler ordering is used has been studied by several authors. Strahler (in Schumm, 40, p. 13) suggested that the relationship of lengths was better described by a power function than an exponential function. Work by Maxwell (27, p. 23) and
Melton (28) indicated considerable variation of segment length data from a geometric series. Eroscoe (2) found by substituting cumulative mean length \( L'_u \) for average length in this law that a geometric series was indeed obtained. Bowden and Wallis (1, p. 770) independently arrived at the same results. This suggests that the Law of Stream Lengths should now be stated:

\[
L'_u = L_1 R'_u^{U-1}
\]

The length of each Stahler segment \( D \) is obtained in subroutine ORDL by summing the lengths of the reaches \( \text{DIST}(L) \) which compose the segment. The average length of segments is computed for each order along with its statistics. The stream length ratio is not computed, but the lengths of each segment may be punched as output for further investigation.

**Shreve Link Magnitude and Basin Magnitude**

The classification of stream networks by the magnitude of links, as discussed previously, was introduced by Shreve (44) and retains the advantages noted for Strahler's orders of a simple classification procedure and non-fractional class values. The magnitude of a basin is defined as the magnitude of the largest link which it contains.

It should be noted that Consistant Stream Order proposed by Scheidegger (37) precedes Shreve's work and has been shown by Scheidegger to be identical to the system of magnitudes although it is not as simple to use.
Smart (48) has suggested that stream magnitude provides a more promising method for grouping basins with similar topologic and hydrologic properties than does stream order. First-order Strahler segments are established in subroutine LINKER and are identical to links of magnitude one. Subroutine ORD2 then computes the magnitudes for the remaining links.

**Number of Shreve Links**

No relationship has yet been identified to relate link magnitude to the number of links of that size in a basin. However, the number of links (NUMMAG) of each magnitude and the total number of links in the basin (MACMAX) are counted in subroutine ORD2.

**Average Length of a Shreve Link**

Studies by both Smart (47) and Shreve (45) of the relationship between magnitude and link length have not resulted in any positive correlation. Some of the networks studied by Smart show no significant change in link length with magnitude, whereas others showed both positive and negative changes in length as magnitude increased. On the other hand, Gosh and Scheidegger (14) have found that link length increases geometrically with Strahler Order, and thus a Law of Link Lengths similar to the Law of Stream Lengths can be proposed with link length ratios between 1.04 and 2.34.
The length of each link (D) is obtained in subroutine ORD2 by summing the lengths of reaches (DIST(L)) which compose the link. The average length of links of each magnitude is computed.

**Total Length of Channels**

Horton (20) was the first to use the total length of all channels as a morphometric measure. Total length of channels is related to channel storage. Normally, channel storage varies with stream length as a simple power function. The total length of all channels (TOTD) is computed in subroutine CALC by summing the lengths of all stream reaches.

**Mainstream Length**

Hack (19) has related the length of the mainstream (LM) to drainage basin area by the formula LM = CA^n where C = 1.4 and n = 0.6 for basins in Maryland and Virginia. Horton (20) defined mainstream length (ordinary length) as the length obtained by tracing the segment of highest order, beginning at the mouth, back to its origin.

Smart (46) in a paper discussing the influence of sinuosity on the value of n in the above formula has noted that the mainstream length may be used as a single parameter to replace the lengths of segments of different orders in any characterization of a stream system. The mainstream length (BIG) is obtained in subroutine CALC by locating the path of maximum length from mouth to the farthest stream tip in the basin.
Wandering Ratio

The Wandering Ratio has been shown by Smart and Surkan (46) to be the deviation of the mainstream path from the straight line length from the mouth to the tip of the mainstream. The wandering ratio is not to be confused with sinuosity or meandering as the wandering ratio represents a more gross deviation of the path of the master stream from a straight line course.

The wandering ratio (WANDR) is computed in subroutine CALC by dividing the mainstream length (BIG) by the valley length (VLEN). It should be noted that for unusually shaped basins the straight line distance from tip to mouth (VLEN) may not actually follow the valley and the resulting value of the wandering ratio will appear abnormally high.

Azimuth of Main Stream Valley

The Azimuth of the mainstream valley is given as the compass azimuth in degrees of the direction of water flow for the major stream in the valley. The azimuth of the flow of water, especially when constant for a number of subbasins, may indicate regional trends in structure, lithology, or slope. The azimuth of the main stream (AZMAIN) is obtained in subroutine CALC by determining the azimuth of the straight line distance of the mainstream (VLEN).

Basin Perimeter

The length of the basin outline (perimeter) was emphasized by Smith (50) in his derivation of the texture
ratio. The perimeter is measured along the divides between basins and may be used as an indicator of basin size and shape.

The length of the perimeter (PERIM) is obtained in subroutine CALC by summing the lengths of the reaches composing the basin outline.

**Basin Length**

Schumm (40) defined the length of a basin as the longest dimension of a drainage basin measured parallel to the principle drainage line (mainstream). Maxwell (27) detailed criteria for determining the basin diameter which in a normally shaped basin is essentially the same as the basin length. He also proposed the Law of Basin Diameters which states that the mean diameter of basins of each order tend closely to approximate a geometric series in which the first term is the mean diameter of first-order basins. The length, or diameter, of a basin is an approximate measure of basin size and an ultimate measure of the maximum distance traveled by a particle of water starting at the basin divide.

The basin length (BLEN) is calculated in subroutine CALC as the maximum straight line distance between a point on the basin perimeter and the stream mouth. In basins of usual shape, it is possible that the value obtained is not that of a line parallel to the mainstream.

**Basin Azimuth**

The Basin Azimuth is the compass azimuth in degrees of the direction of water flow as given for the basin length line.
Basin and mainstream azimuth will normally coincide. Marked deviations of the two directions may indicate drainage anomalies or may result from inaccurate approximation of one of the values by the WATER System because of an unusually shaped drainage basin. The basin azimuth (BAZ) is obtained in subroutine CALC by determining the azimuth of the basin diameter (BLDK).

Texture Ratio

The texture of a basin was originally defined by Smith (50) as a ratio between the number of crenulations along the contour line within the basin containing the maximum crenulations to the length of the perimeter of the basin. Because of the increased accuracy obtained from airphoto-prepared drainage basin maps, it is redefined for use in the WATER System as the total number of Strahler stream segments divided by the basin perimeter.

The Texture Ratio provides a measure of the degree of dissection within a drainage basin. The texture ratio (T) is computed in subroutine CALC by dividing the total number of Strahler stream segments (NUMSEG) by the length of the perimeter (PERIM).

Link-Texture Ratio

The Link-Texture Ratio is proposed by the authors as a potentially more consistent measure of the density of stream length units within a basin. It is defined as the ratio between the total number of stream links and the length
of the basin perimeter. It is believed that the demonstrated consistency (perhaps theoretical constancy) of link lengths improves the usefulness of this textural parameter.

This parameter should be very useful in detecting if an increase in drainage density results from channel lengthening or the addition of new stream segments as was the purpose of Melton's (28) proposed stream frequency of first-order channels. The link-texture ratio (TT) is computed in subroutine CALC by dividing the total number of links (NUMMAG) by the length of the basin perimeter.

Stream Junction Angles

The entrance angle (axil angle) was first discussed by Horton (20). He suggested that this angle was related to the slopes of the joining stream segments by the equation

$$\cos A = \frac{\tan B}{\tan C}$$

where A is the junction angle, B is the channel slope of the larger order stream, and C is the slope of the tributary or smaller order stream.

Schumm (40) showed that the angle of junction decreased with age as gradients were lowered. Thus an initial first-order tributary will join a master stream at nearly right angles and as its slope is lowered the junction angle is reduced. Junction angles are calculated between tributaries according to order in subroutine ANGLE.
Fineness Ratio

Melton (28) suggested that the ratio of channel lengths to the length of the basin perimeter is a measure of topographic fineness. This textural ratio is not computed by the WATER System, but the components are available to permit hand computation.

Part 2

Properties requiring areal measurement.

Area of a Basin

Although Horton (20) had inferred that drainage basin areas of various orders might form a geometric series it was Schumm (40) who introduced the fourth law of drainage composition. The Law of Stream Areas states that the mean drainage basin areas of streams of each order tend to approximate a direct geometric series such that:

\[ A_u = A_1 R_A^{U-1} \]

where \( A_u \) is the area of a stream of order \( U \), \( A_1 \) is the average drainage area of first-order streams, and \( R_A \) is a constant called the stream area ratio.

It is an important point that the mean area of a given segment is actually a cumulative value. For example, the area of a third-order basin is a sum of the areas of the first- and second-order tributary streams. The basin area (AREA) is computed in subroutine CALC.
Drainage Density

Drainage density was introduced by Horton (20) as the ratio of the total length of channels of all orders in a basin to the area of the basin. Drainage density is a textural measure of a basin which is generally independent of basin size. It is considered to be a function of climate, lithology, and stage of development. Numerically, this ratio expresses the number of miles of channel maintained by a square mile of drainage area.

The Drainage Density (DENS) is computed in subroutine CALC as the total length of all channels divided by the basin area.

Constant of Channel Maintenance

The Constant of Channel Maintenance was introduced by Schumm (40) as the ratio between the area of a drainage basin and the total length of all the channels expressed in square feet per foot. It is equal to the reciprocal of the drainage density multiplied by 5280.

The importance of this constant is that it provides a measure of the square feet of area required to support one foot of stream channel. It is thus a quantitative expression of the minimum limiting area required for the development of a length of channel. The constant of channel maintenance (C) is obtained in subroutine CALC by multiplying the reciprocal of the drainage density by 5280 feet.
Channel Segment Frequency

Horton (20) defined the Channel Segment Frequency (Stream Frequency) as the number of streams per unit area in a drainage basin. Horton suggested that the "composition" of a drainage basin provided a more adequate characterization of a stream than did drainage pattern. His "composition" was completely described using the two textural measures of drainage density and stream frequency.

Channel Frequency (FC) is computed in subroutine CALC by dividing the total number of Strahler stream segments by the area of the drainage basin.

Channel Link Frequency

The frequency of the links in a drainage basin is introduced by the authors as the number of links per unit area. It is believed that the link is a more constant and fundamental unit of a stream network than a Strahler segment and thus a measure of link frequency may be much more sensitive to such things as a change in material type, etc.

The Channel Link Frequency (FL) is computed in subroutine CALC by dividing the total number of links by the area of the drainage basin.

Circularity Ratio

Basin circularity was introduced by Miller (31) as the ratio of the basin area to the area of a circle having a circumference equal to the perimeter of the basin. The value of this ratio approaches one as the shape of the basin approaches a circle. Miller believed that in homogeneous
material the Circularity Ratio remained a constant and served as an expression of a universal equilibrium form.

The circularity ratio (CRAT) is computed in subroutine CALC by dividing the basin area by the area of a circle having a circumference equal to the perimeter of the basin.

**Elongation Ratio**

Schumm (40) suggested that the shape of a drainage basin could be described in the same manner as the shape of a mineral grain by using the Wadell sphericity ratio. He defined the Elongation Ratio of a basin as the ratio between the diameter of a circle with the same area as the basin and the basin length.

The value of the elongation ratio approaches one as the shape of a drainage basin approaches a circle. The elongation ratio (ELONG) is computed in subroutine CALC by dividing the diameter of a circle calculated as having an area equal to that of the basin by the basin length.

**Watershed Shape Factor**

The Watershed Shape Factor was defined by Wu (61) as the ratio of the mainstream length to the diameter of a circle having the same area as the watershed. The watershed shape factor (WSF) is calculated in subroutine CALC by dividing the mainstream length by the diameter of a circle having the same area as the basin.
Unity Shape Factor

The Unity Shape Factor was introduced by Smart (46) as the ratio of the basin length to the square root of the basin area. The unity shape factor (USF) is computed in subroutine CALC by dividing the basin length (BLEN) by the square root of the drainage basin area.

Lemniscate Ratio

The Lemniscate Ratio was proposed by Chorley (3) as a comparison between basin shape and the lemniscate (mathematical teardrop shape). The lemniscate ratio is not calculated by the WATER program because it requires calls to mathematical routines which will be special to each different computer. Because of the obvious similarity of natural basins to the petal shape, individual users may wish to build in this computation.

Part 3

Properties involving elevation differences.

Fall of a Strahler Stream Segment

The Law of Average Stream Fall was proposed by Yang (62) and states that under dynamic equilibrium the ratio of the average fall between any two consecutively ordered streams is unity. Since the falls for each Strahler segment should be equal for a stream in equilibrium, the theoretical and actual profiles may be plotted following this concept and used to predict stream aggradation or degradation. The falls (FALL) of each Strahler segment are calculated in
subroutine ORD1 and stored in the temporary array TEMP2.

**Gradient of a Strahler Stream Segment**

Horton (20) introduced the Law of Stream Slopes which states that the average slope of streams of each order tend to approximate an inverse geometric series in which the first term is the slope of first-order streams \( S_1 \), such that

\[
S_u = S_1 R_s^{U-1}
\]

where \( S_u \) is the average slope of streams of order \( U \), and \( R_s \) is a constant called the stream slope ratio. Morisawa (33) demonstrated that streams in the Appalachian Plateau generally did not conform to this law. Broscoe (2), supported by Bowden and Wallis (1) demonstrated that substitution of cumulative for average values into the law resulted in a geometric series. The Law of Stream Slopes may now be stated

\[
S'_u = H'_u/L'_u = S_1 R_s^{U-1}
\]

The slope of each Strahler segment is determined in subroutine ORD1 by dividing the fall by the length.

**Basin Relief**

Introduced by Strahler (54) for hypsometric analysis, the relief of a basin is the maximum vertical distance from the stream mouth to the highest point on the divide. Maxwell (27) postulated a Law of Basin Relief stating that the mean relief of basins of each order in a watershed tend closely to approximate a geometric series in which the first
term is the mean relief of the first-order basins. The total relief of a basin is a measure of the potential energy available to move water and sediment downslope.

The basin relief (REL) is computed in CALC as the difference between the highest point in the basin (HIGH) and the elevation of the stream mouth (E(1)). A study by Hadley and Schumm (19) indicates that residual or abnormally high points on a divide should not be used for determining the basin relief.

**Relief Ratio**

The Relief Ratio was defined by Schumm (20) as the ratio between the basin relief and the basin length. In normally shaped basins the relief ratio is a dimensionless height-length ratio equal to the tangent of the angle formed by the intersection at the basin mouth of a horizontal plane with a plane passing through the highest point on the divide. This parameter permits comparison of the relief of two basins without regard to the scale of the topography.

The relief ratio (HH) is computed in subroutine CALC by dividing the basin relief converted to miles by the basin length.

**Relative Relief**

Relative Relief was introduced by Melton (28) as the ratio of the basin relief, expressed in units of miles, to the length of the perimeter. Relative relief is an indicator
of the general steepness of a basin from summit to mouth. It has an advantage over the relief ratio in that it is not dependent on the basin length which is a questionable parameter in oddly shaped basins.

The relative relief (HR) is calculated in subroutine CALC by dividing the basin relief converted to miles by the length of the basin perimeter.

Ruggedness Number

Melton (28), after Strahler, proposed that the product of the drainage density and relief, both in the same units, be called the ruggedness of a basin. Areas of low relief but high drainage density are thus as ruggedly textured as areas of higher relief having less dissection. The Ruggedness Number is not directly calculated by the WATER system, but the necessary parameters are provided.

Organization of Parameters

Previous fluvial studies have provided statistics on varying numbers of stream parameters. Most commonly, attempts were made to correlate these results with known physical characteristics of the basin such as material type or discharge. All too often the numbers obtained for a given parameter have been subjected to statistical comparisons without regard for the relationship of the parameter to the total river system. In the hope of introducing some order into the myriad of stream parameters existing today the tentative classification shown in Figure 3.1 is proposed.
### 3.3.1 A Tentative Classification of Stream Parameters

#### CHANNEL PROPERTIES

##### HYDROLOGY
- **SCHARGE**
  - Mean Annual
  - Maximum
  - Specified Flow Frequency

##### GEOMETRY
- Length
  - 1) Cumulative
  - 2) Total
  - 3) Segment
  - 4) Link

##### TOPOLOGY
- Stream Segments
  - 1) Channel Order
  - 2) Basin Order
  - 3) Number of segments

##### WATER BUDGET
- Precipitation
  - 1) Cumulative
  - 2) Mean Annual
  - 3) Avg. Monthly

#### DRAINAGE BASIN PROPERTIES

##### FORM
- Size
  - 1) Area
  - 2) Basin length
  - 3) Mainstream length
  - 4) Perimeter

##### FABRIC
- Composition
  - 1) Rock + soil type
  - 2) Erosional resistance
  - 3) Infiltration capacity
  - 4) Vegetation
  - 5) Land usage
  - 6) Structure

##### DISTRIBUTION
- Fall
  - 1) Flow duration
  - 2) Return periods
  - 3) Slopes

##### CHARACTER OF CHANNEL FLOW
- Cross Section
  - 1) Width/Depth
  - 2) Wetted perimeter
  - 3) X-sectional area

##### BRANCHING RELATIONSHIPS
- 1) Bifurcation Ratio
  - 2) Division Ratio
  - 3) Ambilateral Class
  - 4) Junction Angles

##### WATER STORAGE
- 1) Field capacity
  - 2) GWT level
  - 3) Degree of saturation

##### RELIEF
- 1) Total Relief
  - 2) Relief Ratio
  - 3) Relative Relief

##### HYPSOMETRY
- 1) Hypsometric integral
  - 2) Valley slopes
  - 3) Amount of upland
  - 4) Available relief
  - 5) Elevation-relief ratio

##### ENERGY DISTRIBUTION
- Oscillatory
  - Parameter is computed by WATER System.

##### ORIENTATION
- 1) Basin Azimuth
  - 2) Mainstream Azimuth
The river system is divided into two components, the channel network and the drainage basin exclusive of the channels. Each of these components may be further subdivided into three properties, the channel network into the factors concerning hydrology, geometry and topology, and the drainage basin into measures of water budget, form, and fabric. Each property, in turn, consists of a number of characteristics whose descriptions are necessary to have totally explained the property. Under each characteristic are listed a number of quantifiable parameters which approximate the value of the characteristic. One or more of the listed parameters may be needed to completely describe a characteristic. It is believed that such a table as this, quantified and made operational, would provide the first complete classification of a river system.
CHAPTER 4
DATA COLLECTION AND ANALYSIS
IN FLUVIAL GEOMORPHOLOGY

Introduction

The results of any research are no better than the quality of the original data. This is especially true in the study of stream patterns, geometry, and mechanics. Such studies require measurement of the number, length, and gradient of stream segments; width, depth, and velocity of water in the channel; and the area, main stream length and shape of the drainage basin.

Measurement of these parameters in the field generally results in data of excellent quality. However, field measurements are slow and often costly. Few researchers have the time or money to devote to extensive field measurements and, as a result, standard topographic maps have been a favorite source of data.

Whatever the source or method of collection for stream data, the researcher is faced with two problems: -

1) How to identify and accurately locate, on a map of suitable scale, all portions of a stream network and basin boundaries.

2) How to classify the network and then extract such quantitative values as length, fall, and gradient for each classified stream section.
These problems may be defined as "the data collection problem" and "the data analysis problem". The data analysis problem might at first seem rather trivial as it involves rather routine and easily definable measurements of lengths, areas, angles, and simple calculations involving these values. However, problems do arise whenever moderately large basins are studied. The volume of the data makes manual procedures tedious and prone to error. The WATER System programs were developed to perform rapid and accurate analyses of large stream networks.

The Data Collection Problem

Potential Data Sources

There are three main sources of stream network data:

1) Field Surveys
2) Aerial Photographs
3) Topographic Maps

Each method has a different "resolution/cost ratio" which can be defined as the ratio of the percentage of the total number of stream segments identified in an area to the cost, in time and money, of completing the survey. The problem is to identify the smallest stream segments, the unbranched tributaries, because these are really the fundamental units of the drainage system. The term "resolution" thus seems appropriate in this context.
A comprehensive field survey will locate the smallest unbranched tributaries of a river network, so that a comprehensive map can be produced. However, such surveys can be very slow, particularly in rough terrain, and have the lowest resolution/cost ratio of the three sources.

Aerial photographs are a good source of drainage network information. The drainage in the entire State of Indiana has been mapped from aerial photographs by workers at the Airphoto Interpretation and Photogrammetry Laboratory at Purdue University (30).

Black and white air photographs at approximately 1:20,000 scale were studied with normal lens and mirror stereoscopes and the drainage patterns were carefully delineated by two persons working independently. Discrepancies were checked by a third person. Field checks were carried out if necessary to resolve any remaining discrepancies.

Although the level of detail shown varies according to the time of year that the photographs were taken, it is estimated that the resulting maps show on the average 90 percent of all existing stream channels (7). A field check by one of the authors in the till plains of Tippecanoe County, Indiana demonstrated that these maps do show almost all first order segments in such areas. Many of the channels not shown on the maps appeared young and probably have developed since the date of the photography almost 30 years earlier.
Based on these studies, aerial photographs have a much higher "resolution/cost ratio" than field surveys. They appear to have almost as good a resolution as field surveys, yet the study costs much less to complete.

Topographic maps are commonly used as a source of stream data, perhaps because they are cheap to purchase. However, their interpretation requires time if it is to be done properly. Maps are nevertheless probably the cheapest source of data for stream networks. The resolution of maps is variable and thus their resolution/cost ratios are variable.

Weakness of Topographic Maps as a Data Source

Much effort has been devoted to determining the validity of the networks obtained from the various types of maps commonly available.

Morisawa concluded that the 1:62,500 scale U.S.G.S. topographic maps are unreliable for measuring all drainage basin characteristics except basin area (33). She also states that data on numbers and lengths of stream segments show greater variation when taken from maps. While studying streams in Southern Indiana, Coates found that 1:24,000 scale U.S.G.S. maps rarely showed any first- or second-order streams and that most streams interpreted as first-order were actually third-order (6). Strahler proposed a "Method of V's" to improve the interpretation of maps (54). To those channels shown in blue, he added segments where "V's" in the contour lines indicated valleys. This adds otherwise
overlooked segments to the network, but produces further uncertainty as to the classification of the smallest segment now shown.

A study was therefore undertaken by one of the authors to determine the relative accuracies of maps and aerial photographs as sources of stream network data (7). Drainage basins up to sixth-order were selected randomly from different physiographic provinces defined within the State of Indiana.

Topographic maps at a scale of 1:24,000 were obtained and drainage maps were produced for each basin by tracing only those streams shown by solid or dashed blue lines on the map. The maps were then interpreted by the "Method of V's" and new tracings showing more complete networks were produced. Once the two tracings were prepared they were ordered and compared with an ordered map taken from the Atlas of County Drainage Maps (30).

When only the "blue-line streams" were compared with drainage maps prepared from aerial photographs, it was found that about the same percentage of streams of each order were identified in all physiographic provinces. Very few first- or second-order segments, about one-third of the third-order segments, and almost all the fourth-order segments, are shown as blue lines on 1:24,000 scale maps.

After interpretation by the "Method of V's", a significant increase in the number of segments was found in every physiographic province. Figures 4.1 and 4.2 portray the results obtained for one province, the Tipton Till Plain.
FIG. 4.1  TIPTON TILL PLAIN, INDIANA INTERPRETED STREAM ORDERS FOR "BLUE-LINE NETWORKS" COMPARED TO TRUE STREAM ORDERS. (AFTER COFFMAN)
FIG. 4.2 TIPTON TILL PLAIN, INDIANA
INTERPRETED STREAM ORDERS AFTER
APPLYING "METHOD OF V'S" COMPARED
TO TRUE STREAM ORDERS. (after Coffman)
This study led to the very important conclusion that topographic maps are commonly incapable of showing a drainage system which is proportional to the real network. This conclusion follows from the low percentage of streams of low order that are correctly identified, even if the "Method of V's" is used. For example, Figure 4.2 shows only 19 percent of the first-order segments, 17 percent of the second-order segments, 11 percent of the third-order segments, and 21 percent of the fourth-order segments were correctly identified on the Tipton Till Plain.

To emphasize the importance of this point, consider the stream system shown in Figure 4.3. It has a perfect bifurcation ratio ($R_B$) of three, and the numbers ($N$) and average lengths ($L$) for the various orders are indicated. Figure 4.4 is the same drainage basin without first- and second-order segments. This remains a reasonable representation of the original basin and provides an example of the stream net which some researchers assume is obtained by ordering stream systems from large scale topographic maps. The bifurcation ratio is unaltered and after a field check the laws of drainage composition would allow calculation of the numbers and average lengths of stream orders not shown by this map.

Figure 4.5, however, shows what actually happens when a stream net is ordered directly from the blue lines of a U.S.G.S. topographic map scaled 1:24,000. Because approximately only one-third of the third-order stream segments are shown, the ordered basin is no longer proportional to the real stream net. The bifurcation ratio is altered and the
FIG. 4.5 STREAM AS IT MIGHT BE MAPPED FROM BLUE LINES ON USGS MAP

FIG. 4.6 STREAM AS IT MIGHT BE MAPPED USING THE METHOD OF "V'S"
average segment lengths become distorted. It is impossible to extrapolate the properties of the original stream net from this ordered basin. Using the data for the Tipton Till Plain, Figure 4.6 shows a theoretical drainage map produced from a U.S.G.S. topographic map using the method of "V's". It shows more segments than the stream net in Figure 4.5, but the bifurcation ratio is still altered and the measurement of average lengths is meaningless. Thus, in basins where the relief is not sufficient to permit recognition of nearly all stream segments by application of the method of V's, the drainage map produced will not be proportional to the actual stream network.

Some research has indicated that results obtained from variously scaled maps are indeed proportional. Stall and Yang (52) in a comparison of maps scaled 1:62,500 and 1:250,000 concluded that the only difference in Horton's drainage relationships obtained from 15' and 20' maps was the stream order. The present authors believe, however, that any assumption of proportionality between small scale maps and the actual drainage net is not automatically tenable in light of our Indiana studies. It is emphasized that at scales less than 1:15,000 all stream information must be cartographically enhanced (i.e. the width can no longer be accurately displayed for most rivers). Thus, even when working with maps scaled 1:24,000 symbolic representations of the network are being measured, and proportionality between these and maps of even smaller scale may well result from a matter of cartographic choice.
Recommended Data Sources

The authors recommend aerial photographs as the best source of planimetric information for drainage system studies. Topographic maps or photogrammetric methods, as described in the following section, may be used to obtain elevation data once the network has been defined.

Reliability of drainage networks obtained from topographic maps must be initially questioned. No acceptable drainage map can be made from a U.S.G.S. topographic map scaled 1:62,500 without considerable field verification. If drainage maps are traced from 1:24,000 U.S.G.S. topographic maps, the proportionality of the map must be tested. Based on their Indiana field studies, the authors suggest that the average relative relief of apparent first-order stream segments shown by blue lines can be used to predict the quality of a topographic map for use in preparing an accurate drainage map. Based on this average relative relief the 1:24,000 U.S.G.S. topographic maps may be classed as excellent, marginal, and unacceptable (7). Furthermore, as the quality of interpretation by the "Method of V's" varies as a function of 1) relative relief, 2) age of topography, and 3) geology, an approximate guide to the quality of such maps is the physiographic province from which these come.

The Data Analysis Problem

Once a suitable map of the drainage basin has been obtained, it must be converted to a numeric form before computer analysis is possible. Digitization includes
those procedures required to convert graphical data to numeric data.

Network Geometry and Topology

For many geomorphic and most engineering applications, information concerning network geometry, as well as topology, is required. Network topology concerns only those properties which remain invariant under all continuous deformation. Shreve defined topologically identical networks, as shown in Figure 4.7, and stated that "network topology, stream pattern, and drainage density, though perhaps physically connected, are mathematically distinct concepts" (43).

A number of "binary string" methods have been proposed to describe the topology of stream networks (39, 44, 24, 49). Although differences exist in their coding methods, all binary string procedures efficiently describe the network topology. The methods have restricted uses, however, Most proposed applications use additional non-binary strings (8). When geometrical properties, such as length, are required the information must be externally supplied. This effectively off-sets many advantages of using the computer.

Basic Data Requirements of the WATER System

The WATER System has been developed around an extension of such binary string procedures. Basic input data requirements are measured at a series of control points, as follows:
FIGURE 4.7 FIVE TOPOLOGICALLY IDENTICAL STREAM NETWORKS
(after Shreve)

TABLE 4.1
NUMERIC CODES USED BY THE WATER SYSTEM

<table>
<thead>
<tr>
<th>CODE NUMBER</th>
<th>FUNCTION OF POINT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Source point (tip of first-order stream)</td>
</tr>
<tr>
<td>2</td>
<td>Mid-Point (define Reaches)</td>
</tr>
<tr>
<td>3</td>
<td>Junction</td>
</tr>
<tr>
<td>4</td>
<td>Basin boundary point</td>
</tr>
<tr>
<td>5</td>
<td>Mouth of stream network</td>
</tr>
<tr>
<td>6</td>
<td>Dummy point indicating end of data</td>
</tr>
<tr>
<td>7</td>
<td>Contour line crosses stream</td>
</tr>
</tbody>
</table>

*NOTES:*
1) Negative 1, 2, 3 and 7 codes will define tips of longitudinal profiles if profiles are requested.
2) Additional codes may be added to define control points of special types.
1) The horizontal cartesian coordinates, X, and Y, of each point are measured in inches on the map. The map scale is supplied separately so that the coordinates can be converted to the appropriate units. The coordinates can refer to any convenient coordinate system. However, if true azimuths are desired, the azimuth of the positive Y-axis of the chosen system must be supplied separately.

2) The elevation of each point, the Z-axis coordinate, is measured in feet. Because Z-axis data are not always required, and generally are difficult to obtain accurately, the WATER System treats elevation data as optional.

3) The purpose, or function, of each point is defined by an appropriate number code.

**Numeric Point Function Codes**

Table 4.1 indicates code numbers presently used by the WATER System to define the network topology. Numeric codes are used, rather than a binary system, because they give flexibility to the definition of point functions. It should be noted that the point codes define the topology of the network; the point coordinates define its geometry.

**Data Collection Procedures**

In order for the network topology to be uniquely defined, the points must be located according to a pre-defined sequence. The sequence used by the WATER System is exactly equivalent to those defined by earlier workers (39, 44, 24). The points must be located as follows:

1) Start at the stream network mouth.

2) Do either (a) or (b)

   a) Define the basin boundary by making a continuous circuit in either a clockwise or counter-clockwise direction. It is not
necessary to re-locate the mouth to close the circuit.

b) Continue with step 3 if the basin boundary is not to be measured, or if it is desired to sample the boundary last. (See step 5(a)).

3) Move upstream recording mid-points, junctions, and contour-crossing points in their correct sequence, until a stream tip is encountered.

4) Return to the last junction encountered and travel upstream recording mid-points, junctions, and contour-crossing points in sequence until a stream tip is encountered. Repeat this process until the entire network is completed.

5) Do either (a) or (b)
   a) Define the basin boundary as described in 2(a) if it has not been located already and it is desired to include it.
   b) Continue with step 6.

6) Complete data collection by adding one dummy point with a code "6" to indicate "end of data".

In following these steps it should be noted that:

1) Each point need only be digitized once. This includes the mouth.

2) The network must begin at the mouth.

3) Each junction must be a "Y" junction; it must have two, and only two, joining streams to form one outgoing stream. The WATER System cannot handle braided or distributary networks. Multiple junctions can be defined as a series of very closely spaced "Y" junctions.

4) The basin boundary need not be defined at all. If it is defined, it can be defined in its entirety, before or after the points defining the stream network are collected.

5) The authors have found it advantageous to follow some logical pattern at every junction. One can arbitrarily decide to turn left at each fork ("Left-handed Rule") and thus sweep across the basin from left to right; or one can invoke the equivalent
"Right-handed Rule". Difficulties frequently arise, however, if no fixed pattern is used. Sections of the network may be skipped and others done twice.

A Data Collection Example

Figure 4.8A shows the small theoretical network used by Smart to illustrate some topologic properties of networks (49). For simplicity, no basin boundary has been added and no type "7" contour-crossing codes will be used. The curves of certain sections of Smart's network have been emphasized. Figure 4.8B shows the effect in the geometrical properties if too few points are digitized. In this case the minimum acceptable number of points was used; only those locating the mouth, the junctions and the sources of first order streams. The point code string for Figure 4.8B would be:

KB: 53331133131311311116

This accurately describes the network topology. It is equivalent to Smart's "S" string and can be manipulated in all the ways suggested by him (49). However, the geometrical properties defined by the corresponding X, Y, and Z arrays are only approximate in many cases.

Figure 4.8C shows how the geometrical properties may be more faithfully preserved by dividing the network into straight-line segments, termed Reaches, through the use of mid-points. The expanded point code string for Figure 4.8C is:

KC: 5223323113313212321132231231121216
FIG. 4.8  NETWORK DIGITIZATION PROCEDURES

A. MAP OF NETWORK
B. NETWORK GEOMETRY USING LOCATIONS OF MOUTH, JUNCTIONS, & SOURCES ONLY
C. NETWORK GEOMETRY USING LOCATIONS OF MOUTH, JUNCTIONS, MIDPOINTS & SOURCES
This string retains all the topologic information contained in the KB string; yet the corresponding X, Y, and Z arrays contain detailed geometric data.

Methods of Manual and Machine-Assisted Data Collection

The data collection procedures just described govern the type of data to be collected and the sequence of collection. The methods used to actually collect data may vary, depending on

a) total volume of the data to be collected,
b) availability of special digitization equipment, and
c) the manpower or funds available to conduct the data collection.

Manual Methods

Manual methods may be used whenever more sophisticated equipment is not available. Such methods are slow, however, and are error prone. They can only be used reliably for small volumes of data.

The simplest technique is to trace the drainage pattern onto graph paper and directly read off the coordinates, record the coordinates and junction codes on tabulation sheets, and later punch the data onto cards.

Researchers at the Massachusetts Institute of Technology report a data collection rate of 240 points per hour using two-man teams with a simple manual co-ordinatograph.
This corresponds to 120 points per man-hour. Commercially available manual coordinatographs might give higher speeds and slightly higher accuracies.

Machine-Assisted Methods

A wide range of graphical to numerical data conversion equipment is available. The cheapest units cost around $20,000 and place coordinate data for 2 axes only on cards or paper-tape. Photogrammetric equipment costing six to eight times as much can record X, Y, and Z axis data directly from aerial photographs onto magnetic tape.

Figure 4-9 shows the equipment used by the authors. It is a digital coordinatograph which consists of a large drafting table with two arms mounted on it, an electronics unit, and a card punch. Movements of the carriage mounted on one of the arms are converted into distances by electronic circuits contained within the "Telecordex" unit. Using this system, X and Y coordinates, along with "Z" elevations at contour-crossing points and point function codes, are collected at a rate of 1000 points per man-hour. This is at least eight times faster than manual methods.

Advantages of Machine-Assisted Methods

The use of special digitization equipment may, but not always, result in reduced data collection costs. Equipment shown in Figure 4.9 can be rented for ten dollars per hour.
LEGEND

A THE READING TABLE
1 X-axis arm
2 Y-axis arm
3 keyboard arm
4 keypock
5 cursor carriage
6 readout button
7 X-axis encoder
8 Y-axis encoder
9 magnetic hold-down strips
10 roller for long charts

B TELECORDEX UNIT
11 X-axis telepack
12 Y-axis telepack
13 event counter
14 memory and control unit
15 power switches
16 constant data switches
17 patch panel

C IBM MODEL 029 CARD PUNCH

FIGURE 4.9 THE LARR-V DIGITAL COORDINATOGRAPH
Operator wages and other costs add another five dollars per hour. Using these figures and the 1000 points per hour data collection rate, the cost of collecting each data point is 1.5 cents. This is approximately one-half the cost per point of manual methods.

However, there are other advantages to using such digitization equipment. The equipment will increase speed and measurement accuracy, and reduce the number of errors. Detection and correction of errors is slow and difficult, and therefore expensive. Use of data containing errors inevitably leads to considerable frustration.

These considerations suggest that machine-assisted techniques be used whenever possible, and that manual methods be restricted to the collection of small volumes of data.
CHAPTER 5

USING THE WATER SYSTEM

The Purpose of Options

Network geometry and topology are defined for the WATER System according to methods and procedures discussed in Chapter 4. For simplicity, the ordered set of data cards containing the X and Y coordinates will be referred to as "the Network Data Set".

However, the WATER System requires certain other information before it can process these data. Information concerning the name of the basin, the scale of the source data, the orientation of the coordinate grid, and the format of the Network Data Set cards are obviously needed. It is desirable to be able to process more than one drainage basin in a single job; this requires separation and identification of independent analysis requests.

Furthermore, different users might desire to vary their input data or their output requests. For instance, some users might wish to analyze elevation data, or may not need such analyses. A wide variety of output requirements can be expected. Some users might want the network classified according to Strahler's orders, others according to Shreve's magnitudes, others by both systems. Some may require graphical display of the network and longitudinal profiles, others might prefer detailed breakdowns of lengths, falls, or gradients for later study.
Sometimes the size of the available computer would necessitate the subdivision of very large basins into smaller sub-basins which can be processed independently. In other cases several small basins can be combined to form a large basin which can be analyzed at one time.

In order to satisfy these clearly recognizable needs, the WATER System includes a number of options. At present there are eighteen options; seven "Input Options" and eleven "Output Options".

The Option Hierarchy

All the options are not of equal importance. Certain input options must be supplied for every analysis request. Thus they are not options in the normal sense. However, because they have the same appearance and are used in conjunction with the true options, it is convenient to classify and discuss them as options.

Interdependence and relative ranking of the various options are seen most clearly if each is placed in an Option Hierarchy. The "required options" belong to "Class I"; the primary input and output choices facing the user belong to "Class II"; those options in Classes III and IV are dependent on the options selected from the higher classes. The input options all belong to Classes I and II; the output options belong to Classes II, III and IV. Table 5.1 shows the classification and purpose of each option.
<table>
<thead>
<tr>
<th>NAME</th>
<th>CLASS</th>
<th>TYPE*</th>
<th>PURPOSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDSNW</td>
<td>PRERUN</td>
<td>PRERUN</td>
<td>Identifies data as point data or order-magnitude data</td>
</tr>
<tr>
<td>SCALE</td>
<td>PRERUN</td>
<td></td>
<td>Allows maps to be produced at set scale</td>
</tr>
<tr>
<td>WATER</td>
<td>I</td>
<td>INPUT</td>
<td>Begin new basin, initialize all counters</td>
</tr>
<tr>
<td>DATA</td>
<td>I</td>
<td>INPUT</td>
<td>Start of co-ordinate data set</td>
</tr>
<tr>
<td>END</td>
<td>I</td>
<td>INPUT</td>
<td>End of all options and data for a basin</td>
</tr>
<tr>
<td>ENDCALL</td>
<td>I</td>
<td>INPUT</td>
<td>End of all sets of options and data</td>
</tr>
<tr>
<td>HYPsometry</td>
<td>II</td>
<td>INPUT</td>
<td>Elevation data being supplied</td>
</tr>
<tr>
<td>STRAHLER</td>
<td>II</td>
<td>OUTPUT</td>
<td>Classify network into Strahler's orders</td>
</tr>
<tr>
<td>MAGNITUDE</td>
<td>II</td>
<td>OUTPUT</td>
<td>Classify network into Shreve's magnitudes</td>
</tr>
<tr>
<td>ANGLES</td>
<td>II</td>
<td>OUTPUT</td>
<td>Compute junction angle statistics</td>
</tr>
<tr>
<td>JUNCTION</td>
<td>II</td>
<td>OUTPUT</td>
<td>Addition of orders and magnitudes for independently analyzed sub-basin</td>
</tr>
<tr>
<td>CONNECT</td>
<td>II</td>
<td>OUTPUT</td>
<td>Simultaneous analysis of multiple inter-connected basins</td>
</tr>
<tr>
<td>NETWORKS</td>
<td>III</td>
<td>OUTPUT</td>
<td>Make printer-maps of orders and/or magnitudes. Requires *STRAHLER and/or *MAGNITUDE</td>
</tr>
<tr>
<td>PROFILES</td>
<td>III</td>
<td>OUTPUT</td>
<td>Display longitudinal profiles (max=11) of main stream and from selected points. Requires *HYPsometry</td>
</tr>
<tr>
<td>AZIMUTHS</td>
<td>III</td>
<td>OUTPUT</td>
<td>List azimuths of ordered segments. Requires *STRAHLER</td>
</tr>
<tr>
<td>LENGTHS</td>
<td>III</td>
<td>OUTPUT</td>
<td>List lengths of segments by order and/or links by magnitude. Requires *STRAHLER and/or *MAGNITUDE</td>
</tr>
<tr>
<td>FALLS</td>
<td>III</td>
<td>OUTPUT</td>
<td>List falls of segments and/or links. Requires *HYPsometry AND *STRAHLER and/or *MAGNITUDE</td>
</tr>
<tr>
<td>GRADIENTS</td>
<td>III</td>
<td>OUTPUT</td>
<td>List gradients of segments and/or links, Requires *HYPsometry AND *STRAHLER and/or *MAGNITUDE</td>
</tr>
<tr>
<td>PUNCH</td>
<td>IV</td>
<td>OUTPUT</td>
<td>Causes lists produced by *AZIMUTHS, *LENGTHS, FALLS and/or *GRADIENTS options to be punched onto cards and identified by header cards</td>
</tr>
</tbody>
</table>

*TYPE indicates purpose of option, PRERUN options are used with program PRERUN only, INPUT and OUTPUT options affect input and output respectively.
Option Specification Cards

Each option is requested by using an Option Specification Card. As shown in Figure 5.1 these cards have the following format:

a) Column 1 contains an asterisk (*).

b) Columns 2 - 11 contain the option name, which must start in column 2 and be spelled exactly as shown in Table 5.1.

c) Columns 12 - 20 are not used.

d) Columns 21 - 80 contain 15 four column numerical fields (columns 21 - 24, 25 - 29, 30 - 33, etc.). These NTEMP fields are used to supply integer values required by certain options. Values entered in these fields must therefore be right-justified within each field.

Certain input options require additional floating-point values. These are entered on additional card(s) which immediately follow the option specification card. The exact requirements of each option are described in the following sections.

The *WATER Option (CLASS I)

Purpose

This input option defines the beginning of a data set for a particular analysis.

Data Requirements

The option specification card must have *WATER beginning in column 1.

Effect

It causes initialization of all counters, variables, and tables within the WATER System.
<table>
<thead>
<tr>
<th>Option Name</th>
<th>Not Used</th>
<th>15 N Temp Field, Each Four Columns Wide</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2 - 11)</td>
<td>(12 - 20)</td>
<td>(21 - 24, 25 - 29, 30 - 33, etc.)</td>
</tr>
</tbody>
</table>

**Figure 5.1** Format of the Option Specification Card
The #DATA Option (CLASS I)

Purpose

This input option specifies the beginning to the "Network Data Set".

Data Requirements

The option specification card with #DATA beginning in column 1 must be followed immediately by:-

a) a title card; containing, in columns 1 - 80, up to 80 characters identifying the basin name.

b) a source card; containing, in columns 1 - 80, up to 80 characters identifying the source of the network data.

c) a scale-origin card; containing four floating-point numbers, each in 10 column fields (1 - 10, 11 - 20, etc.), specifying as follows:-

i) the scale of the source data by giving the denominator of the scale fraction,

ii) the azimuth of the positive Y-axis, in degrees, of the data coordinate system.

iii) the X-coordinate of the origin of the data coordinate system on a master coordinate system.

iv) the Y-coordinate of the origin of the data coordinate system on a master coordinate system.

d) a format card; containing:-

i) In columns 1 - 3 an integer number which is the number of points recorded per card.

ii) In columns 7 - 79, a format for reading the "Network Data Set" cards.

c) the Network Data Set cards.

It should be noted that the format card must specify a field for Z-data if the #HYPSOMETRY option is requested, and must not do so if the #HYPSOMETRY option is not used.
Also, the azimuth and origin coordinate data are not required unless the azimuths with respect to true north are needed, or several basins are being joined together with the *CONNECT option.

**Effect**

The *DATA option causes the reading in of the basic network data set.

The *END Option (CLASS I)

**Purpose**

This input option signifies the end of all option specifications and data for a particular analysis. This card should be followed by either a *WATER option card indicating the start of another analysis request or a *ENDALL card indicating the end of all the analysis requests.

**Data Requirements**

Only the option specification card with *END beginning in column 1 is required.

**Effect**

On encountering this card the WATER System will begin to analyze the data received since the last *WATER option card. A table showing the input point coordinates and codes will be displayed (see page C-1) followed by the construction of the network into reaches and display of the Reach Table (see page C-2). Further output would follow, depending on
the output options requested. If no further output options are requested, a table summarizing the overall basin statistics (area, length, drainage density, etc.) would be produced. A typical basin statistics table is shown on pages C-14 and C-15.

The *ENDALL Option (CLASS I)

Purpose
This input option signifies the end of all analysis requests.

Data Requirements
Only the option specification card with *ENDALL beginning in column 1 is required.

Effect
This option causes the immediate termination of the job.

The *HYPSOMETRY Option (CLASS II)

Purpose
This input option indicates that elevation data are being supplied and are to be analyzed by the WATER System. Elevation data may be supplied either (1) for every point, or (2) by defining the locations where contour lines cross the streams. If the latter case is chosen the WATER System estimates the elevation of each point according to algorithms contained within the subroutine ZCALC.
Data Requirements

If elevation data are being supplied for every point, the option specification card with *HYPSOMETRY starting in column 1 is all that is required. If the elevations are to be estimated from contour crossing data the option specification card must contain the following additional integer information:

i) In columns 21 - 24, the elevation (in feet) of the highest point in the basin.

ii) In columns 25 - 28, the elevation (in feet) of the mouth of the basin.

iii) In columns 29 - 32, the contour interval (in feet).

Effect

The *HYPSOMETRY option affects the format specifications contained on the format card following the *DATA option specification card. Whenever *HYPSOMETRY is used, the format must include a field specification for elevation data. This option automatically allows the WATER System to calculate additional basin statistics. It is a prerequisite to the *PROFILES, *FALLS, and *GRADIENTS options, because without elevation data these options are meaningless.

The *JUNCTION Option (CLASS II)

Purpose

This input option allows the user to specify up to five points on the network being analyzed as junction points with
networks that have been previously analyzed. As shown in Figure 5.2, this option allows the WATER System to analyze very large networks as a series of smaller problems which can be stored within the computer.

**Data Requirements**

In addition to *JUNCTION beginning in column 1, the option specification card contains from one to five sequences of three numbers in the NTEMP fields. Each sequence of numbers contains:

1) the point number of the junction point
2) the order of the stream of the junction point
3) the magnitude of the stream at the junction point.

Figure 5.3 shows a completed *JUNCTION card for four junction points.

**Effect**

This option substitutes the supplied order and magnitude for the normally computed values. The junctions may be made at endpoints (code 1) or midpoints (code 2); however, to produce a rational map, it is suggested that false first-order streams are coded at proposed points of junction along the mainstream. The endpoint of these false first-order streams may then be used as junction points to produce a short, correctly ordered tributary section on the resulting map.
(A) STEP 1
Determine Drainage Network

(B) STEP 2
Subdivided Basin

(C) STEP 3
Analyze Sub-basins Independently

(D) STEP 4
Use *JUNCTION to Complete the Analysis

FIG. 5.2 OPERATION OF THE *JUNCTION OPTION
Caution should be exercised in using this option. All that this option is meant to produce is a correctly ordered drainage map. The majority of statistics which will be printed, however, are no longer valid. Most length, area, and relief parameters which will appear are incorrect because the area, number of segments, and lengths of the joined tributary have not been provided.

The *CONNECT Option (CLASS II)

Purpose

This input option operates as shown by Figure 5.4. A series of basins may be connected to a main basin at a series of connection points within the main basin. The *CONNECT card replaces the *DATA card, but otherwise the data defining the connecting basin (now a sub-basin) remain unchanged. The "CONNECT card" indicates the beginning of a "Network Data Set".

Data Requirements

The option specification card contains *CONNECT beginning in column 1 and

1) in columns 21 - 24, the number of the connection point in the main basin, which the mouth of this sub-basin will become.
FIG. 5.4  OPERATION OF THE *CONNECT OPTION
11) In column 28, a "1" if the main basin boundary points are to be retained.

This card is followed by the title, source, scale-origin, and format cards, and the Network Data Set cards, as described for the *DATA option. This allows the sub-basin to be easily analyzed at another time as an independent basin by merely substituting a *DATA option card for the *CONNECT option card.

**Effect**

As shown in Figure 5.5 the data points following the *CONNECT option are merged with those of the main basin to form a single basin. Up to five connections may be specified at endpoints or midpoint, and these can be in any order within the main basin sequence. Boundary points of each sub-basin are deleted so that the only boundary remaining is the one belonging to the main basin. If this is large enough to include all the basins it should be retained to allow calculation of basin area, drainage density, and similar statistics. If it no longer encompasses the entire network the main basin boundary should also be dropped. Retention of the main basin boundary is accomplished by entering a 1 in column 28 of the
FIG. 5.5 MERGING OF SUB-BASIN AND MAIN BASIN DATA ARRAYS
*CONNECT option card. If the column is left blank the main basin boundary points will be dropped.

The *STRAHLER Option (CLASS II)

Purpose

This output option causes the calculation and display of statistics for the network classified according to Strahler's orders. It is a prerequisite for the *NETWORKS, *AZIMUTHS, *LENGTHS, *FALLS, and *GRADIENTS options.

Data Requirements

The option specification card requires *STRAHLER to begin in column 1.

Effect

The table produced as a result of requesting this option is shown on page C-4.

The *MAGNITUDE Option (CLASS II)

Purpose

This output option causes the display of statistics for the network when classified into Shreve's magnitudes. It is a prerequisite for the *NETWORKS, *LENGTHS, *FALLS, and *GRADIENTS options.

Data Requirements

The option specification card required *MAGNITUDE to begin in column 1.
Effect

A typical table produced as a result of requesting this option is shown on page C-9.

The *ANGLES Option (CLASS II)

Purpose

This output option causes the computation and display of junction angle statistics.

Data Requirements

The option specification card requires *ANGLES to begin in column 1.

Effect

Page C-3 shows a typical table produced as a result of requesting this option. The angles are classified according to the orders of the joining segments. Junctions involving up to sixth-order segments only are computed. Each angle is defined by the position of the junction point and the nearest upstream points, one located on each connecting branch.

The *NETWORKS Option (CLASS III)

Purpose

This output option requests the production of maps of the stream network on the printer. It operates in conjunction with the *STRAHLER and/or *MAGNITUDE options.
Date Requirements

The option specification card contains *NETWORKS beginning in column 1 and is followed immediately by one additional card which contains six floating-point values, each in 10 column fields (1 - 10, 11 - 20, etc.), specifying as follows:-

i) The width of the desired maps in inches. The maximum allowable is 13 inches.

ii) The maximum x-coordinate of the area to be mapped. This defines the right edge of the map.

iii) The minimum x-coordinate of the area to be mapped. This defines the left edge of the map.

iv) The maximum y-coordinate of the area to be mapped. This defines the top of the map and must be larger than the highest point in the basin.

v) The minimum y-coordinate of the area to be mapped. This defines the bottom of the map.

vi) The desired minimum resolution distance to be shown on the map. The area covered by a single character is checked against this value. If the characters cover a larger map area than this resolution value, perhaps because too small a map width was specified, the map is still produced. However a warning message is printed.

Effect

This option produces a map of orders if the *STRAHLER option is requested, and a map of magnitudes if the *MAGNITUDE option is requested. Examples of printer maps produced by this option are found on pages C-8, C-13, C-20, C-26, and in Appendix E.
The *PROFILES Option (CLASS III)

Purpose

This output option produces longitudinal profiles from selected points in the network to the mouth. The *HYPSOMETRY option is a prerequisite. The longest stream is automatically found by the WATER system programs and its profile is always produced, whether its beginning point was selected or not.

Data Requirements

The option specification card must have *PROFILES beginning in column 1. Profile starting points may be defined in either of two ways:

1) Points having junction codes prefixed with a minus sign in the Network Data Set cards will be entered as profile starting points.

ii) Up to 15 point numbers may be entered in the NTEMP fields (columns 21 - 24, 25 - 28, etc.) of the option specification card.

The first method allows the user to request longitudinal profiles to be constructed from a point within a sub-basin, across the connect point, to the mouth of the main basin when the *CONNECT option is used. It is the only method by which such a profile may be requested. However it is harder to add or delete specific profile requests with the minus sign method than with the NTEMP fields.

Effect

Page C-16 contains a typical profile at reduced scale. The profiles for any one basin will have the same vertical
and horizontal scales. These scales are internally computed and are adjusted from basin to basin.

The *LENGTHS Option (CLASS III)

Purpose

This output option produces a detailed listing of the lengths of ordered segments and/or links up to magnitude 20. It requires either or both the *STRAHLER or *MAGNITUDE options in order to produce any lists.

Data Requirements

The option specification card must have *LENGTHS beginning in column 1.

Effect

A typical lengths table is shown on page C-5.

The *FALLS Option (CLASS III)

Purpose

This output option produces a detailed listing of the falls of ordered segments and/or the falls of links up to magnitude 20. It requires either or both of the *STRAHLER or *MAGNITUDE options in order to produce either table. The *HYPSOMETRy option is also a pre-requisite.

Data Requirements:

The option specification card must have *FALLS beginning in column 1.
Effect

A typical falls table is shown on page C-5.

The *GRADIENTS Option (CLASS III)

Purpose

This output option produces a detailed listing of the gradients of ordered segments and/or gradients of links up to magnitude 20. The *HYPSOMETRY and the *STRAHLER and/or *MAGNITUDE options are pre-requisites.

Data Requirements

The option specification card must have *GRADIENTS beginning in column 1.

Effect

A typical gradients table is shown on page C-6.

The *AZIMUTHS Option (CLASS III)

Purpose

This output option produces a detailed listing of the azimuths of all ordered segments. The *STRAHLER option is a pre-requisite.

Data Requirements

The option specification card has *AZIMUTHS beginning in column 1.

Effect

A typical azimuth table is shown on page C-6.
The *HISTOGRAM Option (CLASS IV)

Purpose

This output option produces histograms showing the distributions of azimuths, lengths, falls and gradients of ordered segments and/or links of various magnitudes.

Data Requirements

The option specification card must have *HISTOGRAM beginning in column 1.

Effect

The number of histograms produced depends on the options requested and the number of values recorded for any given order of magnitude. A typical histogram is shown on page C-7. All histograms contain forty (40) intervals.

The *PUNCH Option (CLASS IV)

Purpose

This output option has a two-fold purpose:

1) to punch a deck of cards that can be used to draw a map of the stream network showing Strahler's orders or Shreve's magnitudes on the CALCOMP plotter. These cards are supplied as an option to Program PRERUN.

11) to punch deck(s) of cards containing the information contained in the tables produced by the *AZIMUTHS, *LENGTHS, *PALLS or *GRADIENTS options.

Data Requirements

The option specification card must have *PUNCH beginning in column 1 and any combination of the following:
1) a "1" in column 24 requests the production of the stream order data for the CALCOMP map. A "2" in column 24 requests the production of the stream magnitude data for the CALCOMP map. A "3" in column 24 requests both data decks.

ii) a "1" in column 28 requests a deck of *AZIMUTHS values.

iii) a "1" in column 32 requests a deck of *LENGTHS values.

iv) a "1" in column 36 requests a deck of *FALLS values.

v) a "1" in column 40 requests a deck of *GRADIENTS values.

Effect

The deck for the Calcomp maps is produced by a special section of Subroutine RITER. It has a format acceptable to program PRERUN. The remaining decks produced in conjunction with the *AZIMUTHS, *LENGTHS, *FALLS and *GRADIENTS options and have identical formats. The card sequence includes a number of identification cards. A typical sequence is shown in Figure 5.6.

Program PRERUN Options

The Effect of Program Water Options

Program PRERUN will accept the regular WATER System options described. It utilizes class I and II input options (*WATER, *DATA, *END, *ENDALL, and *HYPSONTTRY) for their regular purposes, as described previously. However, the output options are merely skipped over, or ignored.
FIGURE 5.6 TYPICAL PUNCHED OUTPUT SUPPLIED BY *PUNCH OPTION.

( EXAMPLE SHOWS LENGTH DATA )
This feature has been incorporated into program PRERUN for convenience to the user. One of the purposes of PRERUN is to help the user find errors in his data. It is thus convenient to be able to submit a data deck without change with a new program whenever errors occur.

PRERUN also has a second purpose - the production of drainage maps on the CALCOMP plotter which show:

1) the locations of data points and their sequence numbers,
2) the Strahler order of each link, or
3) the Shreve magnitude of each link.

When CALCOMP maps are required two new PRERUN output options, *IDSW and *SCALE, are normally required.

It should be noted that whereas WATER options are acceptable to PRERUN, the PRERUN options *IDSW and *SCALE are not acceptable to Program WATER. This is a safety precaution since the deck used to make the CALCOMP maps showing orders or magnitudes cannot be analyzed by Program WATER routines.

The *IDSW Option

This option must be supplied whenever CALCOMP maps are required. The type of map to be produced is specified by entering an integer in the first NTEMP field (column 24) according to the following rules:

A "1" means a map showing data point numbers is required.

A "2" means a map showing the Strahler order of each link is required.

A "3" means a map showing the Shreve magnitude of each link is required.
The data set supplied with the request should contain regular water system data in the first case or special data in which the regular point code values are replaced by link order or magnitude values for the latter two cases. These special decks can be produced by using the *PUNCH option during a regular drainage network analysis.

The *SCALE Option

This option may be used; it is not required. It is used whenever the CALCOMP map is to be produced at a certain scale. If it is not specified PRERUN will determine the largest scale that will allow the map to fit within the width of the paper on the plotter. Thus each basin will have a different scale. The *SCALE option allows user to produce maps of a series of basins at a constant scale.

The scale is specified by giving the denominator of the scale fraction. This is supplied on a second card, as a decimal number.

Sequence of Option Specification Cards

The input options must be supplied in a clearly defined sequence, as defined by the following rules:

1) The *WATER option must be the first card in the analysis request for each basin.

2) The *END option must be the last card in the analysis request for each basin.

3) The *ENDALL option must be the last card in the data deck.

4) The *HYPSOMETRY option must precede the *DATA option.
5) The *CONNECT option(s) must follow the *DATA option, but can be in any relative order among themselves.

Any sequence of the output options and the *JUNCTION option is acceptable, provided none of the above five rules are violated. Figure 5.7 shows a typical input deck prepared for submission.

Restrictions in the Use of Options

The WATER System will ignore lower-class option requests for which insufficient upper class prerequisite options have been requested. Careful study of Table 5.1 will assist in showing the inter-dependence of the various options.

In the versions of the WATER System program included in Appendix A of this report, the following restrictions apply:

1) The maximum number of points used to describe a network is 300.

2) The maximum number of *CONNECT options is five (5).

3) The maximum number of *JUNCTION options is five (5).

4) The maximum number of specified profiles which can be plotted is fifteen (15). One additional profile for the longest stream will be plotted, if not previously specified.

5) Junction angles will be computed only up to sixth-order.

6) Detailed magnitude statistics will be displayed only up to the twentieth magnitude.

7) Azimuths are not available for magnitudes.

8) If the *HYPSOMETRY option is used, all input data format cards following the *DATA and the *CONNECT options must have fields to Z-axis data. It is an all or no-thing procedure, all data have Z-value fields or none of the data have Z-value fields.
FIG. 5.7 A TYPICAL INPUT DECK SHOWING THE ORDER OF VARIOUS OPTION CARDS
Those readers who wish to modify the above size restrictions should refer to the latter portion of Chapter 6.

Examples of WATER System Analyses

Appendices of this report contain several examples of WATER System input and output options. Appendix B contains the input requests for three analyses by the WATER program. Samples of output produced for these requests is shown in Appendix C. In order to reduce repetition some editing of the output was necessary.

Appendix D contains sample input and output for Program PRERUN. Appendix E contains a sequence of printer maps which show the use of *CONNECT and *JUNCTION options.
CHAPTER 6
THE WATER SYSTEM PROGRAMS

Programming Language

The WATER System has been programmed in FORTRAN IV. A conscious effort has been made to use only those features common to all third generation computers. The programs have been tested on two computers, CDC 6500 at Purdue University and an IBM 360/65 at the University of Toronto. The programs have been successfully compiled with three compilers; the CDC "Chippewa" FORTRAN IV compiler, IBM Release 18 FORTRAN IV compiler operating under MVT and HASP, and the WATFOR compiler at the University of Toronto. The programs are thus thought to be reasonably universal.

All subroutines in the WATER System have single entry points. The implementation of multiple-entry subprograms is so far limited to only a few processors and is unfortunately not standardized. Several of the routines, for example RITER and CALC, are called several times with each call requiring different portions of the routine to be executed. In such cases the first argument in the subroutine argument list is used to transfer control to the appropriate section of the program by a "COMPUTED GO TO" statement.
System Organization

The WATER System consists of two independent programs - WATER and PRERUN and 12 subroutines. Table 6.1 describes each subroutine and summarizes the structure of the routines.

During the development of the WATER System an attempt was made to collect all INPUT and OUTPUT operations in Special Subroutines, whereas other routines are concerned primarily with the necessary logical and arithmetic operations. These are called data handling routines and computational routines respectively.

Program Listings and Documentation

Appendix A contains a detailed listing of the FORTRAN statements for all routines. Each routine contains a number of COMMENT cards giving detailed instructions describing its purpose, use, common blocks, arguments, and required or optional subroutines.

FORTRAN IV programs were prepared for publication by first resequencing all statement numbers, removing extraneous numbers, and placing card sequence numbers in columns 73-80 of each card.

In the past much duplication of programming effort has occurred because little or no effort was made to communicate information concerning accomplished programming procedures. The authors hope that the remainder of this chapter and the Appendices contain all the pertinent information concerning these programs and will provide the
TABLE 6.1
LIST OF WATER SYSTEM ROUTINES

<table>
<thead>
<tr>
<th>Name</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROGRAM</td>
<td>Call the following subroutines in order</td>
</tr>
<tr>
<td>WATER</td>
<td></td>
</tr>
<tr>
<td>READIT</td>
<td>Read data and option specifications from cards</td>
</tr>
<tr>
<td>RITER</td>
<td>Print summary tables, punch data on cards if requested</td>
</tr>
<tr>
<td>LINKER</td>
<td>Determine network configuration, classify reaches, compute reach lengths, and junction angles</td>
</tr>
<tr>
<td>CALC</td>
<td>Compute overall basin statistics involving drainage density, shapes, areas, and lengths</td>
</tr>
<tr>
<td>MAPS</td>
<td>Produce maps of network on printer showing orders and magnitudes</td>
</tr>
<tr>
<td>ORD1</td>
<td>Compute segments for Strahler's orders; display statistics</td>
</tr>
<tr>
<td>ORD2</td>
<td>Compute links for Shreve's magnitudes; display statistics</td>
</tr>
<tr>
<td>PROFIL</td>
<td>Produce longitudinal profiles</td>
</tr>
<tr>
<td>ANGLE</td>
<td>Compute an angle defined by three points</td>
</tr>
<tr>
<td>HIST</td>
<td>Produce histograms of supplied data arrays</td>
</tr>
<tr>
<td>ZCALC</td>
<td>Estimate elevations of all points from contour crossing points.</td>
</tr>
<tr>
<td>PROGRAM</td>
<td>Check data for logical errors, prepare CALCOMP maps of basins showing location of data points, orders, or magnitudes</td>
</tr>
<tr>
<td>PRERUN</td>
<td></td>
</tr>
<tr>
<td>DTR</td>
<td>Computes X, Y plotter coordinates to place point numbers, order numbers, or magnitude numbers on map.</td>
</tr>
</tbody>
</table>
basis for understanding, modifying, and using the programs and program results.

Storage Requirements

The maximum size of drainage basin that can be analyzed by the WATER System is controlled by the number of points required to adequately describe it, and by the core storage capacity of the computer used.

The WATER program has been designed to be as efficient as possible in its core storage requirements. The total number of locations assigned to dimensioned arrays is:

\[ 11N + 700 \text{ where } N = \text{number of points} \]

Thus a basin described by 300 points requires 4000 locations for dimensioned arrays. This figure must be added to the storage requirements for the program statements and variables. Program WATER Requires about 24K words (96K bytes). Thus for basins up to 300 points the WATER program requires about 28K words or 110K bytes. (The programs are being run successfully for 300 points in a 110K region on the IBM 360/65.)

Program PRERUN is considerably smaller. When dimensioned for 1000 points, it runs successfully in a 90K byte region on the IBM 360/65.

Description of Program WATER Routines

Program WATER (Main Program)

Program WATER can be visualized as containing up to 22 basic steps, each containing several operations. The
actual number of steps executed in any particular analysis depends on the options requested.

Figure 6.1 and Table 6.2 describe these 22 steps. In Table 6.2 each is defined according to the subroutine call which initiates the step. All input data are supplied by subroutine READIT. A record of the options specified is contained in a series of "switch variables" in the "OPTION" common array. The variable NSTOP is used to detect job termination requirements, due either to input errors or encountering a *ENDALL card. If the program is to continue NSTOP will remain equal to one. When NSTOP equals two the program will terminate.

Figure 6.1 shows how the 11 main storage arrays, each dimensioned equal to the maximum number of points, are used in each step. To conserve storage certain values are shifted from one area of storage to another during program execution, and arrays X and NX and Y and NY are equivalenced. In steps 15 and 21, for example, the X and Y values are saved by being temporarily stored in arrays TEMPl and TEMP2. After step 8, all arrays are used most of the time.

The only major computations performed in MAIN are those required to obtain parameters for subroutine MAPS. The map scale and map size parameters are computed first. Then all X and Y coordinates are transformed into printer character coordinates. Each X coordinate becomes a print position on a line; each Y coordinate becomes a line number. The line numbers begin at the top of the map and increase down the
| STEP NO. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|----------|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| LINK(n,1) |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| LINK(n,2) |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| LINK(n,3) |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| LINK(n,4) |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| LINE(n)   | a |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| NX(n)     |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| NY(n)     |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| X(n)      |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Y(n)      |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| TEMPL(n)  | b |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| TEMP2(n)  | c |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| DIST(n)   | d |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |
| Z(n)      |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |

**EQUIVALENCED**
- a - POINT CODES FOR *CONNECT OPTION
- b - X COORDINATES FOR *CONNECT OPTION
- c - Y COORDINATES FOR *CONNECT OPTION
- d - Z COORDINATES FOR *CONNECT OPTION
- e - REACH AZIMUTHS times 1000
- f - SEQUENCE OF POINTS DOWN MAP
- g - SEQUENCE OF POINTS FORMING PROFILE

**NOT USED**
- h - LENGTHS OF STRAHLER ORDERS
- k - GRADIENTS OF STRAHLER ORDERS
- l - FALLS OF STRAHLER ORDERS
- m - AZIMUTHS OF STRAHLER ORDERS
- n - LENGTHS OF SHREVE MAGNITUDES
- p - GRADIENTS OF SHREVE MAGNITUDES
- q - FALLS OF SHREVE MAGNITUDES

**FIGURE 6.1** THE 24 BASIC STEPS OF PROGRAM WATER (See Table 6.2 for step identification.)
### TABLE 6.2
IDENTIFICATION OF STEP NUMBERS IN FIGURE 6.1

<table>
<thead>
<tr>
<th>Step Number</th>
<th>Program Subroutine Call</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>READIT read options and data</td>
</tr>
<tr>
<td>2</td>
<td>RITER(2) list input data</td>
</tr>
<tr>
<td>3</td>
<td>LINKER compute topology</td>
</tr>
<tr>
<td>4</td>
<td>CALC(1) calculate some basic statistics</td>
</tr>
<tr>
<td>5</td>
<td>RITER(3) list links</td>
</tr>
<tr>
<td>6</td>
<td>ZCALC compute unknown elevations</td>
</tr>
<tr>
<td>7</td>
<td>RITER(15) list completed links and elevations</td>
</tr>
<tr>
<td>8</td>
<td>RITER(13) punch orders</td>
</tr>
<tr>
<td>9</td>
<td>ORD1 compute Strahler orders</td>
</tr>
<tr>
<td>10</td>
<td>RITER(5) junction angles</td>
</tr>
<tr>
<td>11</td>
<td>RITER(6) Strahler lengths</td>
</tr>
<tr>
<td>12</td>
<td>RITER(7) Strahler falls</td>
</tr>
<tr>
<td>13</td>
<td>RITER(8) Strahler gradients</td>
</tr>
<tr>
<td>14</td>
<td>RITER(9) Strahler azimuths</td>
</tr>
<tr>
<td>15</td>
<td>MAPS(1) map of orders</td>
</tr>
<tr>
<td>16</td>
<td>ORD(2) calculate magnitudes</td>
</tr>
<tr>
<td>17</td>
<td>RITER(14) punch magnitudes</td>
</tr>
<tr>
<td>18</td>
<td>RITER(10) magnitude lengths</td>
</tr>
<tr>
<td>19</td>
<td>RITER(11) magnitude falls</td>
</tr>
<tr>
<td>20</td>
<td>RITER(12) magnitude gradients</td>
</tr>
<tr>
<td>21</td>
<td>MAPS(2) map of magnitudes</td>
</tr>
<tr>
<td>22</td>
<td>CALC(2) calculate remaining statistics</td>
</tr>
<tr>
<td>23</td>
<td>RITER(4) print basin statistics</td>
</tr>
<tr>
<td>24</td>
<td>PROFIL long profiles</td>
</tr>
</tbody>
</table>
map. A LINE table is constructed which contains the point sequence numbers in order of ascending printer line numbers. Thus the first entry in the LINE table contains the point number of the point nearest the top of the map.

Subroutine READIT

Subroutine READIT is called by the MAIN program to read all option specification and data cards. The array NAM contains the names of all seventeen valid WATER System Options. As each option specification card is read, the option name is checked against the entries in the NAM array. Failure to find a match indicates an invalid option name. When this occurs, an error message is printed and NSTOP set equal to two so that the program will terminate.

Whenever a valid option name is encountered control is transferred by a "COMPUTED GO TO" statement to the appropriate section. In most cases the appropriate "switch variable" in the OPTION common block is set to one to indicate the option has been requested.

When the *WATER option is encountered all variables and option "switch variables" are initialized. When the *DATA option is encountered the basin identification cards and coordinates of all data points are read. The number of points used to define the basin (NTOT) is determined.

When the *CONNECT option is encountered the additional data points are inserted into the original coordinate data at the appropriate position and the NTOT value is updated.
When the *END or *ENDALL options are encountered control is returned to the WATER program.

**Subroutine RITER**

This subroutine produces most of the summary tables required by the WATER System. However, it does not produce the printer maps specified by the option *NETWORKS or the tables produced in response to options *STRAHLER (see Subroutine ORD1) or *MAGNITUDE (see Subroutine ORD2).

Subroutine RITER is called at various points in the MAIN program. It is composed of sections needed to produce the desired tables. Control is passed to the appropriate section according to the value of an integer argument (KOUNT) passed at the time of calling. No calculations are performed in this subroutine other than a few required to produce the table values. Control is returned to the WATER program after each table has been completed.

Table 6.3 summarizes the purposes of each section of RITER and shows the corresponding value of KOUNT for each.

**Subroutine LINKER**

Subroutine LINKER is the cornerstone routine of the WATER System. Its primary purpose is to take the data defining the topology (KODE values) and geometry (X, Y, and Z values) for a series of points and to construct a hierarchically structured topological table of reaches (the LINK table).
### TABLE 6.3

**OUTPUT TABLES PRODUCED BY SUBROUTINE RITER**

<table>
<thead>
<tr>
<th>Contents of Table</th>
<th>KOUNT Value</th>
<th>Source of Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic input data</td>
<td>2</td>
<td>READIT</td>
</tr>
<tr>
<td>Reach table</td>
<td>3</td>
<td>LINKER</td>
</tr>
<tr>
<td>Junction angles</td>
<td>5</td>
<td>LINKER and ANGLE</td>
</tr>
<tr>
<td>Basic statistics</td>
<td>4</td>
<td>CALC</td>
</tr>
<tr>
<td>Segment lengths</td>
<td>6</td>
<td>ORD1</td>
</tr>
<tr>
<td>Link lengths</td>
<td>10</td>
<td>ORD2</td>
</tr>
<tr>
<td>Segment azimuths</td>
<td>9</td>
<td>ORD1</td>
</tr>
<tr>
<td>Segment falls</td>
<td>7</td>
<td>ORD1</td>
</tr>
<tr>
<td>Link falls</td>
<td>11</td>
<td>ORD2</td>
</tr>
<tr>
<td>Segment gradients</td>
<td>8</td>
<td>ORD1</td>
</tr>
<tr>
<td>Link gradients</td>
<td>12</td>
<td>ORD2</td>
</tr>
</tbody>
</table>
Although this is its primary function, subroutine LINKER performs a number of crucial calculations required by several options. These include:

1) the identification and storage of profile requests initiated by negative code values.
2) the calculations required for the *JUNCTION option.
3) the calling of the ANGLE subroutine to compute the junction angle statistics.
4) the estimation elevations when subroutine ZCALC is requested.

Only the primary function of subroutine LINKER, the construction of the LINK table, will be described in this section.

The routine begins by progressively scanning the input data KDE values to define the topology of the basin. In order to save storage requirements the KDE values are equivalenced to the LINK (L, 4) values. However, it is easiest to consider these as separate locations. As each point is encountered, a reach is defined as follows:

LINK(L, 1) = current point sequence number
LINK(L, 2) = "last point" sequence number.
LINK(L, 3) = n = "order" of the reach
where n = -1 if the current point is on the boundary (KODE = 4)
       n = 1 if the current point is tip (KODE=1)
       n = 100 otherwise.
As each stream junction is encountered (KODE = 3) the junction sequence number is entered in the JUNC table. Whenever a stream tip (KODE = 1) is encountered the current reach is entered normally, then the sequence number of the "last point" is obtained as the last value in the JUNC table (which is reduced in size by one). Thus the next reach will extend from the last junction to the next point. This is equivalent to retracing to the last junction each time a stream tip is encountered. Figure 6.2 shows this procedure for a simple case.

Whenever a stream tip is encountered the stream reaches are traced back to the first junction point, each reach having its order reset to one (LINK(L, 3) = 1). This step is required to complete the ordering of all first-order reaches. Figure 6.3 shows this method. This retracing is a simple operation because the reaches are located in sequence and will occur immediately above the reach containing the stream tip.

Once the entire LINK table has been built in this way, it contains reaches ordered as -1, 1, or 100. A sort procedure follows, so that all reaches defining the basin boundary occur at the top of the table, followed by all first-order reaches, followed by all the higher order reaches. Figure 6.4 shows a LINK table at this stage for a simple basin. It should be noted that, within each order, the original sequence of the reaches (the topologic sequence) remains intact. For example the first, first-order reach remains at the top of its group.
FIG. 6.2  RETRACING OF "LAST POINTS"
UPON ENCOUNTERING A STREAM TIP
A: STREAM NETWORK SHOWING THE ORDER OF DATA POINT COLLECTION

B. STRAHLER ORDER FIRST ASSIGNED TO ESTABLISHED LINKS (I.E. THE VALUE OF LINK(L,3))

C. RETRACING OF REACHES TO ESTABLISH CORRECT ORDER AFTER ENCOUNTERING A STREAM TIP

---- REACHES ALREADY IN THE LINK TABLE

FIG. 6.3 REORDERING OF REACHES UPON ENCOUNTERING A STREAM TIP
<table>
<thead>
<tr>
<th>REACH TERMINI</th>
<th>NUMBERS</th>
<th>STRAHLER ORDERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPSTREAM</td>
<td>DOWNSTREAM</td>
<td>LINK (L,3)</td>
</tr>
<tr>
<td>LINK (L,1)</td>
<td>LINK (1,2)</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>12</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>15</td>
<td>14</td>
<td>1</td>
</tr>
<tr>
<td>18</td>
<td>17</td>
<td>1</td>
</tr>
<tr>
<td>19</td>
<td>18</td>
<td>1</td>
</tr>
<tr>
<td>20</td>
<td>17</td>
<td>1</td>
</tr>
<tr>
<td>25</td>
<td>24</td>
<td>1</td>
</tr>
<tr>
<td>28</td>
<td>27</td>
<td>1</td>
</tr>
<tr>
<td>29</td>
<td>27</td>
<td>1</td>
</tr>
<tr>
<td>30</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>31</td>
<td>30</td>
<td>1</td>
</tr>
<tr>
<td>32</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>33</td>
<td>32</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
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</tr>
<tr>
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</tr>
<tr>
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<td>100</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>100</td>
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<tr>
<td>7</td>
<td>6</td>
<td>100</td>
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<tr>
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<td>5</td>
<td>100</td>
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<tr>
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<td>100</td>
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<tr>
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<td>100</td>
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<td>100</td>
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<tr>
<td>26</td>
<td>24</td>
<td>100</td>
</tr>
<tr>
<td>27</td>
<td>26</td>
<td>100</td>
</tr>
</tbody>
</table>

1 Horizontal lines define individual Strahler orders

Fig. 6.4 The Link table for the stream network shown in Figure 4.8C after the first sort.
Subroutine LINKER now moves into its second phase. It searches the first-order links to find a pair of identical end points. Each pair found defines a junction point, and the start of a second-order reach. Thus a search is made in the lower portion of the LINK table to find reaches beginning at those points. These have their orders reset to two. Once again each such reach is traced downstream until a junction (or the mouth) is encountered, each intermediate reach having its order reset to two.

This defines the basic second-order reaches; however, some of the junctions just found may in fact be junctions with first-order tributaries. Thus a further search is undertaken to guard against this possibility. If any such junctions are found, the downstream reaches until the next junction are reset to second-order. Once all second-order reaches have been defined, the sorting action is repeated to bring all second-order reaches behind the first-order reaches.

The process of junction location, ordering, tracing downstream, and junction checking, followed by sorting, proceeds through progressively higher orders until the mouth is reached. Figure 6.5 shows the completed LINK table for the sample basin shown in Figure 6.4.

The array NSEG contains the number of reaches forming the basin boundary and each order. The variable NORDER is one greater than the basin order.
<table>
<thead>
<tr>
<th>REACH</th>
<th>TERMINI</th>
<th>NUMBERS</th>
<th>STRAHLER&lt;sup&gt;1&lt;/sup&gt; ORDERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>UPSTREAM</td>
<td>DOWNSTREAM</td>
<td>LINK (L,1)</td>
<td>LINK (L,2)</td>
</tr>
<tr>
<td>8</td>
<td>7</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>7</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>11</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>13</td>
<td>1</td>
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<tr>
<td>15</td>
<td>14</td>
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<td>18</td>
<td>17</td>
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<td>19</td>
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<td>20</td>
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<td>24</td>
<td>1</td>
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<tr>
<td>28</td>
<td>27</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>27</td>
<td>1</td>
<td></td>
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<tr>
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<td>21</td>
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<td>30</td>
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<tr>
<td>32</td>
<td>4</td>
<td>1</td>
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<td>33</td>
<td>32</td>
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<td>5</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

<sup>1</sup> Horizontal lines define individual Strahler orders

Fig. 6.5 Completed Link table for the stream network shown in Figure 4.8C
Subroutine CALC

Subroutine CALC is responsible for the computation of basin statistics within the WATER system. Subroutine CALC is divided into three portions. The first portion of the subroutine calculates the basic statistics of the basin. The calculations performed include: the length of each reach; the longest (main) stream; the straight line distance from tip to mouth; the azimuth of this straight line; the wandering ratio of the main stream; the basin area, length, and perimeter; the azimuth of basin length; total length of drainage channels; drainage density; constant of channel maintenance; the circularity ratio; elongation ratio; and the shape factor of the basin. Definitions of these quantities are given in Chapter 3.

The second portion of the subroutine is called after the stream network has been classified into Strahler's orders and/or Shreve's magnitudes (subroutines ORD1 and ORD2). The calculations performed include: channel segment frequency, texture ratio, link (magnitude) frequency, and link texture ratio.

The third portion of subroutine CALC requires elevation data. Therefore it is called only when the HYPSOMETRY option is requested. It computes the following quantities: the basin relief, the relative relief, the relief ratio, and the main stream slope.

The computer values are stored in the named COMMON array "BASIN". A call to subroutine RITER causes these quantities
to be displayed in a table at the end of the analysis. Subroutine CALC is automatically called by the WATER program so that these values are computed and displayed for every analysis of every basin.

Subroutine MAPS

Subroutine MAPS produces maps on the printer of the basin, showing the streams classified according to Strahler's orders or Shreve's magnitudes. The first argument (KMAP) defines whether the map is to be of orders or magnitudes. The size of the map is contained within the scaling parameter RATIO.

The routine uses information contained in the LINK, NX, NY, and LINE arrays. NX and NY values are the X and Y coordinates of the data points transformed into line and character coordinates. The LINE array contains the sequence number of each point ordered so that the point nearest the top of the map is first, and the point nearest the bottom last.

The routine proceeds through the map line by line. Only one line is stored at any one time to reduce storage requirements to a minimum. Each line is filled with blanks and an "I" placed at each end. The LINE array is scanned to the first (or next) point to be plotted, and the NY value of this point is compared with the current line number. When a match occurs a point has been found which is on the current print line. A search follows to locate reaches using this point by scanning the LINK table. Once a reach, or reaches, have been found a search of the LINE array is made to find the end of the reach. Only reaches which have ends located
farther down the map are of interest since those having
ends higher up the map are actually terminating at the current
point. These two searches result in the locating of one or
more new links. The information for each such reach is
entered in the LPlot table as follows:

\[
\begin{align*}
\text{LPlot}(L, 1) &= \text{line number of upper point} \\
\text{LPlot}(L, 2) &= \text{line number of lower point} \\
\text{LPlot}(L, 3) &= X \text{ coordinate of beginning point} \\
\text{LPlot}(L, 4) &= 1 \text{ (this is used as a count of the number of lines intersected by this reach from its start to the current print line).}
\end{align*}
\]

The slope of the line is computed and the number of
characters per line of print is stored in SPLNE(L).

This series of searches and checks is repeated until
all new reaches from all new points have been tested and
entered into LPlot if required. Then a test is made of
all LPlot entries to see if any reaches have just been
terminated and should be dropped. Once this is completed
the LPlot and SPLNE tables contain only entries which inter-
sect the current line on the printer.

The routine loops through the LPlot table to build the
line image. The equation of each reach is stored in the
LPlot and SPLNE values. These are used to calculate the
left and right limits of the characters (IXA, IXB) which
define the intersection of the reach with the current print
line. The characters between IXA and IXB (inclusive) must
be assigned appropriate characters. The order or magnitude of each reach is determined by examining the LINK table and the characters are assigned.

Once all the characters for all reaches intersecting the current print line have been determined, the line is printed. This procedure is repeated for all lines in the map. Once the map is completed an appropriate legend is printed.

Subroutine ORD1

Subroutine ORD1 is called whenever the *STRAHLER option is requested. All the Strahler stream order statistics are computed and displayed. This subroutine uses the results of computations performed by subroutine LINKER and CALC. The orders of each reach, as determined by LINKER, are found in the third column of the LINK array (LINK(L, 3)). The length of each reach, as computed by CALC, are found in the DIST array.

Subroutine ORD1 uses the information stored in the LINK, DIST, X, Y, and Z arrays and in the named common block "LINKR" to aggregate the reaches into Strahler segments. The length of each ordered segment is stored temporarily in the TEMPl array, the fall in the TEMP2 array, and the integer equivalent of 1000 times the azimuth in the fourth column of the LINK array (LINK(L, 4)). These values can be later extracted as required for further analysis if the *LENGTHS, *FALLS, *GRADIENTS, or *AZIMUTHS options are requested.
The output is displayed in the form of a summary table which includes the basic statistics for each stream order. The computed statistics include the maximum, minimum, and average length, fall, gradient, and azimuth of each order. If there are more than five segments in any one order the standard deviation and variance is also included for these values. The bifurcation ratios are also included. At the conclusion of the calculations and the display of all values, control is returned to the WATER program.

Subroutine ORD2

Subroutine ORD2 is called whenever the *MAGNITUDE option is requested. It computes the stream magnitude, according to Shreve's definition, for each reach. These values are stored in the fourth column of the LINK array (LINK(L, 4)). This routine operates in a similar fashion to Subroutine ORDI, accepting data already in the LINK, DIST, and Z arrays and in the common block "LINKR" to aggregate the reaches into "links". A link is a section of the stream network consisting of one or more reaches, and extending from junction to junction, mouth to junction, or tip to junction.

A table displays the mean, range, maximum and minimum values of length, gradient and fall for each magnitude. Where there are more than five links of a given magnitude the variance and standard deviation at the conclusion of these calculations.
Subroutine PROFIL

Subroutine PROFIL is called whenever the *PROFILES option is requested. It is called by the WATER program and uses information contained in the LINK, DIST and Z arrays to determine the length, elevation, order, and magnitude of each reach. The number of profiles requested (NP) and numbers of their starting points (NPROP) are stored in the named COMMON block "OPTION". The call to the subroutine is contained within a DO-LOOP and the starting points are supplied, one at a time, to PROFIL via the argument NTIP.

The routine produces the profile for the longest stream automatically. The vertical scale of all profiles is set to the nearest 10-foot increments above and below the basin's extreme elevations. The horizontal scale is adjusted so that the longest stream is 130 printer lines long. This scale factor is computed in WATER and supplied as argument DY. Thus all profiles for a given analysis will have the same horizontal and vertical scales, but these scales will vary from one analysis to the next. Mileage markers are printed along the profile as are the orders and magnitudes of each reach.

Subroutine ANGLE

Subroutine ANGLE computes the junction angle statistics for the WATER system.

This subroutine is called by subroutine LINKER each time a junction point is located in the link table (LINK array).
The junction angle is then computed from the azimuths of the stream reaches forming the junction. The junction angle is then placed in the proper array (ANGTAB array) according to the orders of the joining streams. For example, a first-order stream flowing into a second-order stream is separated from a first-order stream flowing into a third-order stream or a second-order stream flowing into a third-order stream.

The sum of the angles, the sum of squares of the angles, the number of angles and the maximum and minimum angle are computed for each category. These values are later used by subroutine RITER to compute the mean, range, standard deviation, and variance of the angles in each category.

**Subroutine HIST**

Subroutine HIST is called by subroutine RITER as required to produce histograms of length, gradients, falls, or azimuths of reaches according to either orders or magnitudes. The options specified determine the number of different types of histograms produced.

Histograms are not produced if fewer than 10 reaches belong to a class being analyzed. Each histogram divides the data supplied into 40 evenly spaced classes. A star is printed for each observation encountered opposite the appropriate class. If more than fifty observations fall in any class, 45 stars are printed followed by the number of the observations occurring. Thus scaling of all histograms is taken care of automatically.
Subroutine ZCALC

Subroutine ZCALC is called by the main program to estimate elevation values for points on the stream network as requested by the *HYPSOMETRY card. Subroutine LINKER will have already determined the exact elevation for each point with KODE = 7, using information provided about the elevation of the mouth of the stream and the contour interval of the map. ZCALC works on one segment at a time starting with the highest order segment in the basin. The elevation of the downstream end of the segment is always known (in the first case it is the elevation of the stream mouth), and other points whose elevations were established in LINKER are used to calculate a slope from which unknown elevations along the segment may be assigned. In the special case where no contour line crosses a segment, only the downstream elevation is known. The elevation of the upstream end is then determined from an arbitrary percentage of the maximum difference between the elevation of the downstream end and the elevation of the next contour line.

Descriptions of Program PRERUN Routines

Program PRERUN

Program PRERUN is designed to produce CALCOMP maps from the network data set. PRERUN reads the data in a manner identical to that used in subroutine READIT, and connects the data points for production of a map in a
manner identical to that used in subroutine LINKER for production of the link table. Thus, PRERUN serves the secondary purpose of checking the network data set for errors which would prevent the correct operation of program WATER.

**Subroutine DTR**

Subroutine DTR determines the X and Y coordinates which will be used in each call to CALCOMP subroutines. Different portions of DTR are entered as controlled by the switch IDO, which reflects the #1DSW option for production of maps with data point numbers, Strahler stream orders, or Shreve link magnitudes.

**Calcomp Subroutines**

Unlike the WATER programs, PRERUN requires calls to system library routines, namely CALCOMP. The subroutines which are called include PLOTS, PLOT, FACTOR, SYMBOL, and NUMBER.

**Modifications to the Programs**

The internal calculations performed during the analysis of a drainage basin produce potentially much more information than is presented as output. For example, an individual user may be interested in knowing the numerical value of the stream length ratio or in having the Consistant orders of segments calculated. Such information can be easily
obtained through slight modifications to the computer programs by a competent programmer.

**Increasing the Maximum Number of Points**

Perhaps the most useful modification that a user can make once the WATER System is operational on his computer is to increase the number of points which can be analyzed to as large a figure as possible. This is accomplished by increasing all arrays in program MAIN dimensioned with a 300 to the desired number of points. NSIZ in the DATA statement should also be increased, thus automatically correcting all necessary arrays in the following subroutines. The only changes outside the main program which must be made occur in subroutines LINKER and ZCALC where the arrays JUNC, BEG, EFN, and E, and ISTRIN and ELEV, respectively, must have their size increased. The amount of increase should be proportional to the increase in the number of points. Thus if the number of points is doubled (from 300 to 600) the size of these arrays would increase from 50 to 100.

**CALCOMP Calls**

In most instances another mandatory modification will require changes to the CALCOMP calls in program PRERUN. These calls should be modified by the user to satisfy the requirements of his systems library.
EPilogue

"Descriptive geography, or that which ordinarily passes for the physical geography of the land, lags far behind the present stage of knowledge of land sculpture.... The rational understanding of the features of the land surface can be advanced only by the introduction of some natural system of description of land forms, based on the natural processes of their evolution."

Wm. M. Davis, 1892
REFERENCES CITED


57. Targioni-Tozzetti, G., 1752, Realizzazione d'alcuni viaggi fatti in diverse parti della Toscana, V. 3 (Florence); Translated in Mather, K. F., and S. L. Mason, 1939, A Source Book of Geology, pp. 74-75.


PROGRAM  WATER

C PROGRAM WATER INPUT, OUTPUT, TAPES 1-5 INPUT, TAPE 6 OUTPUT
C ARBE CARDS MUST BE FIRST EXECUTABLE STATEMENT IN MAIN PROGRAM
C ON CDC COMPUTERS.
C
C THE WATER SYSTEM
C COMPUTER PROGRAMS FOR WATERSHED ANALYSIS
C DEVELOPED AT
C UNIVERSITY OF TORONTO  PURDUE UNIVERSITY
C TORONTO, ONTARIO  LAFAYETTE, INDIANA
C
C
C MAIN PROGRAM
C
C PURPOSE --
C TO ANALYZE ANY WATERSHED DEFINED BY DIGITAL DATA, TO CALL
C SYSTEM SUBROUTINES IN THE PROPER SEQUENCE SO AS TO --
C 1) READ OPTION SPECIFICATIONS AND DATA FROM CARDS,
C 2) CONSTRUCT AND HIERARCHICALLY CLASSIFY THE NETWORK
C ACCORDING TO ALL STREAMERS OR SERIES AND
C 3) SIZES MAGNITUDES,
C 3) PRODUCE SUMMARY AND DETAILED STATISTICS FOR EACH
C CLASSIFICATION,
C 4) PRODUCE MAPS OF THE DRAINAGE BASIN ON THE PRINTER,
C 5) COMPUTE AND DISPLAY BASIC PARAMETERS MEASURING ITS
C GEOMETRY,
C 6) PRODUCE LONGITUDINAL PROFILES OF SELECTED STREAMS.
C
C
C REQUIRED SUBROUTINES --
C READIT
C PTER
C LINKR
C CALC
C ANGLF
C
C
C OPTIONAL SUBROUTINES --
C ORDI
C ORO2
C MAPS
C PROFIL
C HIST
C ZCALC
C
C NAMFD COMMON BLOCKS --
C BASIN - BASIN GEOMETRY PARAMETERS DETERMINED IN CALC
C INFO - TITLE, SOURCE, SCALE PLACED IN PAGE HEADINGS
C LIMIT - NECESSARY PRINTER MAP SPECIFICATIONS
C LINKR - VARIABLES USED IN CREATING STREAM REACHES
C OPTION - RECORD OF ALL OPTIONS SPECIFIED
C PLOTS - NECESSARY PRINTER MAP SPECIFICATIONS
C
C
C INTEGER SYsin, SYsot
C DIMENSION NFG(101), ANGTAB(55, 5)
C DIMENSION PUTC(40)
C DIMENSION NKF(301), VIV(301), LIV(301)
C DIMENSION DIST(301), TEMPER(301), TEMPE(301)
C DIMENSION TITL(201), SOURC(201)
C DIMENSION JTAB(5, 3), NPROF(16)
C DIMENSION HNUM(201), HATB(201, 2, 4)
C COMMON /INFO/ TITL, SOURCE, SCALE, ZBASE, CONTOR
C COMMON /BASIN/ AREA, ACRES, PERIM, TODT, JOVS, C, CRAT, BIG, VLEN, A2MAIN, B
C COMMON /HNUM/ HAT, HNUM(2), HATB(201, 2, 4)
C COMMON /EQUIVALENCEN/ (NX, TEMPE), (NY, TEMPE)
C DATA NT1/T1000/,
C DATA SYSIN, SYsot/5,5/,
C INTEGER HNUM
A-2

5 NSTMP=1

C -------------------------------
C READ IN CONTROLS AND DATA
C NSTMP=2 MEANS ERRORS ENCOUNTERED AND JOB IS
C TO BE ABORTED.
C -------------------------------

CALL READIT (NSTMP,YSIZ,X,Y,Z,LINK,TEMPI,TEMP2,DIST,LINE)
GO TO 10,120, NSTMP

C ---------------------------------
C PRINT INPUT DATA
C ---------------------------------

10 CALL RITER (2,NSIZ,X,Y,Z,LINK,DIST,TEMPI,TEMP2,LINE)

C ---------------------------------
C COMPUTE REACHES AND BASIC RASIN STATISTICS
C ---------------------------------

CALL LINTER (NSIZ,LINK,X,Y)
CALL CALC (1,NSIZ,X,Y,Z,LINK,DIST,SCALE)
IF (IFMTW,FO,2) CALL ZCALC (NSIZ,2,LINK,DIST)

C ---------------------------------
C PRINT TABLE OF REACHES
C ---------------------------------

CALL RITER (3,NSIZ,X,Y,Z,LINK,DIST,TEMPI,TEMP2,LINE)

C ---------------------------------
C PUNCH ORDERED REACHES FOR CALCOMP MAP IF REQUESTED
C ---------------------------------

IF (TOUNW,ED,1,.OR.TPUSW,ED,.31) CALL RITER (11,NSIZ,X,Y,Z,LINK,DIST
1,TEMPI,TEMP2,LINE)

C ---------------------------------
C IF SWL1, STRAHLER ORDER STATISTICS REQUESTED
C ---------------------------------

IF (ISWL1,.NE.1) GO TO 20

C ---------------------------------
C COMPUTE AND PRINT BASIC STATISTICS
C ---------------------------------

CALL RITER (1,NSIZ,X,Y,Z,LINK,DIST,TEMPI,TEMP2,LINE)
CALL PR01 (NSIZ,X,Y,Z,LINK,DIST,TEMPI,TEMP2,LINE)

C ---------------------------------
C PRINT JUNCTION ANGLE TABLE IF REQUESTED
C ---------------------------------

IF (TANGSW,ED,.1) CALL RITER (5,NSIZ,X,Y,Z,LINK,DIST,TEMPI,TEMP2,LINE)

C ---------------------------------
C PRINT OPTIONAL LENGTHS, FALLS, GRADIENTS AND AZIMUTHS
C ---------------------------------

IF (TISW,ED,.1) CALL RITER (6,NSIZ,X,Y,Z,LINK,DIST,TEMPI,TEMP2,LINE)
IF (TIPW,LT,.1) GO TO 15
IF (TISW,ED,.1) CALL RITER (7,NSIZ,X,Y,Z,LINK,DIST,TEMPI,TEMP2,LINE)
IF (TISW,ED,.1) CALL RITER (8,NSIZ,X,Y,Z,LINK,DIST,TEMPI,TEMP2,LINE)
IF (TISW,ED,.1) CALL RITER (9,NSIZ,X,Y,Z,LINK,DIST,TEMPI,TEMP2,LINE)

15 IF (TISW,ED,.1) CALL RITER (10,NSIZ,X,Y,Z,LINK,DIST,TEMPI,TEMP2,LINE)

C ---------------------------------
C MSW=1, MAPS DESIRED
C ---------------------------------

IF (MSW,.NE.1) GO TO 50
COMPUTE MAP SCALE (RATIO) AND BASIC PARAMETERS

RATIO = (SCALE * (XMAX - XMIN))/WIDTH
     = (SCALE * (YMAX - YMIN))/HEIGHT

WDX = (XMAX - XMIN)/WIDTH
WDY = (YMAX - YMIN)/HEIGHT

COMPUTE PRINT CHARACTER COORDINATES FOR ALL DATA POINTS

KMAP = 1
DO 25 J = 1,NTOT
     X(J) = (X(J) - XMIN)/WDX + .5
     Y(J) = (Y(J) - YMIN)/WDY + .5
IF (ISW1 .NE. 1) GO TO 50
25 CONTINUE

PREPARE LINE TABLE CONTAINING LINE NOS OF VX, NY DATA IN ORDER OF INCREASING NY

CONTINUE
IF (ISW.VF,.NE. 1) GO TO 40

PRINT MAP OF ORDERS OR MAGNITUDES ACCORDING TO KMAP SPECIFICATIONS

CALL RITER (1,NSIZ,6,F,Z,LINK,DIST,TEMP1,TEMP2,LINE)
CALL MAP (KMAP,NSIZ,LINK,NX,NY,LINE,TATT)
IF (KMAP.EQ.2) GO TO 55

PRINT BASIC MAGNITUDE STATISTICS

CALL RITER (1,NSIZ,K,Y,Z,LINK,DIST,TEMP1,TEMP2,LINE)
CALL RRO2 (NSIZ,Z,LINK,DIST,TEMP1,TEMP2)

PUNCH MAGNITUDES OF REACHES FOR CALCINDEX MAP IF REQUESTED

IF (ISW.S,GE.2) CALL RITER (1,NSIZ,K,Y,Z,LINK,DIST,TEMP1,TEMP2,LINE)

PRINT OPTIONAL LENGTHS, FALLS, AND GRADIENTS

A 312
A 314
A 316
A 318
A 324
A 326
A 328
A 330
A 332
A 334
A 336
A 338
A 340
A 342
A 344
A 346
A 348
A 350
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A 458
IF (TIPSW,LT,10) GO TO 30
IF (TIPSW,EQ,5) CALL RITER (11,NSIZ,X,Y,Z,LINK,DIST,TEMP1,TEMP2,TEMP3,TEMP4,TIPSW)
IF (STW,EQ,3) CALL RITER (12,NSIZ,X,Y,Z,LINK,DIST,TEMP1,TEMP2,TEMP3,TEMP4,TIPSW)
IF (STW,EQ,1) CALL RITER (13,NSIZ,X,Y,Z,LINK,DIST,TEMP1,TEMP2,TEMP3,TEMP4,TIPSW)

CHECK IF WARP REQUIRED.
IF IT IS, OFFSCREEN.

IF (FSW .NE. 1) GO TO 65

COMPLETE GASL RESULTS CALCULATIONS

CALL CALC (7,NSIZ,X,Y,Z,LINK,DIST,SCALE)

PRINT TABLE OF GASL RESULTS

CALL RITER (14,NSIZ,X,Y,Z,LINK,DIST,TEMP1,TEMP2,TEMP3,TEMP4,TIPSW)

PRINT PROFILES IF REQUESTED

IF (IPSW .NE. 1 .OR. NIPSW .NE. 11) GO TO 105

SEARCH NPROF TABLE FOR DUPLICATES

DO 10 = 1,NP
IF (INPROF(11,EQ,NPROF(I))) GO TO 75
CONTINUE
GO TO 10

DO 90 = 1,NP
NIP = NIP + 1
IF (INPROF(I1,GT,NP)) NPROF(NP) = 1
CONTINUE

COMPUTE THE PLOT PARAMETERS

ZMAX = 0
ZMIN = 1
DO 95 = 1,NTOT
IF (Z(I1) .LT. ZMAX) ZMAX = Z(I1)
IF (Z(I1) .LT. ZMIN) ZMIN = Z(I1)
CONTINUE
ZMAX = ZMAX/10.
ZMIN = ZMIN/10.

DO 100 = 1,NIP
CALL RITER (11,NSIZ,X,Y,Z,LINK,DIST,TEMP1,TEMP2,TEMP3,TEMP4)
CONTINUE

ADDIITINAL OPTIONS GO HERE

GO TO 5
SUBROUTINE READIT

C ** THE WATER SYSTEM **

C COMPUTER PROGRAMS FOR WATERSHED ANALYSIS
C DEVELOPED AT
C UNIVERSITY OF TORONTO  PURDUE UNIVERSITY
C TORONTO, ONTARIO  LAFAYETTE, INDIANA

C

SUBROUTINE READIT

C PURPOSE --
C TO READ IN DATA AND DESIRED OPTION SPECIFICATIONS

C USAGE --
C CALL SUBROUTINE READIT (NSIZE, NSZ, X, Y, Z, LINK)
C WHERE NSTOP = INTEGER VARIABLE USED TO DETERMINE PROGRAM STATUS
C NSTOP = 1, NO ERRORS ENCOUNTERED, CONTINUE
C EXECUTION
C NSTOP = 2, ERRORS ENCOUNTERED, STOP EXECUTION
C NSIZE = MAXIMUM NUMBER OF POINTS ALLOWED TO BE READ IN
C MAY BE SET TO AS MANY AS IS DESIRED BY THE USER
C X = ARRAY OF X COORDINATE POINTS
C Y = ARRAY OF Y COORDINATE POINTS
C Z = ARRAY OF Z COORDINATE POINTS
C LINK = ARRAY USED TO RETAIN THE POSITION, ORDER, AND
C MAGNITUDE OF EACH REACH (LINKI,4) TEMPORARILY
C USED TO STORE POINT CODES

C REQUIRED SUBROUTINES --
C NONE

C OPTIONAL SUBROUTINES --
C NONE

C NAMED COMMON BLOCKS USED --
C INFO - TITLE, SOURCE, SCALE PLACED IN PAGE HEADINGS
C LIMIT - NECESSARY PRINTER MAP SPECIFICATIONS
C LINK - VARIABLES USED IN CREATING STREAM REACHES
C OPTION - RECORD OF ALL OPTIONS SPECIFIED
C PLOTS - NECESSARY PRINTER MAP SPECIFICATIONS

SUBROUTINE READIT (NSIZE, X, Y, Z, LINK)

DIMENSION NSEG(101), ANGTAB(55, 5)
DIMENSION JTAB(5,3), NPROP(16)
DIMENSION XX(51), YY(51), ZZ(51), KVAL(5)
DIMENSION TITL(120), SOURCE(120), SUBT(120), FORM(18), ATITL(20), ASOUR(20)
DIMENSION NAM(5, 15), NNAME(15), NTEMP(15)
DIMENSION TEMP(NSIZE), NSIZE(2, DIST(NSIZE)), LINE(NSIZE)
DIMENSION HRNUN(20), HFA(20, 2, 4)
DIMENSION CPA(5, 2)
DIMENSION XN(SIZE), YN(SIZE), Z(SIZE), LINK(SIZE, 4)
DIMENSION INPUT(5)
DIMENSION IPCA(5), IP(5)
INTEGER SYSIN, SYSDOT
INTEGER GERR, CPA, CP
DATA SYSIN, SYSDOT / 0, 0 /
DATA X, Y, Z, LINK / 0, 0, 0, 0 /
COMMON / INFO / TITLE, SOURCE, SCALE, EBASE, CONTOR
COMMON / LNK / LDT, HDT, WSEG, NLNK, ANG, NORDER, MOUTH, MAGMAX, NUMSEG
COMMON / ANGTAB, NPROP, JTAB, NPROP /
COMMON / HTAB, FUA /
COMMON / NAM, NAME, NTEMP /
COMMON / TITL, SOURCE, SCALE, EBASE, CONTOR /
COMMON / LNK / LDT, HDT, WSEG, NLNK, ANG, NORDER, MOUTH, MAGMAX, NUMSEG
COMMON / ANGTAB, NPROP, JTAB, NPROP /
COMMON / HTAB, FUA /
COMMON / NAM, NAME, NTEMP /
COMMON / TITL, SOURCE, SCALE, EBASE, CONTOR /
COMMON / LNK / LDT, HDT, WSEG, NLNK, ANG, NORDER, MOUTH, MAGMAX, NUMSEG
COMMON / ANGTAB, NPROP, JTAB, NPROP /
COMMON / HTAB, FUA /
COMMON / NAM, NAME, NTEMP /
COMMON / TITL, SOURCE, SCALE, EBASE, CONTOR /
COMMON / LNK / LDT, HDT, WSEG, NLNK, ANG, NORDER, MOUTH, MAGMAX, NUMSEG
COMMON / ANGTAB, NPROP, JTAB, NPROP /
COMMON / HTAB, FUA /
COMMON / NAM, NAME, NTEMP /
COMMON / TITL, SOURCE, SCALE, EBASE, CONTOR /
COMMON / LNK / LDT, HDT, WSEG, NLNK, ANG, NORDER, MOUTH, MAGMAX, NUMSEG
COMMON / ANGTAB, NPROP, JTAB, NPROP /
COMMON / HTAB, FUA /
COMMON / NAM, NAME, NTEMP /
COMMON / TITL, SOURCE, SCALE, EBASE, CONTOR /
READ AND IDENTIFY OPTIONS

K=0
READ (SYSIN, 315) (NAME(I), I=1,3), (NTEMP(I), I=1,15)
GO TO 10 K=1,18

IF (NAME(1), K), EQ., NAME(1), AND, NAME(2), K), EQ., NAME(2), AND, NAME(3), K), EQ.
1. NAME(3)) GO TO 15
CONTINUE

ERROR IN OPTION CARD.

WRITE (SYSOT, 3451) (NAME(I), I=1,31)
NSTOP=2
GO TO 300

GO TO CORRECT SECTION

150, 2651 + K)

WATER CARD FOUND

NP=1
N>0
NJ=0
ISMI=0
ISM2=0
MSW=0
IPSW=0
JSS=0
IC5=0
IANGS=0
IAS=0
IFSW=0
ILSW=0
IGSW=0
IMHSW=0
IPHSV=0
IPUSW=0
GO 22 II=1,20

WRITE (SYSOT, 3351)
GO TO 270

STRAHLER CARD FOUND

MAGNITUDE CARD FOUND

NETWORKS CARD FOUND

NSW=1
READ (SYSIN, 320) WIDTH, XMAX, XMIN, YMAX, YMIN, TOL
GO TO 270
C
C *PROFILES CARD FOUND
C
C 40 DO 45 I=1,15
C 41 I5W = 1
C 42 IF (NTEMP(I).LT.1) GO TO 270
C 43 NP=NP+1
C 44 NPROF(NP)+NTEMP(I)
C 45 GO TO 270
C
C *DATA CARD FOUND
C
C 50 READ (SYSIN,325) I5W
C 51 READ (SYSIN,325) SOURCE
C 52 READ (SYSIN,320) SCALE,ANG,KORG,YORG
C 53 READ (SYSIN,330) NPTS,FORM
C 54 NUM=N
C
C READ IN DATA
C IF *HYPSOMETRY CARD PREVIOUSLY ENCOUNTERED
C Z-DATA EXPECTED, OTHERWISE NO Z-DATA READ
C
C 60 IMP=1MPSW=1
C 61 GO TO (55,70), IMP
C 62 DO 65 K=1,5
C 63 Z(K) = 0.0
C 64 READ (SYSIN,FORM) (XX(K),YY(K),KVAL(K),K=1,NPTS)
C 65 GO TO 75
C
C 70 READ (SYSIN,FORM) (XX(K),YY(K),KVAL(K),ZL(K),K=1,NPTS)
C 75 IF (KVAL(K).NE.5 .AND. NUM.EQ.0) GO TO 295
C 76 NUM=1
C 77 DO 85 K=1,NPTS
C 78 IF (KVAL(K).EQ.6) GO TO 90
C 79 N=N+1
C
C FOLLOWING LINE CHECKS IF MOUTH HAS BEEN RECORDED
C TWICE DURING DATA COLLECTION
C
C 80 N=N-1
C 81 CONTINUE
C 82 GO TO (65,70), IMP
C
C 90 NTOT=N
C 91 GO TO 270
C
C *JUNCTION CARD FOUND
C
C IJSW = 1 ONLY IF VALID POINTS FOUND
C NJ = NUMBER OF VALID JUNCTION REQUESTS
C MAXIMUM NUMBER = 5
C
C 95 JT=1
C 100 DO 105 JJ=1,5
C 101 IF (NTEMP(JT).LT.1) GO TO 270
C 102 IJSW=1
C 103 NJ=NJ+1
C 104 IF (NJ.GT.NJ) GO TO 270
C 105 JTAB(JJ,1)=NTEMP(JT)
C 106 JTAB(JJ,2)=JTAB(JJ,2)+1
C 107 JTAB(JJ,3)=JTAB(JJ,3)+1
C 108 JTAB(JJ,4)=JTAB(JJ,4)+1
C 109 JTAB(JJ,5)=JTAB(JJ,5)+1
C 110 CONTINUE
C 111 GO TO 270
C ----------------------------------
C *CONNECT CARD FOUND
C IF [NTEMP2] IS NOT ZERO SET ICW=2 SO BOUNDARY
C REACHES WILL NOT BE DELETED
C ----------------------------------
C 105 ICW=1
C IF [NTEMP2]=GE.1 ICW=2
C KT=KT+1
J=0
C READ (SYSIN,325) ATITL
C READ (SYSIN,325) ASDUR
C READ (SYSIN,320) SCALE,ANGX,XORGX,YORGX
C READ (SYSIN,330) NPTS,FORM
C IF (KT,GT=5) GO TO 165
C CPA(KT,1)=NTEMP1
C CP=CPA(KT,1)
C IF (KT,GT=5) GO TO 110
C GO TO 120
C ----------------------------------
C CONNECT POINT IS CALCULATED AS THE ORIGINAL POINT PLUS ANY
C DISPLACEMENT CAUSED BY PREVIOUS CONNECT OPTIONS, IF ANY
C HAVE OCCURRED BEFORE THIS POINT
C ----------------------------------
C 110 KT=KT+1
C DO 115 I=1,KTM
C IF (CPA(KT,11),GT=CPA(I,11)) CP=CP+CPA(I,2)
C CONTINUE
C 120 IF (LINE(CP,61),GT=2) GO TO 180
C CPA(KT)=CP
C CPA(KT)=CP
C ----------------------------------
C READ OUT ALL AFFECTED POINTS
C ----------------------------------
C DO 125 K=CP,KTOT
C TEMPI(K)=X(K)
C TEMPI(K)=Y(K)
C DISTI(K)=2(K)
C LINEK=LINEK+1
C 125 CONTINUE
N=CP-1
C ----------------------------------
C TRANSLATE CONNECT DATA INTO MAIN BASIN COORDINATES
C ----------------------------------
C DO TO 130,1451.1 MPH
C 130 GO TO 135, K=15
C 135 IQ(K)=Q
C 140 READ (SYSIN,FORM) (XX(K),YY(K),KVAL(K),K=1,NPTS)
C GO TO 150
C 145 READ (SYSIN,FORM) (XX(K),YY(K),KVAL(K),Z2(K),K=1,NPTS)
C 150 IF (KVAL(I),GE.5,ANP),NUM.EQ.0) GO TO 295
C IF (J+GT=0) GO TO 125
C YORG=XX(I)
C YORG=-YY(I)
C THETA=-ANG
C THETA=THETA/ST,2957
C 155 DO 165 K=1,NPTS
C IF (KVAL(K),EQ,6) GO TO 170
C N=N+1
C X(N)=(XX(K)-XORGX)*COS(THETA)+YY(K)-YORGX)*SIN(THETA)
C Y(N)=(YY(K)-YORGX)*COS(THETA)+(XX(K)-XORGX)*SIN(THETA)
C Y(N)=Y(N)+TEMPI(CP)
C Y(N)=Y(N)+TEMPI(CP)
C Z(N)=Z(I)
C IF (J,NE.0) GO TO 160
C IF (LINE(CP,61),GT=2) GO TO 180
C LINK(N,4)=LINE(CP)+1
C J=J+1
C GO TO 165
C 160 J=J+1
C LINK(N+4)=KVAL(K)
C IF (LINK(N+4),EQ,4) GO TO 156
C GO TO 165
C ----------------------------------
A-10

C *GRADIENTS CARD FOUND

C

C 245 IGSW=1
GO TO 270

C

C *HISTOGRAM CARD FOUND

C

C

C 250 IHMSW=1
GO TO 270

C

C *HYPSOMETRY CARD FOUND

C

C

C 255 IHPSW=1
IF INTEMP(11).LT.10 GO TO 260
IHPSW=2
HIGH=INTEMP(11)
ZBASE=INTEMP(2)
CONTR=INTEMP(13)
GO TO 270

C

C *PUNCH CARD FOUND

C

C

C 260 IPUSW=INTEMP(6)
DO 375 I=1,5
IPUTA(11)=INTEMP(11)

C

C WRITE OUT OPTION CARD

C

C

C 265 WRITE (SYSOT,340) (NAME(I),I=1,3),(INTEMP(11),I=1,15)

C

C UPDATE JTAB AND NPROF TABLE VALUES TO
ACCOUNT FOR ALL POINTS ADDED BY CONNECT

C

C IF (JNUM.LT.7,KR,JNUM,GT.81) GO TO 290
IF (K1,LT.1) GO TO 5
IF (KN,LT.1) GO TO 280
IF (CURR,LE.11) GO TO 290
DO 275 J=1,NJ
DO 275 1=1,KT
IF (JTAB(J,1),GT,ICPA(11)) JTAB(J,1)=JTAB(J,1)+ICPA(11)
CONTINUE

C

C WRITE (SYSOT,350)

C NSTP=2

C RETURN

C

C 300 FORMAT (18,4H56**ERROR** NUMBER OF CONNECTIONS GREATER THAN 51

C 305 FORMAT (18,4H56**ERROR** INVALID CONNECTION POINT: SUBASIN CONNECT

C

C 310 FORMAT (18,6H56**ERROR** INVALID CONNECTION POINT: OUTSKIRTING MATCH

C

C 315 FORMAT (18,12X,8A4)

C 320 FORMAT (18,12X,4H16**ERROR** OPTIONS REQUESTED ARE.../)

C 325 FORMAT (18,12X,4H16**ERROR** UNRECOGNIZABLE OPTION NAME.../)

C 330 FORMAT (18,12X,4H16**ERROR** FIRST DATA POINT IS NOT CODED AS THE

C 335 FORMAT (18,12X,4H16**ERROR** 1 STREAM BASIN OR SUBNETWORK MOUTH)

C 340 FORMAT (18,12X,4H16**ERROR** 1 STREAM BASIN OR SUBNETWORK MOUTH)

C 345 FORMAT (18,12X,4H16**ERROR** 1 STREAM BASIN OR SUBNETWORK MOUTH)

C 350 FORMAT (18,12X,4H16**ERROR** 1 STREAM BASIN OR SUBNETWORK MOUTH)

C 986
C 988
C 989
C 990
C 902
C 903
C 904
C 905
C 906
C 907
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C 974
C 975
C 976
C 977
C 978
SUBROUTINE RITER

C-------------------------
C THE WATER SYSTEM
C
C COMPUTER PROGRAMS FOR WATERSHED ANALYSIS
C DEVELOPED AT
C UNIVERSITY OF TORONTO - PURDUE UNIVERSITY
C TORONTO, ONTARIO - LAFAYETTE, INDIANA
C
C-------------------------
C
SUBROUTINE RITER

C PURPOSE --
C TO PRODUCE MANY OF THE OUTPUT STATISTICS TABLES

C-------------------------
C USAGE --
C CALL SUBROUTINE RITER (KOUNT,NSIZ,X,Y,Z,LINK,DIST,TEMPL,TEMP2)
WHERE KOUNT = INTEGER VARIABLE WHICH DIRECTS PROPER ENTRY INTO
THE APPROPRIATE SECTION OF THE SUBROUTINE
NSIZ = MAXIMUM NUMBER OF POINTS ALLOWED TO BE READ IN
MAY BE SET TO AS MANY AS IS DESIRED, BY THE USER
X = ARRAY OF X COORDINATE POINTS
Y = ARRAY OF Y COORDINATE POINTS
Z = ARRAY OF Z COORDINATE POINTS
LINK = ARRAY USED TO RETAIN THE POSITION AND ORDER OF
EACH REACH
DIST = ARRAY CONTAINING THE LENGTH OF EACH REACH
TEMPL = TEMPORARY ARRAY CONTAINING THE LENGTH OF EACH
SEGMENT AND LATER EACH LINK (SHREVE MAGNITUDE)
TEMP2 = TEMPORARY ARRAY CONTAINING THE FALL OF EACH
SEGMENT AND LATER EACH LINK (SHREVE MAGNITUDE)

C-------------------------
C
C REQUIRED SUBROUTINES --
C READIT
C LINKER
C CALC
C
C OPTIONAL SUBROUTINES --
C GROI
C GPO2
C
C NAMED COMMON BLOCKS USED --
C BASIN LINKER
C INFO OPTION
C
C-------------------------
C
SUBROUTINE RITER (KOUNT,NSIZ,X,Y,Z,LINK,DIST,TEMPL,TEMP2,LINL)
INTEGER SYN,SYST,SYSPU
DIMENSION IPUTAB(51), NAME(3,6)
DIMENSION TITL(20), SOURCE(20)
DIMENSION XINSIZ, YINSIZ, ZINSIZ
DIMENSION LINKNSIZ, DISTNSIZ
DIMENSION HOLD321, THOLD321
DIMENSION LINL(NSIZ)
DIMENSION TEMPLINSIZ, TEMPP2INSIZ
DIMENSION NSEG(3), ANGTAB(55,51)
DIMENSION HNUM(20), HTAB(20,2,4)
DIMENSION NPROF(6), PR(6)
DIMENSION NAME4H, LEN, HLYTH, 1H, 4H, FA, 4HLS, 1H1, 4HGRAO, 4HMINTL, 1H1, 4HMAG, 4HMINTL, 1H1,
DATA SYSIN, SYST, SYSPU, 5, 6, 7
DATA NAME, BASIN, AREA, ACRES, PERIM, TOTD, DEVS, C, CRAT, BIG, VLEN, A2, MAINB
DATA WANDR, LEN, USF, NZC, ELONG, WFS, FC1, FT, T, CARE, H, R, H, H, H,
DATA INFOD, TITL, SOURC, SCALE, ZBASE, CONTOR
DATA VLINK, LIT, NIT, NPseg, NLEN, LANCE, ANG, ORDER, MOUTH, MAGMAX, NUMSEG,
DATA HNUM, ANGTAB, HNUM, HTAB, IPUTAB
COMMON /COMMON1/ ISW, ISW2, MSW, IPSW, IPSW1, IPSW2, IPSW3, IPSW4, ILS
COMMON /COMMON2/ HPSW, VPROF, NP, NJ, JTAB, IPUSW
COMMON /INFO/ HNUM
INTEGER HNUM
WRITE PAGE HEADINGS AND TITLES

GO TO CORRECT PORTION OF RITER

GO TO (285, 10, 30, 30, 40, 120, 130, 140, 165, 260, 265, 270, 275, 280), KOUNT

RITER 2
DISPLAY INPUT DATA TABLE
NSW=2, EVEN NUMBER OF POINTS, TABLE STOPS TOGETHER
NSW=2, ADD NUMBER OF POINTS, LEFT HALF OF TABLE IS 1 LINE LONGER

CONTINUE
GO TO (25, 20), NSW
20 N=NN+1
WRITE (SYSOT, 320) N, X(N), Y(N), LINK(N+4), Z(N), NP1, (NPI1), Y(NPI1)
GO TO 285

WRITE (SYSOT, 325)
GO TO 285

RITER 3
DISPLAY TABLE OF REACHES

CONTINUE
GO TO (45, 40), NSW
40 N=NN+1
WRITE (SYSOT, 345) (LINK(N), M=1, 3), DIST(N), GRA01, (LINK(N), M)
GO TO 285

WRITE (SYSOT, 350)
GO TO 285

RITER 4
DISPLAY CALCULATED BASIN STATISTICS

WRITE (SYSOT, 360)
WHILE (SYSOUT,400) NJRD
WRITE (SYSOUT,390)
WRITE (SYSOUT,410) NUMSEG
WRITE (SYSOUT,390)
55 IF (ISW2,NE,1) GO TO 60
WRITE (SYSOUT,405) MAXMAG
WRITE (SYSOUT,390)
WRITE (SYSOUT,415) NUMHAG
WRITE (SYSOUT,390)
WRITE (SYSOUT,420) T3TD
WRITE (SYSOUT,395)
WRITE (SYSOUT,390)
WRITE (SYSOUT,360)
WRITE (SYSOUT,365)
WRITE (SYSOUT,385)
WRITE (SYSOUT,425) BIG
WRITE (SYSOUT,390)
WRITE (SYSOUT,430) VLEN
WRITE (SYSOUT,390)
WRITE (SYSOUT,435) WANDR
WRITE (SYSOUT,390)
WRITE (SYSOUT,440) AZMAIN

C ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
C DELETE ALL PARAMETERS USING AREA AND PERIMETER CALCULATIONS
C IF BOUNDARY POINTS ARE NOT SPECIFIED
C
C IF (NSEG,.EQ.0) GO TO 85
WRITE (SYSOUT,390)
WRITE (SYSOUT,445) PERIM
WRITE (SYSOUT,390)
WRITE (SYSOUT,450) LBLN
WRITE (SYSOUT,390)
WRITE (SYSOUT,455) B&Z
IF (ISW1,NE,1) GO TO 65
WRITE (SYSOUT,390)
WRITE (SYSOUT,480) T
IF (ISW2,NE,1) GO TO 70
WRITE (SYSOUT,390)
WRITE (SYSOUT,490) TT
70 WRITE (SYSOUT,390)
WRITE (SYSOUT,380)
WRITE (SYSOUT,360)
WRITE (SYSOUT,370)
WRITE (SYSOUT,385)
WRITE (SYSOUT,460) AREA+ACRES
WRITE (SYSOUT,390)
WRITE (SYSOUT,465) DENS
WRITE (SYSOUT,390)
WRITE (SYSOUT,470) C
WRITE (SYSOUT,390)
IF (ISW1,NE,1) GO TO 75
WRITE (SYSOUT,475) FC
WRITE (SYSOUT,390)
IF (ISW2,NE,1) GO TO 80
WRITE (SYSOUT,485) FL
WRITE (SYSOUT,390)
80 WRITE (SYSOUT,495) CAREA
WRITE (SYSOUT,390)
WRITE (SYSOUT,500) DCIRC
WRITE (SYSOUT,390)
WRITE (SYSOUT,505) CRAT
WRITE (SYSOUT,390)
WRITE (SYSOUT,510) ELONG
WRITE (SYSOUT,390)
WRITE (SYSOUT,515) WSF
WRITE (SYSOUT,390)
WRITE (SYSOUT,520) USF
WRITE (SYSOUT,390)

C ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
C PRINT RELIEF PARAMETERS
C SKIP IF NO Z DATA
C
C IF (HPSW,LT,1) GO TO 285
WRITE (SYSOUT,380)
WRITE (SYSOUT,360)
WRITE (SYSOUT,375)

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F 468
F 470
F 472
F 474
F 476
F 478
F 480
WRITE (SYSOT,385)
WRITE (SYSOT,525) REL
WRITE (SYSOT,300)
WRITE (SYSOT,530) HR
WRITE (SYSOT,300)
WRITE (SYSOT,535) H4
85 WRITE (SYSOT,395)
GO TO 285
c
-----------------------------------------------
c
C RITER 5
C WRITE OUT ANGLE TABLE
C -----------------------------------------------
c
90 KTR=0
NSTOP=6
JAB=1
KX=0
NL=0
DO 95 I=1,6

95 PRF(I)=0.0
IF (NORD(I),6) NSTOP=NORD
WRITE (SYSOT,540)
WRITE (SYSOT,545)
DO 115 KT=1,NSTOP
DO IF4 I=1,KT
IF (KT,500,1) GO TO 106
JAB=JAB+1
IF (FANGTAB(JAB,3),GE,1.0) GO TO 106
CONTINUE
106 CONTINUE
107 KX=KX+KT
NL=NL+KT
GO TO 115
106 DO 100 KX=1,KT
KX=X+1
IF (FANGTAB(KX,3),LT,1.0) GO TO 102
PRF(KX)=ANGTAB(KX,5)-ANGTAB(KX,6)
ANGTAB(KX,1)=ANGTAB(KX,1)/ANGTAB(KX,3)
IF (FANGTAB(KX,3),LT,5.0) GO TO 102
WRITE (SYSOT,700) KT,KX,ANGTAB(KX,1),ANGTAB(KX,3),ANGTAB(KX,5),
1 ANGTAB(KX,4),PRF(KX)
1 ANGTAB(KX,1)=ANGTAB(KX,1)/ANGTAB(KX,3)
1 ANGTAB(KX,5)=SORT(ANGTAB(KX,4))
WRITE (SYSOT,700) ANGTAB(KX,1),ANGTAB(KX,3),ANGTAB(KX,5),
1 ANGTAB(KX,4),PRF(KX)
102 CONTINUE
GO TO 102
101 WRITE (SYSOT,702) KT,KX,ANGTAB(KX,1),ANGTAB(KX,3),ANGTAB(KX,5),
1 ANGTAB(KX,4),PRF(KX)
102 CONTINUE
NL=NL+1
GO TO (103,100,100,100,103,100,100,100,100,103,100,100,100,103)
1 .100,100,100,100,100,100,100,100,103),NL
103 WRITE (SYSOT,545)
100 CONTINUE
GO TO 285
c
-----------------------------------------------
c
C RITER 6
C DISPLAY LENGTHS OF ORDERED SEGMENTS
C -----------------------------------------------
c
120 WRITE (SYSOT,585)
ISTP=ORDER
125 KTYPE=COUNT
GO TO 155
c
-----------------------------------------------
c
C RITER 7
C DISPLAY FALLS OF ORDERED SEGMENTS
C -----------------------------------------------
c
130 WRITE (SYSOT,590)
ISTP=ORDER
135 KTYPE=COUNT
GO TO 175
c
C RITER 8
C DISPLAY GRADIENTS OF ORDERED SEGMENTS
C
C 140 WRITE (SYSOT,595)
C ISP=NORDER
145 KTYPE=KOUNT
DO 150 IM=1,NUMSEG
150 TEMP11=TEMP21/TEMP11
155 KBEG=1
KEND=0
IPUTYP=IPUTYP-5
IF (KTYPE,GT,9) IPUTYP=IPUTYP-4
IF (IPUTAB(IPUTYP+1),NE,1) GO TO 146
WRITE (SYSOT,550) (TITL(I),I=1,163),(NAME(I),IPUTYP,I=1,3)
146 DO 160 IM=2,ISP
150 IM=1-1
IF (HHNUM(IM),LT,1) GO TO 160
KEND=KEND+HHNUM(IM)
WRITE (SYSOT,605) IM
WRITE (SYSOT,610) (TEMP1(K),K=KBEG,KEND)
WRITE (SYSOT,615)
IF (IPUTAB(IPUTYP+1),NE,1) GO TO 156
IPKOD=6
MK=IPUTAB(IM)
GO TO (158,159,157), MK
157 IF (KTYPE,GT,9) GO TO 159
GO TO 156
159 IPKOD=6
158 WRITE (SYSOT,555) HHNUM(IM), (NAME(I),IPKOD,I=1,3), IM
WRITE (SYSOT,560) (TEMP1(K),K=KBEG,KEND)
156 KBEG=KBEG+HHNUM(IM)
160 CONTINUE
GO TO 185

C RITER 9
C DISPLAY AZIMUTHS OF ORDERED SEGMENTS
C
C 165 WRITE (SYSOT,600)
C ISP=NORDER
KTYPE=KOUNT
DO 170 IM=1,NUMSEG
170 TEMP21=FLOAT(LINE11)/1000.
175 KBEG=1
KEND=0
IPUTYP=IPUTYP-5
IF (KTYPE,GT,9) IPUTYP=IPUTYP-4
IF (IPUTAB(IPUTYP+1),NE,1) GO TO 166
WRITE (SYSOT,550) (TITL(I),I=1,163),(NAME(I),IPUTYP,I=1,3)
166 DO 170 IM=2,ISP
170 IM=1-1
IF (HHNUM(IM),LT,1) GO TO 180
KEND=KEND+HHNUM(IM)
WRITE (SYSOT,605) IM
WRITE (SYSOT,610) (TEMP21(K),K=KBEG,KEND)
WRITE (SYSOT,615)
IF (IPUTAB(IPUTYP+1),NE,1) GO TO 176
IPKOD=5
MK=IPUTAB(IM)
GO TO (176,179,177), MK
177 IF (KTYPE,GT,9) GO TO 179
GO TO 176
179 IPKOD=6
178 WRITE (SYSOT,555) HHNUM(IM), (NAME(I),IPKOD,I=1,3), IM
WRITE (SYSOT,560) (TEMP21(K),K=KBEG,KEND)
176 KBEG=KBEG+HHNUM(IM)
180 CONTINUE
C PRODUCE HISTOGRAMS IF REQUESTED
C KTYPE DEFINES TYPE OF HISTOGRAM DATA.
C
C 185 IF (IHMWS,NE,1) GO TO 285
JBEG=1
JEND=0
DO 255 IM=1,20
255 255
C DECREASE IF ORDERS OR MAGNITUDES
C CONVERT KTYPE TO RANGE 1 TO 4
C JOE=1 FOR ORDERS, JOE=2 FOR MAGNITUDES
C
C IF (KTYPE.GT.9) GO TO 195
IF (KTYPE.LE.4) GO TO 200
KTYPE=KTYPE-5
JDE=1
GO TO 20C
C 195
KTYPE=KTYPE-9
JDE=2
200 XMAX=HTABLE(1,KTYPE)
XMIN=HTABLE(2,KTYPE)
NUM=NUM+1
JEND=JEND+1
C C SKIP HISTOGRAM IF TOO FEW POINTS
C OTHERWISE SELECT CORRECT DATA AND PLACE IN H ARRAY
C
C IF (NUM.LT.15) GO TO 240
WRITE (SYSOT,300)
WRITE (SYSOT,305) TITLE, SOURCE, SCALE
ID=1
GO TO (205,215,205,215,1, KTYPE
205 GO TO (235,230,1, JOE
230 KTYPE=KTYPE+4
235 CALL HIST (KTYPE, XMAX, XMIN, TEMP1, JBEG, JEND, NSIZ, IO)
GO TO 255
215 GO TO (236,234,1, JOE
234 KTYPE=KTYPE+9
236 CALL HIST (KTYPE, XMAX, XMIN, TEMP2, JBEG, JEND, NSIZ, IO)
GO TO 255
240 GO TO (245,250), JOE
245 WRITE (SYSOT,295) 1
GO TO 285
C 250 WRITE (SYSOT,290) 1
255 JBEG=JBEG+NUM
GO TO 285
C C RITER 10
C DISPLAY LENGTHS OF SHREVE LINKS
C
C 260 WRITE (SYSOT,320)
ISTP=21
GO TO 125
C C RITER 11
C DISPLAY FALLS OF SHREVE LINKS
C
C 265 WRITE (SYSOT,625)
ISTP=21
GO TO 135
C C RITER 12
C DISPLAY GRADIENTS OF SHREVE LINKS
C
C 270 WRITE (SYSOT,630)
ISTP=21
GO TO 145
C C RITER 13
C PUNCH ORDERED REACHES FOR CALCOMP MAP
C
C 275 WRITE (SYSOT,705)
IPKOD=5
WRITE (SYSPE,550) (TITL(I),I=1,16), (NAME(I),IPIKOD), I=1,3
K=0
GO TO 905
WRITE (SYSOT,708)
IPKOD=6
WRITE (SYSOUT,5501,TITLE=1,NAME=1,IPKOD)1
K=1
DO 920 I=1,3
K+K=1
IF (K+GT,NEQ) GO TO 925
HOLD(I,1)=K(K)
HOLD(I,2)=Y(K)
I(HOLD(I,1))=LINK(K,6)
IF (IPKOD,NEQ) GO TO 906
HOLD(I,1)=LINE(4)
906 IF 910=1,11,60,6,TOT
IF (LINK(I,1),I,EQ,1) GO TO 915
910 CONTINUE
915 I(HOLD(I,2))=LINE(I,3)
IF (IPKOD,NEQ) GO TO 920
[Continued on next page]
11H),/13X,13HI ORDER /,39X,6VALUES,38X,1HI,/,13X,97(1H-)

590 FORMAT (/48X,25HFAIIS OF ORDERED SEGMENTS,/,49X,25(1H-),/13X,97(1H)
=1-1/,13X,13HI ORDER /,39X,6VALUES,38X,1HI,/,13X,97(1H-)
=1280
=1282

595 FORMAT (/46X,24HGRAIENTS OF ORDERED SEGMENTS,/,46X,24(1H-),/13X
197(1H-),/13X,13HI ORDER /,39X,6VALUES,38X,1HI,/,13X,97(1H-)
=1286
=1288

600 FORMAT (/47X,23HVALUES OF ORDERED SEGMENTS,/,47X,23(1H-),/13X,9
171(1H-),/13X,13HI ORDER /,39X,6VALUES,38X,1HI,/,13X,97(1H-)
=1290
=1292

605 FORMAT (/1H,12X,1HI,/,4X,12X,1HI,/,83X,1HI,1)
=1294
=1296

610 FORMAT (/1H,12X,1HI,/,11X,1HI,/,810X,3,4H 1)
=1298
=1300

615 FORMAT (/1H,108X,1HI,/,13X,97(1H-))
=1302
=1304

620 FORMAT (/42X,36HLENGTHS OF SHREVE LINKS (MAGNITUDES),/,42X,36(1H-
1//,13X,97(1H-),/13X,13HI MAGNITUDE /,39X,6VALUES,38X,1HI,/,13X,9
271(1H-))
=1306
=1308

625 FORMAT (/43X,34HFAIIS OF SHREVE LINKS (MAGNITUDES),/,43X,36(1H-),/13X,97(1H-),/13X,13HI MAGNITUDE /,39X,6VALUES,38X,1HI,/,13X,97(1H-)
=1310
=1312

630 FORMAT (/41X,38HGRAIIENTS OF SHREVE LINKS (MAGNITUDES),/,42X,36(1H-1//,13X,97(1H-),/13X,13HI MAGNITUDE /,39X,6VALUES,38X,1HI,/,13X
2,97(1H-))
=1314
=1316

700 FORMAT (/15X,1HI,214X,11,5X,1HI,51X,F6.3,2H 11)
=1318

701 FORMAT (/1H,93X,F6.3,2M 1,1AFB,3,2H 11)
=1320

702 FORMAT (/15X,1HI,214X,11,5X,1HI,51X,F6.3,2M 1,29X,2H 11)
=1322

705 FORMAT (/1H,20X,6HPEUNCED OUTPUT FOR CALCIMAP MAP OF ORDER OF E
1ACH REACH IN BASIN.)
=1324

707 FORMAT (/1H,20X,6HPEUNCED OUTPUT FOR CALCIMAP MAP OF MAGNITUDE
OF EACH REACH IN BASIN.)
=1326

708 FORMAT (/1H,20X,6HPEUNCED OUTPUT FOR CALCIMAP MAP OF MAGNITUDE
END
=1328
=1330
=1332
SUBROUTINE LINKER

PURPOSE --
   TO DETERMINE THE REACHES AND COMPUTE THE STREAMLINE ORDER FOR EACH
   STATION JUNCTION ANGLE (COMPUTED IN SUBROUTINE ANGLE) IN ANGTAB
   ARRAY

USAGE --
   CALL SUBROUTINE LINKER (NSIZ, LNKX, LNKY, LNKZ)
   WHERE NSIZ = MAXIMUM NUMBER OF POINTS ALLOWED TO BE READ IN
   LNKX = ARRAY USED TO RETAIN THE POSITION AND ORDER OF
   EACH SEGMENT
   LNKY = ARRAY OF X COORDINATE POINTS
   LNKZ = ARRAY OF Y COORDINATE POINTS
   LNKZ = ARRAY OF Z COORDINATE POINTS

REQUIRED SUBROUTINES --
   READIT
   ANGLE

OPTIONAL SUBROUTINES --
   NONE

NAME COMMON BLOCKS USED --
   LINKER
   OPTION

SUBROUTINE LINKER (NSIZ, LNKX, LNKY, LNKZ)
  DIMENSION JUNC(50), REGE(50), ENN(50), E(50)
  DIMENSION NMH(20), HTAR(20,2,40)
  DIMENSION HSNRG(10), ANGTAB(55,5)
  DIMENSION LNZ(7)
  DIMENSION LNKSIZ(41,41), LNZSIZ(41,41)
  DIMENSION JTAR(5,31), NRPROF(161)
  DIMENSION NSEX(20), SOUR(20)
  COMMON /LINKA/ LNZT宁N, HSNRG, LNZSIZ, HTNR, ANG, NORDER, MOUTH, MAGMAX, HSNMAX,
               LHNR, ANGTH, HNUN, HTAR, NRTH, NRPR, N
  COMMON /OPTION/ ISW1, ISW2, MSW, IWSM, ISC, IANGSW, IAZSM, IFSW, ILS,
               IWS, IWSM, IMSW, INPM, NPM, NP, NJ, JTAR, IPUSH
  COMMON / Orig, TITLE, SOURCE, SCALF, ZBASE, CONTOR
  INTEGER HNUN
  INTEGER SYSDT
  INTEGER REGE, ENN
  DATA SYSDT/6/

ZERO COUNTERS AND INITIALIZE ANGTAB ARRAY

  ELEV=0.0
  NR=0
  JR=0
  L=0
  DO 10 KJ=1,55
    DO 5 NI=1,5
      ANGTAB(JR,N)=0.0
  5 CONTINUE
  10 CONTINUE

CHECK IF CODE IS NEGATIVE, IF NEGATIVE SET POSITIVE

IF IFSW(I) PROFILES REQUESTED, ENTER NEGATIVE CODES
ON INPUT TAIL OF INPUT PROGRAM.
DO 100 N=1,NDT
  MYK=LINK(N,4)
  IF (MYK) 15,280,30
  MYK=N
  IF (TPSW,NE,1) GO TO 30
  IF (ND<LT,2) GO TO 25
  DO 20 N=N,1,40
  IF (NPROF(I),I,EQ,N) GO TO 30
  CONTINUE
20  CONTINUE
  NPROF=N+1
  IF (NPROF,EQ,16) GO TO 30
  NPROF=N
  GO TO (35,65,90,85,95,1280,97), MYK
C C STREAM TIP FOUND
C
35  L=L+1
  LINK(L,1)=N
  LINK(L,2)=NLAST
  LINK(L,3)=1
C C FOLLOWING SECTION USED BY #JUNCTION OPTION
C
43  IF (IJSW,NE,1) GO TO 50
  DO 45 JJ=1,NJ
    LPT=JTAR(JJ,1)
    IF (LINK(JJ,1),EQ,LPT) GO TO 40
  GO TO 45
C
45  CONTINUE
C
52  LL=L
55  LL=LL-1
  IF (LINK(LM+1,1),NE,LINK(LL+2)) GO TO 60
  IF (LINTERM,1),EQ,LPT) GO TO 57
  IF (LINK(KK,1),NE,71) GO TO 60
  LINK(LM+1,3)=LINK(LM+3)
  LL=LL-1
  IF (LL,LT,1) GO TO 60
  GO TO 55
C
60  IF (J,LT,1) GO TO 100
  NLAST=JUNC(J)
  ELEV=FP(JJ)
  J=J-1
  GO TO 100
C C MID POINT FOUND
C
65  L=L+1
  LINK(L,1)=N
  LINK(L,2)=NLAST
  LINK(L,3)=100
  NLAST=N
C C FOLLOWING SECTION USED BY #JUNCTION OPTION
C
73  IF (IJSW,NE,1) GO TO 100
  DO 75 JJ=1,NJ
    LPT=JTAR(JJ,1)
    IF (LINK(JJ,1),EQ,LPT) GO TO 70
  GO TO 75
C
75  CONTINUE
  LINK(LPT,9)=3
  GO TO 100
C C STREAM JUNCTION FOUND
C
```c
J=J+1
F(J)=FLEV
SUMF(J)=N
L=L+1
L(IFK(L+1))=N
LINK(L+2)=NLAST
LINK(L+3)=100
NLAST=N
GO TO 100

C

C BOUNDARY POINT FOUND
C
C
45
L=L+1
  IF (NB.EQ.0) NLAST=MOUTH
  LINK(L+1)=N
  LINK(L+2)=NLAST
  IF (I(IFPSW,GE,21)=1) Z(N)=2BASE
  IF (NP1.EQ.NTOT) GO TO 90
  NP1=NP1+1
  IF (LINK(NP1,GE,41).EQ.41) GO TO 100
  L=L+1
  LINK(L+1)=MOUTH
  LINK(L+2)=NLAST
  NLAST=MOUTH
  GO TO 100

C

C MOUTH OF DRAINAGE BASIN FOUND
C
C
95
  MOUTH=N
  NLAST=N

C

C IF ESTIMATION OF ELEVATIONS REQUESTED SET ELEVATION
C OF MOUTH = 2BASE AND FIND LOWEST CONTOUR LINE
C
C
C
C
  IF (I(IFPSW,NE,21).EQ.0) GO TO 100
  Z(N)=2BASE
  TEST=2BASE/CONTOR
  TEST=1.TEST
  ELEV=ELEV+CONTOR
  GO TO 100

C

C CONTOUR CROSSING FOUND
C
C
97
  ELEV=ELEV+CONTOR
  Z(N)=FLEV
  GO TO 65
  CONTINUE

C

**************
C FOR DEBUGGING REPLACE ABOVE STATEMENT WITH THE FOLLOWING
C 100 IF (L.GT.7) WRITE(SYSOT,500) (LINK(L),KT=1,3)
C
C
**************
C
C FOLLOWING SECTION USED BY JUNCTION OPTION
C
C
C```
IF (JSW .NE. 1) GO TO 115
DO 110 J=1,NJ
LPT=LINK(JJ,1)
IF (LAM(LPT,4),GT,3.AND.LINK(LPT,4),LT,7) GO TO 105
GO TO 110

C WRITE (SYSST,290) JTAB(JJ,1)
110 CONTINUE
115 LTOT=L
C
C ------------------------------
C SORT THE LINK TABLE, RENSING ALL BOUNDARY REACHES
C ON TOP AND FIRST ORDER REACHES BELOW.
C
C LSTART=1
LNEG=1
NORDER=0
120 L=1; LTOT=1
125 LSW=0
DO 130 L=LNEG,L91
LP=1+1
IF (LINK(L,3),LE,LINK(LPI,3)) GO TO 130
LMP=LINK(LPI,3)
LINK(LPI,3)=LINK(L3)
LINK(L3)=LMP
ITMP=LINK(LPI,2)
LINK(LPI,2)=ITMP
ITMP=LINK(LPI,1)
LINK(LPI,1)=ITMP
LINK(LP,1)=LINK(L1)
LINK(LP,1)=ITMP
LSW=1
130 CONTINUE
IF (LSW .NE. 0) GO TO 125
IF (NORDER .NE. 0) GO TO 170

C
C COUNT THE NUMBER OF BOUNDARY REACHES (LINK(3)=-1).
C AND STORE IN NSFG(I), then COUNT THE FIRST ORDER
C REACHES AND STORE IN NSFG(2)
C
C ----------------------------

C DO 150 I=1,2
KOUNT=0
IF (L.EQ.1.AND.LINK(L3),EQ,1) GO TO 145
DO 135 L=LSTART,L1
KOUNT=KOUNT+1
LP=LP+1
IF (LINK(L,3),NE,LINKLP,3)) GO TO 140
135 CONTINUE
140 LSTART=LP
145 NSFG(I)=KOUNT
150 CONTINUE
IF (NSW,NE.1) GO TO 165
IF (NSFG(I),EQ,1) GO TO 165
C
C ----------------------------
C GET RID OF BOUNDARY POINTS SINCE WE ARE NOT SURE OF CORRECT
C BASIN WHEN CONNECT OPTION IS USED
C
C -----------------------------

C LST=NSFG(I)+1
DO 160 L=LST,LTOT
LSW=L-NSFG(I)
DO 155 L=1,L3
155 CONTINUE
160 CONTINUE
C
C **********
C THE FOLLOWING WRITE STATEMENTS MAY BE
C INSERTED FOR DEBUGGING PURPOSES.
C DO 510 I=1,LTOT
C 510 WRITE(SYSST,5000) (LINK(L,KTL),KTL=1,3)
C **********

NORDER=2
LSW=NSFG(I)+1
LNEG=LSW
LST=LSW+NSFG(I-NORDER)-1
LOW IS LINE IN LINK TABLE FOR START OF 1ST ORDER REACHES.
LEN IS LINE IN LINK TABLE FOR START OF (CURRENT ORDER+1) REACHES.
LUP IS LINE IN LINK TABLE FOR LAST ORDERED REACH.
LSTRT = LUP+1 = LINE IN LINK TABLE FOR FIRST UNORDERED REACH.
LEN = LUP-1 = SECOND LAST ORDERED REACH.

170 LEND=LUP-1
LSW=0

SEARCH UPPER LINK TABLE (LSW-LEND) FOR IDENTICAL END POINTS.
WHEN FOUND THESE FROM A JUNCTION AND START OF NEXT HIGHER ORDER REACH.
THIS ENTER VALUES IN BEG TABLE. LSW IS COUNTER OF BEG TABLE.
IF *JUNCTION OPTION USED, MUST ALSO CHECK FOR SPECIFIED
JUNCTION POINTS (CONTAINED IN JTAB TABLE).

IF (LSW .NE. 1) GO TO 180
DO 175 J=1,LSW
IF (JTAB(JJ,JJ) .NE. ORDER) GO TO 175
LSW=LSW+1
BEGL=JTAB(JJ,LSW)

175 CONTINUE
190 CONTINUE
DO 200 L=BEGL,LEN
LP(L)=1
IF (LSW .EQ. 0) GO TO 190

THIS LOOP PREVENTS DOUBLE ENTERS IN BEG TABLE.

DO 185 LP=1,LSW
IF (BEGL(LP).EQ.LINK(LP,1)) GO TO 200
185 CONTINUE
190 LTEMP=LINK(LP,1)
JTEMP=LINK(LP,11)
JORD=LINK(LP,31)
DO 195 LL=LP+1,LUP
IF (LTEMP .NE. LINK(LP,1)) GO TO 195

A JUNCTION POINT HAS BEEN FOUND
ENTER THE POINT IN BEG TABLE AND COMPUTE THE ANGLE

LSW=LSW+1
BEGL=LSW+1
KTEMP=LINK(LP,11)
KORD=LINK(LP,31)
CALL ANGLET (ANGTAB,ITEMP,JTEMP,KTEMP,JORD,KORD,X,Y,NS2)

ANGLE CONTAINS THE ANGLE STATISTICS

GO TO 200

135 CONTINUE
200 CONTINUE
IF (LSW .EQ. 0) GO TO 205
GO TO 210
C 235 KOUNT=0
GO TO 270
210 CONTINUE

SEARCH LOWER PARTS OF LINK TABLE TO FIND REACHES
STARTING FROM BEG VALUE, STORE ENDS OF THESE IN ENY TABLE.

THE FOLLOWING WRITE STATEMENTS MAY BE
INSERTED FOR DEBUGGING PURPOSES.
DO 515 KT=1,LSW
515 WRITE (SYSNT,500) BEG(KT)
KOUNT=0
LSTART=LUP+1
DO 225 J=1,LSW
   DO 220 L=LSTART,LMT
   IF (LINK(L,1).NE.ND) GO TO 220
   ENDLJ=LINK(L,2)
   KOUNT=KOUNT+1
   LINK(L,3)=NORDER
C
C MUST CHECK IF END IS A MIDPOINT. IF SO, THE NEXT
C HIGHER REACH IN THE LINK TABLE ALSO HAS THE SAME ORDER.
C UPDATE ENN VALUE.
C
LINE=LINK(L,2)
LM1=L
215 IF (LINK(LINE,4).EQ.2.OR.LINK(LINE,4).EQ.7) GO TO 217
   GO TO 225
C
217 KOUNT=KOUNT+1
   LM1=LM1+1
   LINK(LM1,3)=NORDER
   BEG(IJ)=ENNLJ
   ENNLJ=LINK(LM1,2)
   LINE=LINK(LM1,2)
   GO TO 215
C
220 CONTINUE
224 CONTINUE
C
***************
C THE FOLLOWING WRITE STATEMENTS MAY BE
C INSERTED FOR DEBUGGING PURPOSES.
C DO 520 KT=1,LSW
C 520 WRITE(SYSOUT,500) BEG(KT),ENN(KT)
C ***************
C
NOW MUST CHECK TO SEE IF ANY REACHES JUST ORDERED JOIN
WITH OTHER ORDERED REACHES. IF THEY DO, THEN ADDITIONAL
REACHES BELONG TO THIS ORDER.
C
JJ=LSW
J=1
230 IF (ENNJ,1).EQ.1) GO TO 275
   DO 235 L=LM1,LUP
   IF (ENNJ,1).NE.LINK(L,2)) GO TO 235
      KTEMP=BEG(IJ)
      JTEMP=LINK(L,1)
      JORD=LINK(L,3)
      GO TO 240
C
235 CONTINUE
   GO TO 260
C
C
A REACH END MATCHES

240 IF (KTEMP.EQ.ENNJ,1)
   KTEMP=MDERK
   CALL ANGLE (ANGTAB,ITEMP,JTEMP,KTEMP,JORD,KDR,IY,MSIZE)
   DO 255 L=LSTART,LMT
      IF (ITEMP.NE.LINK(L,1)) GO TO 255
         J=JJ+1
         BEG(IJ)=ITEMP
         ENNJ=LINK(L,2)
         LINK(L,3)=NORDER
         KOUNT=KOUNT+1
         LINE=LINK(L,2)
         LM1=L
255 IF (LINK(LINE,4).EQ.2.OR.LINK(LINE,4).EQ.7) GO TO 246
   GO TO 250
C
246 LM1=LM1-1
   KOUNT=KOUNT+1
   LINK(LM1,3)=NORDER
   BEG(IJ)=ENNJ
   ENNLJ=LINK(LM1,2)
   LINE=LINK(LM1,2)
   GO TO 245
C 250 IF (LINRILINE.41,EC,51) GO TO 275
C 255 CONTINUE
C 260 J=J+1
C 265 IF (I,J.GT.JJ) GO TO 265
C 270 CONTINUE
C ***************
C THE FOLLOWING WRITE STATEMENTS MAY BE
C INSERTED FOR DEBUGGING PURPOSES.
C D7 525 KT=1,JJ
C 525 WRITE(SYSNT,500) REG(KT),ENN(KT)
C ***************
C C 275 CONTINUE
C LREG=LABEG+MSEG(NORDER)
C NORDER=MORDER+1
C NSEG(NORDER)=KOUNT
C LSTART=LSTART+KOUNT
C LUP=LUP+KOUNT
C GO TO 120
C C 275 MORDER=MORDER+1
C MOUT=MSTART
C NSEG(NORDER)=KOUNT
C RETURN
C C 280 WRITE(SYSNT,245) NYK
C RETURN
C C ***************
C FOLLOWING FORMAT USED BY DEBUGGING STATEMENTS
C 500 FORMAT(1H4,31I10)
C ***************
C C C
C 285 FORMAT(1HO,10X,39H*** ERROR *** ILLEGAL POINT CODE. CODE=,I3)
C 290 FORMAT(1HO,7H*** ERROR *** JUNCTION ATTEMPTED WITH BASIN BOUNDARY
C TRY RJ MOUTH AT POINTS 14,18H JUNCTION IGNORED=1
C END
SUBROUTINE CALC

PURPOSE --
TO COMPUTE THE BASIC BASIN STATISTICS

USAGE --
CALL SUBROUTINE CALC(KSW, NSIZ, X, Y, Z, LINK, DIST, SCALE)
WHERE KSW = INTEGER VARIABLE WHICH DIRECTS PROPER ENTRY INTO
the appropriate section of the subroutine
1 = BASIC BASIN STATISTICS SECTION
2 = STATISTICS COMPILED AFTER ORDERING AND/OR
NSIZ = MAXIMUM NUMBER OF POINTS ALLOWED TO BE READ IN
MAY BE SET TO AS MANY AS IS DESIRED BY THE USER
X = ARRAY OF X COORDINATE POINTS
Y = ARRAY OF Y COORDINATE POINTS
Z = ARRAY OF Z COORDINATE POINTS
LINK = ARRAY USED TO RETAIN THE POSITION AND ORDER OF
 EACH SEGMENT
DIST = ARRAY CONTAINING THE LENGTH OF EACH
SCALE = SCALE OF THE SOURCE DATA PROVIDED BY USER
DIST = ARRAY CONTAINING THE LENGTH OF EACH
SCALE = SCALE OF THE SOURCE DATA PROVIDED BY USER

REQUIRED SUBRoutines --
READIT
LINKR

OPTIONAL SUBRoutines --
NONE

NAMED COMMON BLOCKS USED --
BASIN
LINKR
OPTION

SUBROUTINE CALC(KSW, NSIZ, X, Y, Z, LINK, DIST, SCALE)
DIMENSION NPROF(16)
DIMENSION KNSIZ, YNSIZ, LINCKNSIZ, 4J, DISTSIZ
INTEGER HNUM
DIMENSION HNUM(201, HTAB(20, 2, 4))
DIMENSION ZNSIZ
DIMENSION NSEG(101, ANGTAB(55, 5))
COMMON /BASIN/ AREA, ACRES, PERIM, TOTD, DENS, C, CRAT, BIG, VLEN, AZMAIN, B
COMMON /LNR/ DLEN, USF, DOR, C, ELONG, WSC, PC, T, FL, TT, CAREA, HIGH, REL, HR, SH
COMMON /LINKR/ LDT, NDT, NSEG, NLNK, ANG, NORDER, MOUTH, MACMAX, HMNSEG,
NUMHSR, ANGTAB, HNUM, HTAB, IPUTAB
COMMON /OPTION/ I5W, I5SW, M5W, M5SW, I5PSW, M5PSW, I5P, M5P, I5PS, M5PS
COMMON /HNUM/ HTAB, I5P, I5PSW, NPROF, NP, N, JTAB, IPUSW
GO TO (15, 115), KSW

PART ONE - CALCULATIONS OF LENGTHS, ANGLES, AND AREAS
FOR WHICH TRUE X AND Y COORDINATES ARE NEEDED.

CALCULATE LENGTHS OF REACHES

SCL = SCALE/63360.
DO 10 I = 1, LDT
J = LINK(I, 1)
L = LINK(I, 2)
DIST(I) = SORT((X(J) - X(I))**2 + (Y(J) - Y(I))**2)
10 DIST(I) = DIST(I)*SCL
FIND THE MAIN (LONGEST) STREAM

```
ILEG=NSSEG(1)+1
BIG=0.0
NSTART=1
DO 20 N=START,MOT
   IF (LINK(N,4)=EQ,1) GO TO 25
20 CONTINUE
GO TO 50
```

A STREAM TIP HAS BEEN FOUND

```
NSTART=N+1
NTIP=N
DSUM=0.0
```

TRACE STREAM FROM TIP TO MOUTH

```
DO 30 L=ILEG,LMT
   IF (LINK(L,1)=EQ,N) GO TO 40
30 CONTINUE
GO TO 45
```

```
DSUM=DSUM+DIST(L)
N=LINK(L,2)
   IF (N,ME=1) GO TO 30
   IF (BIG,GT,DSUM) GO TO 45
   BIG=DSUM
   NPROF(I)=NTIP
   IF (NSTART,LE,NTOTI) GO TO 15
```

```
C
C   BIG=LENGTH OF LONGEST STREAM
C   NPROF(I) CONTAINS POINT NUMBER OF TIP
C   COMPUTE VLEN = STRAIGHT LINE DISTANCE TIP TO MOUTH
C
C```

```
NPROF(I)=NTIP
VLEN=SQRT((X(INTIP)-X(I)**2)+(Y(INTIP)-Y(I)**2)
VLEN=VLEN*SCAL
```

```
C```

```
IF (Y(INTIP)-Y(I)) 60,55,60
   IF (Y(INTIP)-LT,Y(I)) AZMAIN=270.+ANG
   IF (Y(INTIP)-GT,Y(I)) AZMAIN=90.+ANG
   GO TO 65
```

```
AZMAIN=ATAN((X(INTIP)-X(I))/(Y(INTIP)-Y(I)))
AZMAIN=ANG+AZMAIN=57.2957
   IF ((X(INTIP)-X(I))GT,O.00 AND (Y(INTIP)-Y(I))GT,O.0) AZMAIN=AZMAIN+180.
   IF ((X(INTIP)-X(I))LT,O.00 AND (Y(INTIP)-Y(I))LT,O.0) AZMAIN=AZMAIN-180.
   IF ((X(INTIP)-X(I))LT,O.00 AND (Y(INTIP)-Y(I))GT,O.0) AZMAIN=AZMAIN+360.
   IF ((X(INTIP)-X(I))LT,O.00 AND (Y(INTIP)-Y(I))LT,O.0) AZMAIN=AZMAIN-360.
```

```
C```

```
C   COMPUTE WANDR= WANDERING RATIO FOR MAIN STREAM
C   FIND MINIMUM X COORDINATE
C```

```
WANDR=BIG/VLEN
XMIN=1000.0
DO 70 N=1,NTOT
   IF (X(N,LT,XMIN) XMIN=X(N)
70 CONTINUE
```

```
C```

```
IF BASIN BOUNDARY NOT DEFINED? NSSEG(1)=0
THE REMAINING CALCULATIONS CANNOT BE DONE
```
COMPUTE BASIN AREA, PERIMETER AND LENGTH

LTOP=NSEG(1)
BLEN=0.0
PERIM=0.0
AREA=0.0
DO 80 L=1,LTOP
   L1=LINK(L,1)
   L2=LINK(L,2)
   AREA=AREA+(X(L1)+X(L2)-2.0*WMINH)*|Y(L1)-Y(L2)|/2.0
   BL=SORT|X(L1)-X(L2)|**2+(Y(L1)-Y(L2))**2
   IF (BL.LE.BLEN) GO TO 75
   BLEN=BL
   NPER=L1
75 PERIM=PERIM+DIST(L1)
80 CONTINUE
IF (AREA.LT.0.0) AREA=-AREA

CONVERT AREA TO 50 MILES

AREA=AREA*SCAL**SCAL
ACRES=AREA*640.
BLEN=BLEN*SCAL
USF=BLEN/SORT(ARRAY)

COMPUTE RAZ=AZIMUTH OF BASIN LENGTH

IF (Y(NPER)-Y(II)) 90.85.90
IF (Y(NPER)1 GT Y(II)) RAZ=270.
IF (Y(NPER)=LT Y(II)) RAZ=90.
GO TO 95
90 RAZ=ATAN((X(NPER)-X(II))/((Y(NPER)-Y(II))
RAZ=ANG+BAZ*2.97
IF ((X(NPER)-X(II)) GT 0.0 AND (Y(NPER)-Y(II)) GT 0.0) BAZ=BAZ
1 + 180.
IF ((X(NPER)-X(II)) LT 0.0 AND (Y(NPER)-Y(II)) LT 0.0) BAZ=BAZ
41.4
IF ((X(NPER)-X(II)) LT 0.0 AND (Y(NPER)-Y(II)) LT 0.0) BAZ=BAZ+360.
IF ((X(NPER)-X(II)) LT 0.0 AND (Y(NPER)-Y(II)) LT 0.0) BAZ=BAZ-180.
95 TOTD=0.0

CALCULATE TOTAL LENGTH OF DRAINAGE CHANNELS

LSTART=NSEG(1)+1
DO 100 L=LSTART,LTOT
100 TOTD=TOTD+DIST(L)

ORAIMAGE DENSITY AND CONSTANT OF CHANNEL MAINTENANCE

DENS=TOTD/AREA
C=5280./DENS

CALCULATE CIRCULARITY RATIO

CAREA=(PERIM**2/(4.*PI**3.1416))
CRAT=AREA/CAREA
DCIRC = DIAMETER OF CIRCLE HAVING AREA OF BASIN
ELONG = ELONGATION RATIO
WSF = WATERSHED SHAPE FACTOR

DCIRC = SQRT(4 * A / PI * 3.1416)
ELONG = DCIRC / BLEN
WSF = BLEN / DCIRC

FIND HIGHEST POINT

IF (IPHSW.EQ.1) GO TO 110
HIGH = 0.0
DI 105 L = LTOP
LI = LINK(L,1)
IF (HIGH.LT.LI) HIGH = L
CONTINUE
110 IF (IPHSW.EQ.1) GO TO 125

COMPUTE RELIEF PARAMETERS

REL = HIGH - Z(I)
HR = REL / 5280.0 / PERIM
HH = REL / 5280.0 / BLEN
GO TO 125

PART TWO - CALCULATIONS WHICH REQUIRE PRIOR USE
OF SUBROUTINES ORDI OR ORD2

115 IF (ISW1.NE.1) GO TO 120
FC = NUMSEG / AREA
T = NUMSEG / PERIM
120 IF (ISW2.NE.1) GO TO 125
FL = NUMHAG / AREA
TT = NUMHAG / PERIM
125 RETURN
END
SUBROUTINE ANGLE

THE WATER SYSTEM

COMPUTER PROGRAMS FOR WATERSHED ANALYSIS
DEVELOPED AT
UNIVERSITY OF TORONTO PURDUE UNIVERSITY
TORONTO,ONTARIO LAFAYETTE,INDIANA

SUBROUTINE ANGLE

PURPOSE --
TO COMPUTE ANGLES IN DEGREES GIVEN CO-ORDINATES OF 3 POINTS

USAGE --
CALL ANGLE (ANGTAB, IPT, JPT, KPT, J, K, X, Y, NSIZ)
WHERE ANGTAB = ARRAY USED TO RETAIN CERTAIN ANGLE STATISTICS,
SUM OF ANGLES OF CLASS N, SUM OF SQUARES OF
ANGLES, NUMBER OF ANGLES, MAXIMUM AND MINIMUM
ANGLES
IPT = JUNCTION POINT OF TWO JOINING REACHES
JPT = BEGINNING POINT OF ONE OF THE JOINING REACHES
KPT = BEGINNING POINT OF OTHER JOINING REACH
J = ORDER OF JPT-IPT REACH
K = ORDER OF KPT-IPT REACH
X = X COORDINATE OF EACH POINT
Y = Y COORDINATE OF EACH POINT
NSIZ = MAXIMUM NUMBER OF POINTS ALLOWED TO BE READ IN
MAY BE SET TO AS MANY AS IS DESIRED BY THE USER

REQUIRED SUBROUTINES --
LINKER

OPTIONAL SUBROUTINES --
NONE

COMMON BLOCKS USED --
NONE

SUBROUTINE ANGLE (ANGTAB, IPT, JPT, KPT, J, K, X, Y, NSIZ)
DIMENSION ANGTAB(55,5), ANG(10)
DIMENSION X(NSIZ), Y(NSIZ)
DATA (ANG/1,2,4,7,11,16,22,29,37,46/

SWITCH J AND K SO THAT J IS SMALLEST

IF (J<K) 10, 10, 5
5 1 = J
J = K
K = I
10 CONTINUE
KJ = 1ANG(K) + (J-1)*J/J
IF ((X(JPT)-X(IPT)) > 15, 20, 20
15 IF ((Y(JPT)-Y(IPT)) > 20IF (Y(JPT)-Y(IPT)) LT Y(IPT) A1 = 270.
GO TO 25
C
20 A1 = ATAN((Y(JPT)-Y(IPT))/(X(JPT)-X(IPT)))
A1 = A1+90.
IF (Y(JPT)-Y(IPT)) > 10IF (X(JPT)-X(IPT)) GT 0.0 A1 = 180.
IF (Y(JPT)-Y(IPT)) > 20IF (X(JPT)-X(IPT)) LT 0.0 A1 = 360.
IF (X(KPT)-X(IPT)) < 10IF (Y(IPT)-Y(KPT)) LT 0.0 A1 = A1+180.
IF (X(KPT)-X(IPT)) > 10IF (Y(IPT)-Y(KPT)) LT 0.0 A1 = A1+360.
IF (X(KPT)-X(IPT)) < 10IF (Y(IPT)-Y(KPT)) LT 0.0 A1 = A1+180.
IF (X(KPT)-X(IPT)) > 10IF (Y(IPT)-Y(KPT)) LT 0.0 A1 = A1+360.
GO TO 45
C
40  \( A_2 = \frac{\text{ATAN}(y(KPT)-y(IPT))/(x(KPT)-x(IPT)))}{\left(\frac{y(KPT)-y(IPT)}{x(KPT)-x(IPT)}\right) + G + O} \) E 164
    \( A_2 = A_2 + 67.2957 \) E 166
    IF (\( y(KPT) > y(IPT) \)) LT. O. AND. (\( x(KPT) - x(IPT) \)) + G.O. \( A_2 = A_2 + 360 \) E 168
    IF (\( y(KPT) > y(IPT) \)) LT. O. AND. (\( x(KPT) - x(IPT) \)) + G.O. \( A_2 = A_2 + 180 \) E 170
    IF (\( y(KPT) > y(IPT) \)) LT. O. AND. (\( x(KPT) - x(IPT) \)) + G.O. \( A_2 = A_2 + 180 \) E 172
    IF (\( y(KPT) > y(IPT) \)) LT. O. AND. (\( x(KPT) - x(IPT) \)) + G.O. \( A_2 = A_2 + 180 \) E 174
    \( \text{ANG} = \text{ABS} (A_1 - A_2) \) E 176
    IF (\( \text{ANG} > 180 \)) OR (\( \text{ANG} < 0 \)) \( \text{ANG} = 360 - \text{ANG} \) E 184
C
--------------------------
C
\( \text{ANGTAB}(N,1) = \text{SUM OF ANGLES OF CLASS N} \) E 192
\( \text{ANGTAB}(N,2) = \text{SUM OF SQUARES OF ANGLES} \) E 194
\( \text{ANGTAB}(N,3) = \text{NUMBER OF ANGLES} \) E 196
\( \text{ANGTAB}(N,4) = \text{MINIMUM ANGLE} \) E 198
\( \text{ANGTAB}(N,5) = \text{MAXIMUM ANGLE} \) E 200
--------------------------
C
\( \text{ANGTAB}(K,J,1) = \text{ANGTAB}(K,J,1) + \text{ANG} \) E 202
\( \text{ANGTAB}(K,J,2) = \text{ANGTAB}(K,J,2) + \text{ANG} \) E 204
\( \text{ANGTAB}(K,J,3) = \text{ANGTAB}(K,J,3) + 1 \) E 206
    IF (\( \text{ANGTAB}(K,J,4) > \text{ANG} \)) \( \text{ANGTAB}(K,J,4) = \text{ANG} \) E 208
    IF (\( \text{ANGTAB}(K,J,5) > \text{LT} \)) \( \text{ANGTAB}(K,J,5) = \text{ANG} \) E 210
RETURN
C
END
E 212
E 214
E 216
E 218
SUBROUTINE ORD1

THE WATER SYSTEM

COMPUTER PROGRAMS FOR WATERSHED ANALYSIS
DEVELOPED AT
UNIVERSITY OF TORONTO PURDUE UNIVERSITY
TORONTO, ONTARIO LAFAYETTE, INDIANA

SUBROUTINE ORD1

PURPOSE --
TO CALCULATE THE BASIC STATISTICS FOR EACH BASIN

USAGE --
CALL SUBROUTINE ORD1 (NSIZ, X, Y, Z, LINK, DIST, TEMP1, TEMP2, LINE)
WHERE NSIZ = MAXIMUM NUMBER OF POINTS ALLOWED TO BE READ IN
      MAY BE SET TO AS MANY AS IS DESIRED BY THE USER
      K = ARRAY OF K COORDINATE POINTS
      Y = ARRAY OF Y COORDINATE POINTS
      Z = ARRAY OF Z COORDINATE POINTS
      LINK = ARRAY USED TO RETAIN THE POSITION, ORDER, AND
             MAGNITUDE OF EACH REACH
      DIST = ARRAY CONTAINING THE LENGTH OF EACH REACH
      TEMP1 = TEMPORARY ARRAY CONTAINING THE LENGTH OF EACH
              SEGMENT
      TEMP2 = TEMPORARY ARRAY CONTAINING THE FALL OF EACH
              SEGMENT
      LINE = TEMPORARY ARRAY CONTAINING THE AZIMUTH OF EACH
             SEGMENT

REQUIRED SUBROUTINES --
LINKER

OPTIONAL SUBROUTINES --
NONE

NAMED COMMON BLOCKS USED --
NONE

SUBROUTINE ORD1 (NSIZ, X, Y, Z, LINK, DIST, TEMP1, TEMP2, LINE)
DIMENSION LINE(NSIZ)
DIMENSION X(NSIZ), Y(NSIZ), Z(NSIZ), DIST(NSIZ)
DIMENSION K(NSIZ), X(NSIZ), Y(NSIZ), TEMP1(NSIZ), TEMP2(NSIZ)
DIMENSION NSEG(10), ANGTHB(55,5)
DIMENSION HNUM(20), HTAB(20,2,4)
INTEGER HNUM
COMMON /LINKR/, LTDI, NTOT, NSEG, NLNK, NORDER, MOUTH, MAGMAX, NUMSEG,
           INNUMAG, ANGTHB, HNUM, HTAB, IPUTAB
INTEGER ORD, SYSOT
DATA SYSOT/6/

SPECIFY FUNCTION VAR1
WRITE TITLES AND INITIALIZE COUNTERS

VAR1(A,B,N)=(A-FLOAT(N)+B)/FLOAT(N-1)
WRITE (SYSOT, 65)
WRITE (SYSOT, 95)
WRITE (SYSOT, 100)
WRITE (SYSOT, 95)
NSEG=1
ORD=NORDER-1
LREG=1

E 2
E 4
E 6
E 8
E 10
E 12
E 14
E 16
E 18
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E 134
E 136
E 138
E 140
E 142
E 144
E 146
E 148
LOOP THROUGH ORDERS
FIRST INITIALIZING STATISTICS COUNTERS

DO 40 I=2,ORD
NUM=0
D=0.0
DSUM=0.0
DSUMQ=0.0
DMIN=1000.0
DMAX=0.0
FSUM=0.0
FSUMQ=0.0
FKIN=1000.0
FKMAX=0.0
GRAD=0.0
GSUM=0.0
GSUMQ=0.0
GMIN=1000.0
GMAX=0.0
ASUM=0.0
ASUMQ=0.0
AMIN=1000.0
AMAX=0.0
IM=1-1

CHECK FOR MISSING ORDERS
THIS CAN HAPPEN WITH JUNCTION OPTION

IF (NSEG11 EQ 0) GO TO 40
LSEG=LSEG+NSEG(11)
LUP=LSEG+NSEG(11)-1

FIND A SEGMENT OF CURRENT ORDER AND COMPUTE
LENGTH, FALL, GRADIENT, AND AZIMUTH

UU CU L=LSEG,LUP
PL=1+1
IF (D EQ 0.0) NBEG=LINK(L,2)
D=D+DIST(L)
IF (LINK(L+1) EQ LINLPL,23) GO TO 20
DSUM=DSUM+D
DSUMQ=DSUMQ+D*D
NUM=NUM+1
IF (DMIN GT 0) DMIN=D
IF (DMAX LT 0) DMAX=D
NEND=LINK(L,11)
FALL=ABS(ZIN(NBEG-ZENDE))
GRAD=FALL/D
IF (Y(NBEG)-Y(NEND)) 10,5,10
IF (X(NBEG) GT X(NEND)) AIZ=270.0 + ANG
IF (X(NBEG) LT X(NEND)) AIZ=90.0 + ANG
GO TO 15

AZI=ATAN((X(NBEG)-X(NEND)) / (Y(NBEG)-Y(NEND)))
AZI=ANG+AZI+57.2957
IF (((X(NBEG)-X(NEND)) GT 0.0) AND (Y(NBEG)-Y(NEND)) GT 0.0) AZI = AZI
IF (((X(NBEG)-X(NEND)) LT 0.0) AND (Y(NBEG)-Y(NEND)) LT 0.0) AZI = AZI+360
IF (((X(NBEG)-X(NEND)) LT 0.0) AND (Y(NBEG)-Y(NEND)) GT 0.0) LT = AZI
IF (((X(NBEG)-X(NEND)) LT 0.0) AND (Y(NBEG)-Y(NEND)) LT 0.0) AIZ = AZI
IF (((X(NBEG)-X(NEND)) LT 0.0) AND (Y(NBEG)-Y(NEND)) LT 0.0) AIZ = AZI+180

STORE VALUES IN TEMPORARY ARRAYS FOR LATER DISPLAY
COMPUTE SUMS, SUMS OF SQUARES, MAXIMUMS, AND MINIMUMS

KTR=KTR+1
TEMP1(KTR)=0
TEMP2(KTR)=FALL
LINE(KTR)=AZI+1000.0
FSUM=FSUM+FALL
ASUM=ASUM+AZI
FSUMQ=FSUMQ+FALL*FALL
ASUMQ=ASUMQ+AZI*AZI
IF (FMN>GT,FALL) FMN=FALL
IF (FMX>LT,FALL) FMX=FALL
IF (AMN>GT,AZI) AMN=AZI
AMX=AZI
GSUM=GSUM+GRAD
GSUMSQ=GSUSMSQ+GRAD*GRAD
IF (GMN>GT,GRAD) GMN=GRAD
IF (GMAX>LT,GRAD) GMAX=GRAD
DQ=Q
CONTINUE

ALL SEGMENTS OF CURRENT ORDER FOUND
COMPUTE STATISTICS

DANG=OMAX-OMIN
FRANG=OMAX-OMIN
ARANG=AMAX-AMIN
GRANG=GMAX-GMIN
GBAR=GSUM/NUM
ABAR=ASUM/NUM
FBAR=FSUM/NUM
DBAR=DSUM/NUM

COMPUTE AND PRINT BIFURCATION RATIO IF POSSIBLE

IF (1.0E21 .GE. DQ) GO TO 30
IF (NLAST.EQ.0 OR .EQ.0) GO TO 25
BIRAT=FLOAT(NLAST)/FLOAT(NUM)
WRITE (SYSOT,80) BIRAT
GO TO 30

WRITE (SYSOT,85)

PRINT STATISTICS

WRITE (SYSOT,70) DBAR,FBAR,GBAR,ABAR,OMAX,OMIN,GRANG,FRANG,GRANG,ARANG

STORE VALUES FOR HISTOROMS

HTAB(I,1,1)=OMAX
HTAB(I,1,2)=OMIN
HTAB(I,1,1)=GMAX
HTAB(I,1,2)=GMIN
HTAB(I,1,1)=AMAX
HTAB(I,1,2)=AMIN
HNUM(I)=NUM

COMPUTE AND PRINT VARIANCE AND STANDARD DEVIATION
IF HAVE AT LEAST FIVE VALUES

IF (NUM.LT.5) GO TO 35
DVAR=VAR(DSUMSQ, DBAR, NUM)
DSIG=SIG(DVAR)
GVAR=VAR(GSUMSQ,GBAR,NUM)
GSIG=SIG(GVAR)
FVAR=VAR(FSUMSQ,FBAR,NUM)
FSIG=SIG(FVAR)
AVAR=VAR(AFUMSQ,ABAR,NUM)
ASIG=SIG(AVAR)
WRITE (SYSOT,75) DVAR,FVAR,GVAR,AVAR,DSIG,FSIG,GSIG,ASIG
NLAST=NUM
NUMSEG=NUMSEG+NUM
CONTINUE
COMPUTE VALUES FOR HIGHEST ORDER SEGMENT

BIRAT=FLOAT(MLAST)/1+D
WRITE (SYSOT,80) BIRAT
LABEG=BEG+NESSGORD
D=0,D
DO 45 L=LABEG,LTOT
D=0,D

LABEG RE-DEFINED AS BEGINNING POINT OF HIGHEST ORDER

IF (Y(LABEG)-Y(1)) .LT. 55.50,55
IF (X(LABEG)-X(1)) .LT. 15.10,15

AZI=ATAN((X(LABEG)-X(1))/(Y(LABEG)-Y(1)))
AZI=ANG+AZI+360

IF ((X(LABEG)-X(1)) .LT. 10,.AND. (Y(LABEG)-Y(1)) .GT. 0)
AZI=AZI+180

KTR=KTX+1
TEMP(KTX)=D
TEMP2(KTR)=FALL
LINE(KTR)=AZI+100
NUMGORD=1
NUMH=1

COMPLETE TABLE WITH HIGHEST ORDER VALUES
AND FINAL MESSAGE

WRITE (SYSOT,90) ORD,NUM,O,FALL,GRAD,AZI
WRITE (SYSOT,95)
WRITE (SYSOT,105) ORD,NUMSEG
RETURN

FORMAT (1H0,4(1X,2H5)) STRAHLER STREAM ORDER STATISTICS

FORMAT (1X,2(1H1),13X,4(1H1) MEAN = F7.3,1X,F7.3,1X,F7.3,1X,F7.3,1X
MINIMUM = F7.3,1X,F7.3,1X,F7.3,1X,F7.3,1X
MAXIMUM = F7.3,1X,F7.3,1X,F7.3,1X,F7.3,1X
RANGE = F7.3,1X,F7.3,1X,F7.3,1X,F7.3,1X

FORMAT (1X,2(1H1),13X,4(1H1) SLOPE = F7.3,1X,F7.3,1X,F7.3,1X,F7.3,1X
AZIMUTH = F7.3,1X,F7.3,1X,F7.3,1X,F7.3,1X

FORMAT (1X,2(1H1),13X,4(1H1) STREAM ORDER 1 OF I RATIO (MILES)

FORMAT (1X,2(1H1),13X,4(1H1) 1 SEGMENTS 1,13X,1H1,4(11X,1H1))

FORMAT (1H0,2(1H1),3(1H1) THIS DRAINAGE NETWORK OF ORDER 1,13.21H CONTAINS
A TOTAL OF 1,14,10H SEGMENTS)

END
SUBROUTINE ORD2

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DEVELOPED AT
UNIVERSITY OF TORONTO PURDUE UNIVERSITY
TORONTO, ONTARIO LAFAYETTE, INDIANA

SUBROUTINE ORD2

PURPOSE --
TO CALCULATE THE SHREVE MAGNITUDE FOR EACH REACH AND THE BASIC
MAGNITUDE STATISTICS

USAGE --
CALL SUBROUTINE ORD2 (NSIZ, Z, LINK, DIST, TEMP1, TEMP2)
WHERE NSIZ = MAXIMUM NUMBER OF POINTS ALLOWED TO BE READ IN
MAY BE SET TO AS MANY AS IS DESIRED BY THE USER
Z = ARRAY OF I COORDINATE POINTS
LINK = ARRAY USED TO RETAIN THE POSITION AND MAGNITUDE
OF EACH REACH
DIST = ARRAY CONTAINING THE LENGTH OF EACH REACH
TEMP1 = TEMPORARY ARRAY CONTAINING THE LENGTH OF EACH
LINK (SHREVE MAGNITUDE)
TEMP2 = TEMPORARY ARRAY CONTAINING THE FALL OF EACH
LINK (SHREVE MAGNITUDE)

REQUIRED SUBROUTINES --
LINKER

OPTIONAL SUBROUTINES --
NONE

NAMED COMMON BLOCKS USED --
LINKP

SUBROUTINE ORD2 (NSIZ, Z, LINK, DIST, TEMP1, TEMP2)
DIMENSION Z(NSIZ), LINK(INNSIZ), DIST(NSIZ)
DIMENSION TEMP1(INNSIZ), TEMP2(INNSIZ)
DIMENSION NPROF(16), JTAB(5,3)
DIMENSION HNUM(201), HTAB(202,41)
INTEGER HNUM
COMMON /LINKP/ LTOT, NTOT, NSEG, MLNK, ANG, NORDER, MOUTH, MAGMAX, NUMSEG,
INUMAG, ANGTAB, HNUM, HTAB, JLUTAB
COMMON /OPTION/ IVSW, ISM2, MSW, IMSW, JSMW, ISCM, ISM, IAMSW, IASM, IFSW, ILS
LM, IGMSW, IHMSW, THEPSM, NPROF, HNUM, HTAB, JLUTAB

MAKE BORDER REACHES LINK(L,4)=1

KTR=0
LBEG=1
LUP=NSSEG(1)
IF (NSSEG(1) .LE. 1) GO TO 10
DO 5 L=LBEG,LUP
5 LINK(L,4)=1
INTEGER SYSOT
DATA SYSOT/67/

SPECIFY FUNCTION VARI

VARIA(B,N)=(A-FLOAT(N)*B*B)/FLOAT(N-1)
FIRST ORDER REACHES MUST HAVE MAGNITUDES = 1

SET THEIR LINK(L,4) = 1

LBEG-NSEG11+1
LUP=LBEG-NSEG12-1
DO 15 L=LBEG,LUP
LINK(L,4)=1

COMPUTE MAGNITUDES FOR HIGHER ORDERS
MUST START AT LOWEST REACH IN EACH ORDER IN LINK TABLE
AND ASSIGN IT A MAGNITUDE BY ADDING ORDERS OF ALL REACHES WHICH ENTER IT

DO 35 I=3,NIORDR
LUP=LUP+NSEG11
LN=NSEG11
DO 30 LL=1,LN
L=LUP+1-LL

CHECK IF START OF THIS REACH IS REFERENCED
BY *JUNCTION OPTION
IF IT IS, ADD VALUE TO MAGNITUDE

IF (IJSW.NE.1) GO TO 25
DO 20 J=1,NJ
IF (JTAB(J,1).EQ.LINK(L,1)) LINK(L,4)=JTAB(J,3)

CONTINUE
DO 25 LK=LBEG,LUP
IF (LINK(L,1).EQ.LINK(LK,LK+2)) LINK(LK,4)=LINK(LK,4)+LINK(LK,LK+4)

CONTINUE

Determine Maximum Magnitude

MAGMAX=LINK(L,4)

NOW WRITE THE HEADINGS

WRITE (SYSOT,75)
WRITE (SYSOT*80)
WRITE (SYSOT*85)
WRITE (SYSOT*80)

LOOP THROUGH ALL POTENTIAL MAGNITUDES
FIRST INITIALIZE STATISTICS COUNTERS

NUMHAG=0
DO 70 K=1,MAGMAX
NUM=0
D=0.0
DSUM=0.0
DSUM50=0.0
DMAX=100.0
DMAX=0.0
GRAD=0.0
FSUM=0.0
FSUM50=0.0
FMIN=100.0
FMAX=0.0
GSUM=0.0
GSUM50=0.0
GMIN=100.0
GMAX=0.0

70 CONTINUE
DO 45 L=1,L6E5,L10
IF (LINK(L,4).NE.M) GO TO 45
L=L+1
IF (D.EQ.0.0) NBEG=LINK(L,2)
D=D+DIST(L)
IF (L.EQ.LTOT) GO TO 40
IF (LINK(L,1).EQ.LINK(LPI,2).AND.LINK(L,4).EQ.LINK(LPI,4)) GOTO 434
40 D=0 TO 45

COMPLETE LINK FOUND
ADD VALUES TO SUMS, SUMSQOF SQUARES, MAXIMUMS, AND MINIMUMS

40
DSUM=DSUM+D
DSUMSQ=DSUMSQ+D*D
NUM=NUM+1
IF (DMIN.GT.D) DMIN=D
IF (OMAX.LT.D) OMAX=D
MEN=LINK(L,1)
FALL=ABS((INBEG-1-ZINEND))
GRAD=FALL/D
FSUM=FSUM+FALL
FSUMSQ=FSUMSQ+FALL*FALL
IF (FMIN.GT.FALL) FMIN=FALL
IF (FMAX.LT.FALL) FMAX=FALL
GSUM=GSUM+GRAD
GSUMSQ=GSUMSQ+GRAD*GRAD
IF (GMIN.GT.GRAD) GMIN=GRAD
IF (GMAX.LT.GRAD) GMAX=GRAD
KTR=KTR+1

STORE VALUES IN TEMPORARY ARRAYS FOR LATER DISPLAY

45 CONTINUE
NUMAG=NUMAG+NUM

ALL LINKS OF CURRENT MAGNITUDE FOUND
IF NUM=0 . SKIP THIS MAGNITUDE
IF NUM=1 . PRINT VALUES
IF NUM=2 OR MORE . COMPUTE AND PRINT STATISTICS

IF (NUM.LT.1) 65,50-55
WRITE (SYSOT,100) M,NUM,DSUM,FALL,GRAD
WRITE (SYSOT,60) GO TO 65

NUM IS 2 OR MORE

50 OBAR=DSUM/NUM
GBAR=GSUM/NUM
FBAR=FSUM/NUM
FRANG=FMAX-FMIN
GRANG=GMAX-GMIN
WRITE (SYSOT,90) OBAR,FBAR,GBAR,FRANG,GRANG

COMPUTE AND PRINT VARIANCE AND STANDARD DEVIATION
IF HAVE AT LEAST FIVE VALUES

GMIN,GRANG,FRANG,GRANG

C
C
C
IF (NUM.W.51) GO TO 60
DVAR=VAR(1:SUM500, DBAR, NUM)
GVAR=VAR(1:SUM50, GVAR, NUM)
FVAR=VAR(1:FSUM50, FVAR, NUM)
DSIG=SORT(DVAR)
FSIG=SORT(FVAR)
GSIG=SORT(GVAR)
WRITE (SYSOUT, 95) DVAR, FVAR, GVAR, DSIG, FSIG, GSIG
WRITE (SYSOUT, 60)

60  

--- STORE VALUES FOR HISTOGRAMS ---

65  
IF (M.GT.201) GO TO 70
HTABM1, 1 = DMAX
HTABM2, 1 = DMIN
HTABM1, 2 = FMAX
HTABM2, 2 = FMIN
HTABM4, 1 = GMAX
HTABM2, 3 = GMIN
HTNUM = NUM
CONTINUE

70  

--- TABLE FINISHED; PRINT FINAL MESSAGE ---

75  
WRITE (SYSOUT, 105) HMAX, NUMH, RETURN

80  

--- FORMAT (1HD,47X,27STREAM MAGNITUDE STATISTICS,...) ---

85  
FORMAT (1H, 21X, 781H-1)
FORMAT (1H, 21X, 24H1 STREAM I NUMBER I 5X, 6HLLENGTH, 6X, 1HI, 6X,
14HFA1, 7X, 1HI, 4X, 6HDENSITY, 5X, 1HI, 22X, 24H1 LINK I OF
2I, 3I, 7X, 2H1, 8X, 1HI, 22X, 24H1 MAGNITUDE I LINKS I MILES
3I, 1X, 7H1, 2X, FEET/MILE
4I, 1X, 7H1, 10X, 1HI, 10X, 310H1 MEAN = F7.3, 1XI, 1HI, 22X
1.1HI, 11X, 1HI, 10X, 310H1 MAXIMUM = F7.3, 1XI, 1HI, 22X, 1HI, 4X, 13, 4X, 1
2HI, 3X, 13, 4X, 310H1 MINIMUM = F7.3, 1XI, 1HI, 22X, 1HI, 11X, 1HI, 10X, 31I
30H1 RANGE = F7.3, 1XI, 1HI
95  
FORMAT (1H, 21X, 1HI, 11X, 1HI, 10X, 310H1 EVAR = E11, 4X, 1HI, 22X, 1HI
1.11X, 1HI, 10X, 310H1 SD = F7.3, 1XI, 1HI
100  
FORMAT (1H, 21X, 1HI, 4X, 1HI, 13X, 4X, 1HI, 10X, 1HI, 10X, 1HI LENGTH = F7.3, 11HI
1X, 1HI, 22X, 1HI
1.11X, 1HI, 10X, 310H1 SD = F7.3, 11HI
105  
FORMAT (1H, 25X, 35T HIS DRAINAGE NETWORK OF MAGNITUDE = F7.3, 11HI
1X, 1HI, 22X, 1HI
1.11X, A TOTAL OF 14, 7M LINKS)
END
SUBROUTINE MAPS

THE WATER SYSTEM

COMPUTER PROGRAMS FOR WATERSHED ANALYSIS
DEVELOPED AT
UNIVERSITY OF TORONTO  PURDUE UNIVERSITY
TORONTO, ONTARIO  LAFAYETTE, INDIANA

PURPOSE --
TO PRODUCE PRINTER MAPS OF EACH BASIN SHOWING THE STRAHLER ORDER
AND/OR SHEVRE MAGNITUDE FOR EACH REACH

USAGE --
CALL SUBROUTINE MAPS(KMAP, NSIZ, LINK, NX, NY, LINE, RATIO)
WHERE KMAP = INTEGER VARIABLE INDICATING WHETHER THE MAP IS
TO HAVE A STRAHLER ORDER OR SHEVRE MAGNITUDE
TITLE PRINTED AT THE TOP OF THE PAGE
NSIZ = MAXIMUM NUMBER OF POINTS ALLOWED TO BE READ IN
MAY BE SET TO AS MANY AS IS DESIRED BY THE USER
LINK = ARRAY USED TO RETAIN THE POSITION, ORDER, AND
MAGNITUDE OF EACH REACH
NX = ARRAY CONTAINING THE X COORDINATE OF THE PRINT
CHARACTER FOR ALL DATA POINTS
NY = ARRAY CONTAINING THE Y COORDINATE OF THE PRINT
LINE = TABLE CONTAINING THE LINE NUMBERS OF NX, NY DATA
IN ORDER OF INCREASING NY
RATIO = THE DENOMINATOR OF THE ACTUAL SCALE OF THE
PRINTER MAP

REQUIRED SUBRoutines --
LINKR
ORD1
ORD2

OPTIONAL SUBRoutines --
NONE

NAMED COMMON BLOCKS USED --
LINKR
PLOTS

SUBROUTINE MAPS(KMAP, NSIZ, LINK, NX, NY, LINE, RATIO)
INTEGER OPTNAM,HNUM
INTEGER SYMTAB, SYSDT, BLANK
DIMENSION OPTNAM(6,2)
DIMENSION LPLT(40,4), SPLN(40)
DIMENSION SYMTAB(42), SYMB(131)
DIMENSION NXINSIZ, NYINSIZ, LINKINSIZ,4
DIMENSION HNUM(20), HTAB(20,2,4)
DIMENSION NSEG(10), ANGTAB(55,5)
COMMON /LINKR_/LDT, NDT, NSEG, NLK, ANG, NORDER, MOUTH, HMAX, NNUMSEG,
HNUM, ANG, NSEG, NSEG, HTAB, IPUTAB
COMMON /PLOTS_/ TOL, NCOL, NRDO, DODY
DATA OPTNAM/4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST,
4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST,
4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST,
4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST,
4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST,
4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST,
4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST,
4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST,
4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST, 4HST,
4HST
C SET COUNTERS FOR NEW TABLES
C L = COUNTER FOR LAYOUT TABLE
C KOUNT = COUNTER FOR LINE TABLE
C
L=0
KOUNT=1

C START THRU MAP ROW BY ROW
C
DO 140 J=1,NROW

C BLANK OUT ALL CHARACTERS IN THE LINE
C
DO 5 I=1,L1
  ISYMB(I)=BLANK
  ISYMB(I)=SYMTAB(I)
  IF (J,.EQ.,60,.OR.J,.EQ.,NROW) GO TO 10
  GO TO 20

10  HH=NCOL-1
  DO 15 I=2,NH
    ISYMB(I)=SYMTAB(I)
  15  CONTINUE
  JKT=LINE(KOUNT)

C JKT IS THE CURRENT ENTRY IN THE LINE TABLE
C
IF (J,.NE.,NYJKT) GO TO 10
LSW=LSW+1

C A NEW DATA POINT LIES ON THIS PRINT LINE
C MUST FIND LINKS USING THIS POINT
C THEREFORE START SEARCHING LINK TABLE
C
TK=1
25  GO TO 35
  IF (LINK(I),.EQ.,JKT) GO TO 35
  IF (LINK(I+1),.EQ.,JKT) GO TO 40
  CONTINUE

30  IF (LINK(I),.EQ.,JKT) GO TO 35
    IF (LINK(I+1),.EQ.,JKT) GO TO 40
    CONTINUE

C NO MORE LINKS FOUND, CONTINUE
C
GO TO 65

C LINK FOUND BEGINNING OR ENDING AT JKT
C
35  KBEG=LINK(I,1)
    KEND=LINK(I,2)
    GO TO 45

40  KBEG=LINK(I,2)
    KEND=LINK(I,1)
    KPI=KOUNT+1

C SEARCH LINE TABLE FROM NEXT LOCATION TO THE END TO FIND KEND, THE
C OTHER END OF THIS LINK. WE ONLY WANT NEW LINKS, WHOSE END POINTS OCCUR
C FURTHER DOWN THE MAP, THOSE WHICH HAVE THEIR OPPOSITE ENDS HIGHER UP
C THE MAP WILL ALREADY BE IN THE LAYOUT TABLE, THEREFORE DROP ANY LINK WHOSE
C END POINT IS NOT FOUND IN THIS SEARCH.
C
IF (KPI,.GT.,NPTOT) GO TO 100
  GO TO 50
  LINE=KPI,NPTOT
  IF (KEND,.EQ.,LINE(I,LINE)) GO TO 55
  CONTINUE
GO TO 50

C
L=L+1
L plot(L1)=1
L plot(L2)=1
L plot(L3)=N(KBEG)
L plot(L4)=1
NSPACE=ABS(NX(KEND)-NX(KBEG))+1
IF(NX(KEND)-LT.-NX(KBEG))NSPACE-NSPACE
NLIN=ABS(NY(KEND)-NY(KBEG))+1
SPLINE(L)=FLOAT(NSPACE)/FLOAT(NLIN)
IX=1+1

-----------------------------------------------

IF NOT ALL LINK TABLE SEARCHED FOR INITIAL MATCH, GO BACK
-----------------------------------------------

IF [IXLE.LT.10] GO TO 25

ALL NEW LINKS FOUND FOR THIS POINT AND ENTERED IN LPlot
-----------------------------------------------

KOUNT=KOUNT+1
-----------------------------------------------

RETURN TO 2B TO SEE IF NEXT POINT DOWN LINE TABLE ALSO ON THIS LINE
-----------------------------------------------

GO TO 20

IF [L.LT.11] GO TO 135
DO 75 L=1,L
LOC=L plot(Lj+2)
LOC=Lime(LDC)
IF(NYLOC+1.LT.J) GO TO 60

75 CONTINUE
GO TO 100

-----------------------------------------------

HAVE FOUND AN LPlot ENTRY TO BE DROPPED
-----------------------------------------------

DO 90 LL=1,L
LP1=LL+1
IF [LP1.LT.11] GO TO 95
DO 85 LK=1,L
L plot(LL,LK)=L plot(LP1,LK)
SPLINE(LL)=SPLINE(LP1)

85 CONTINUE
90 CONTINUE
95 L=L-1
GO TO 70

-----------------------------------------------

LPlot TABLE NOW CONTAINS ONLY CURRENT ENTRIES
-----------------------------------------------

CONTINUE

-----------------------------------------------

NOW LOOP THRU LPlot TABLE TO BUILD LINE IMAGE
-----------------------------------------------

DO 130 LJ=1,L
ISYN=SIGN(J,0)*SPLINE(LL)
IXA=SPLINE(LL)+FLOAT(L plot(LJ)+1)
IXA=L plot(LJ)+1
IXB=SPLINE(LJ)+FLOAT(L plot(LJ)+1)
IF (ABS(IXB)+LT.1) IXB=SIGN(1,IXB)
IF (IXB=IXA) 105,110,110

105 PUT=IXA
IXA=IXB
IXB=PUT

110 L plot(LL)=L plot(LL)+1
IF (IXA.LT.1) IXA=1
IF (IXB.GT.NCOL) IXB=NCOL
NOW HAVE CORRECT CHARACTER LIMITS FOR THIS LINK IN THIS LINE
IX=LEFT LIMIT, IX*RIGHT LIMIT. HAVE TO ASSIGN PRINT CHAR.
KMAP=1 = STRAHLER ORDERS, 2 = MAGNITUDES, ETC
CORRECT VALUES FOUND IN LINK TABLE COLS=KMAP+2

KOL=KMAP+2
LNUM=LNUM(J+1)

LVAL IS LINK MAG. OR ORDER, IF GREATER THAN 60
WE MUST RECYCLE

LVAL=LINK(LNUM,KOL)
IF (LVAL.LE.40) GO TO 120
LVAL=LVAL-40
GO TO 115

115

120
LVAL=LVAL+1

BOUNDARIES OF BASINS HAVE ORDERS2MAGS. OF -1

IF (LINK(LNUM,KOL),LT,1) LVAL=1
DO 125 IX=IXA,IXB
125 ISYMB(IX)=SYMTAB(LVAL)
CONTINUE

ALL LINKS RECORDED FOR THIS LINE, PRINT IT.

WRITE (SYSOT,225) (SYMB(I),I=1,HEOL)

CONTINUE

MAP FINISHED, PRINT LEGEND

GO TO (145,160), KMAP

LEGEND FOR ORDERS

WRITE (SYSOT,230)
DO 150 I=2,NORDER
150 WRITE (SYSOT,235) SYMTAB(I),INI
CONTINUE
IF (INSEG(I),LT,1) GO TO 155
WRITE (SYSOT,240) SYMTAB(I)
155 WRITE (SYSOT,245)
RETURN

LEGEND FOR MAGNITUDES

WRITE (SYSOT,250)
LCYCLE=1
MAG=MAGAX
165 IF (MAG.LE.40) GO TO 170
MAG=MAGAX
LCYCLE=LCYCLE+1
GO TO 165

MBEG=1
170 IF (LCYCLE.LT.21) GO TO 185
LMC=LCYCLE-1
DO 180 MC=1,LMC
180 IBEG=2
DO 180 MCC=1,2
180 ENDO=IBEG+10
WRITE (SYSOT,255) (SYMTAB(I),I=IBEG,ENDO)
WRITE (SYSOT,255)
DO 175 I=1,20
   SYMB(I)=MBEG+I-1
   WRITE (SYSOT,260) (SYMB(I),I=1,20)
   WRITE (SYSOT,265)
   MBEG=MBEG+20
   IBEG=MBEG+20
180  CONTINUE
185  MSTP=MAGMAX-MBEG
   IBEG=2
   ICS=19
   IF (MSTP.GT.20) GO TO 190
   ICS=MSTP
190  IEND=IBEG+ICS
   WRITE (SYSOT,255) (SYMTAB(I),I=IBEG,IEND)
   WRITE (SYSOT,265)
   ICSP=ICS
   DO 195 I=1,ICSP
   ISYMB(I)=MBEG+I-1
   WRITE (SYSOT,260) (ISYMB(I),I=1,ICSP)
   WRITE (SYSOT,265)
   WRITE (SYSOT,270)
   IF (MSTP.LE.20) GO TO 200
   IBEG=IBEG+20
   MEBG=MBEG+20
   MSTP=MAGMAX-MBEG
   ICS=MSTP
   GO TO 190
200  IF (INSEG(1).LT.1) GO TO 205
   WRITE (SYSOT,275) SYMTAB(1)
   RETURN
   C
210  FORMAT (1H35X,32HMAP OF DRAINAGE NETWORK SHOWING *,6A4,///,47X,27H
   THE SCALE OF THIS MAP IS 1/F,FS,O,//)
215  FORMAT (1H0,8H0X IS GREATER THAN TOL, HAP MAY THEREFORE HAVE INAD
   IEQUATE RESOLUTION IN THE X-DIRECTION,//)
220  FORMAT (1H0,8H0Y IS GREATER THAN TOL, HAP MAY THEREFORE HAVE INAD
   IEQUATE RESOLUTION IN THE Y-DIRECTION,//)
225  FORMAT (1H,13I11)
230  FORMAT (1H0,50X,23H1/.1//,51X,1H1,21X,1H1,/,51X,1H1,5X,1H1,1H1,
   EGE IN 0,5X,1H1,/,51X,1H1,21X,1H1,/,51X,23H1/.1//,51X,1H1,Z10X,1H1,1,
   251X,23H1 SYMBL I ORDER 1,/,51X,1H1,211H-------------1))
235  FORMAT (1H0,50X,1H1,210X,1H1,/,51X,1H1,5X,1H1,4X,1H1,3X,13,3X,4X,1H1
   1)
240  FORMAT (1H0,50X,1H1,210X,1H1,/,51X,1H1,5X,1H1,4X,1H1,12H0 BOUNDARY 1)
245  FORMAT (1H0,50X,1H1,210X,1H1,/,51X,1H1,4X,1H1,23H1)
250  FORMAT (1H0,11S11H-1,/,2H I,13X,1H1,/,2H I,51X,1H1,EGEN0,51X
   1,1H1,/,2H 1,34X,45H NOTE SYMBOLS REPEAT EVERY 40 MAGNITUDES 1,3
   24X,1H1,/,2H I,113X,1H1,/,2H I,113H-1,1H1)
255  FORMAT (1H0,11X,1H1,10X,1H1,/,14H 1 SYMBOL 1,20(3X,A1,1X))
260  FORMAT (1H0,1A1,MAGNITUDE 1,2015)
265  FORMAT (1H0,114X,1H1)
270  FORMAT (2H I,111X,1H1,10L0X,1H1,/,1X,115H-1)
275  FORMAT (1H0,18X,35HBOUNDARY POINTS ARE REPRESENTED BY ,A1,8H SYMBOL
   END)
SUBROUTINE PROFIL

C-----------------------------------------------
C                     THE WATER SYSTEM
C-----------------------------------------------
C COMPUTER PROGRAMS FOR WATERSHED ANALYSIS
C DEVELOPED AT
C UNIVERSITY OF TORONTO  PURDUE UNIVERSITY
C TORONTO, ONTARIO  LAFAYETTE, INDIANA
C
C-----------------------------------------------
C SUBROUTINE PROFIL
C
C PURPOSE --
C TO PRODUCE PRINTER MAPS OF STREAM PROFILES USING THE REACH DATA
C COMPILED IN PREVIOUS SECTIONS OF THE PROGRAM
C
C-----------------------------------------------
C USAGE --
C CALL SUBROUTINE PROFIL (KOUNT, NTIP, ZMAX, ZMIN, DZ, NSIZ, LINK, LINE, DIST, Z)
C WHERE KOUNT = INTEGER VARIABLE WHICH INDICATES THE NUMBER OF
C THE PROFILE
C NTIP = THE POINT FROM WHICH THE PROFILE BEGINS
C ZMAX = THE HIGHEST ELEVATION OF THE BASIN
C ZMIN = THE LOWEST ELEVATION OF THE BASIN
C DZ = THE Y-INCREMENT OF THE PRINTED PROFILE
C NSIZ = MAXIMUM NUMBER OF POINTS ALLOWED TO BE READ IN
C LINK = MAY BE SET TO AS MANY AS IS DESIRED BY THE USER
C LINE = ARRAY USED TO RETAIN THE POSITION AND ORDER OF
C EACH REACH
C DIST = ARRAY CONTAINING THE LENGTH OF EACH REACH
C Z = ARRAY OF Z COORDINATE POINTS
C
C-----------------------------------------------
C REQUIRED SUBROUTINES --
C READIT
C LINKER
C
C OPTIONAL SUBROUTINES --
C NONE
C
C NAMED COMMON BLOCKS USED --
C LINK
C
C-----------------------------------------------
C SUBROUTINE PROFIL (KOUNT, NTIP, ZMAX, ZMIN, DZ, NSIZ, LINK, LINE, DIST, Z)
C DIMENSION ANCTAB(55,5), NSEG(10)
C DIMENSION LINK(NSIZ,41), LINE(NSIZ,21), DIST(NSIZ), ZINSIZ)
C INTEGER HNUM
C DIMENSION HNUM(20), HTAB(20,2,4)
C DIMENSION TUT(10)
C INTEGER SYD, BLANK, STAR
C COMMON/LINKR, LTD, NSEG, HNUM, HORDER, MOUTH, MAGMAX, NUMSEG,
C HNUMAG, ANCTAB, HNUM, HTAB, IPYTAB
C INTEGER LINE
C DATA SYD, BLANK, STAR/6, 14, 100/
C
C-----------------------------------------------
C SEARCH OUT POINTS ON PROFILE
C
C LKTL=1
C LPT=NTIP
C DO 20 LL=1,LTOT
C IF (LINKL,I).NE.LPT) GO TO 20
C
20 CONTINUE
C POINT FOUND, CHECK IF ON STREAM NETWORK
C IF IT IS, ENTER IN LINE TABLE
C
C IF (LINKL,3).LT.1) GO TO 70
C LINE(LKT)=L
C LPT=LINKL,2)
C LKT=LKT+1
C
C-----------------------------------------------
CHECK IF NEW END IS A MIDPOINT, IF NOT GO TO ?

5

IF (LMI .EQ. 0) GO TO 15
IF (LINK(LMI,11) .EQ. LINK(LK1,2)) AND LINK(LMI,31) .EQ. LINK(LL,3) GO TO 10

10

LINE(LKT)+=LMI
LPT=LINK(LMI,2)
LKT=LKT+1
LL=LMI
GO TO 5

CONTINUE

FOLLOWING CHECKS TO SEE IF MOUTH HAS BEEN RECORDED
IF NOT ERROR MESSAGE PRINTED

IF (LPT .EQ. 1) GO TO 25
WRITE (SYSOT,80) LPT
GO TO 65

LMI WAYS NUMBER OF ENTRIES IN MOUTH
C EQUALS NUMBER OF ENTRIES IN LINK TABLE
LINE TABLE CONTAINS POSITIONS OF REACHES IN LINK TABLE

CONTINUE

WRITE TITLE HERE

WRITE (SYSOT,901 NTIP
VEX=RUNI/100.0
WRITE (SYSOT,130) VEX
IF (KOUNT .EQ. 1) WRITE (SYSOT,951)

PRINT PROFILE HEADINGS AND SET COUNTERS

WRITE (SYSOT,100) ZMAX,ZMIN
WRITE (SYSOT,105)
WRITE (SYSOT,110)
NLIN=0
MLIN=0
LKT=LKT-1

LOOP THROUGH REACHES IN PROFILE
COMPUTE PRINT POSITIONS FOR REACH ENDS, Nxa AND Nxb
AND LENGTH OF REACH IN LINES NY

DO 60 L=1,LKT
LL=LINE(L1)
XBEG=LINK(LK1,1)
KEND=LINK(LK1,2)
NAX=(100.0*{LINAX-Z2(XBEG)}/RUNI)+0.5
NXB=(100.0*(LINAX-Z2(KEND))/RUNI)+0.5
NY=DISS levy .5
NAX*NAX
A-48

LOOP THROUGH NY FOR CURRENT REACH

DO 55 N=1,NY
  NN=NYA+(NX=1:N-1/NY)
  NNX=NN+1
  DO 30 I=1,NNX
  30 IOUT(I)=BLANK
  DO 35 I=NNXP,100
  35 IOUT(I)=STAR

NY=2*NY/2

NLINE=NLINE+1

CHECK IF LINE PASSES THROUGH BEGINNING POINT, IS MIDDLE LINE OR REACH, OR IS REGULAR LINE.

PRINT LINE USING PROPER FORMAT.

IF (IN,1EQ,1) GO TO 40
IF (IN,1EQ,NY2) GO TO 45
WRITE (SYSOT,135) (IOUT(I),I=1,NY)
GO TO 50

WRITE (SYSOT,120) KBEG,(IOUT(I),I=1,NY)
GO TO 50

WRITE (SYSOT,125) LINK(I),LINK(I+1),IOUT(I),I=1,NY2
CONTINUE

TEST TO SEE IF AT EVEN MILEAGE FROM START.
IF SO, ADD MILEAGE TO LINE.

IF (INLNE,NLE,1KT) GO TO 55
WRITE (SYSOT,75) MILE
MILE=MILE+1
HT=FLOAT(MILE)*DY+1.0

CONTINUE

WRITE (SYSOT,120) KENO,(IOUT(I),I=1,NY)
WRITE (SYSOT,110)
RETURN

WRITE (SYSOT,85) NTIP,LPT
RETURN

FORMAT (1X,12X,2H--12)
FORMAT (1H,10X,2X,7HERROR ** PROFILE HAS NOT REACHED BASIN MOUTH, 1ST LAST POINT REACHED=I)
FORMAT (1H,2X,3HERROR ** PROFILE FROM POINT,15.22H HAS ENDED, LONTEST POINT=15.32H WHICH IS NOT ON STREAM NETWORK.)
FORMAT (1H,40X,33H LONGITUDINAL PROFILE FROM POINT,15.14H TO THE MOUTH.)
FORMAT (52X,2H THIS IS THE LONGEST STREAM.)
FORMAT (1H,10X,15X,4HFEET,45%P=1./1H,2111H,1.,1H,1999,1H, 11)
FORMAT (1M+10X,6.1H POINT IORDER-MAG,1.,100X,7H MILE)
FORMAT (1H,12X1H-1)
FORMAT (2H,17X,3H1,215X,1H1,100A,1H1)
FORMAT (3H+14,3H 1.26H-------11.10DA1,1H1)
FORMAT (2H17X,1H1,211X,13.2H 11.10DA1,1H1)
FORMAT (4DH+41MH VERTICAL EXAGGERATION -- ONE INCH EQUALS 1/8640 FEET.)

END
SUBROUTINE HIST

THE WATER SYSTEM

COMPUTER PROGRAMS FOR WATERSHED ANALYSIS
DEVELOPED AT
UNIVERSITY OF TORONTO Purdue University
Toronto, Ontario Lafayette, Indiana

SUBROUTINE HIST

PURPOSE --

TO PRODUCE HISTOGRAMS SHOWING THE DISTRIBUTIONS OF LENGTHS,
FALLS, GRADIENTS, AND AZIMUTHS OF STREAM SECTIONS FOR EACH
STREAM ORDER AND LENGTHS, FALLS, AND GRADIENTS FOR STREAM
LINKS FOR EACH SHREVE MAGNITUDE.

NOTE --

HISTOGRAMS ARE NOT PRODUCED FOR ANY ORDER OR
MAGNITUDE CONTAINING FEWER THAN 15 STREAMS.

USAGE --

CALL SUBROUTINE HIST (KTYPE, XMAX, XMIN, X, NBEG, NEND, NSIZ, IO)

WHERE KTYPE = INTEGER VARIABLE INDICATING THE TYPE OF HISTOGRAM
1 = LENGTHS
2 = FALLS
3 = GRADIENTS
4 = AZIMUTHS

XMAX = MAXIMUM VALUE OF THE MEASUREMENT
XMIN = MINIMUM VALUE OF THE MEASUREMENT
X = ARRAY CONTAINING THE NECESSARY VALUES FOR ALL
OF THE NECESSARY POINTS
NBEG = BEGINNING OF POINTS TO BE USED FOR HISTOGRAM
NEND = END OF POINTS TO BE USED FOR HISTOGRAM
NSIZ = MAXIMUM NUMBER OF POINTS ALLOWED TO BE READ IN
MAY BE SET TO AS MANY AS IS DESIRED BY THE USER
IO = INTEGER VARIABLE USED TO INDICATE THE ORDER OR
MAGNITUDE OF THE POINTS CONSIDERED

REQUIRED SUBROUTINES --

RITER
ORD1
ORD2

OPTIONAL SUBROUTINES --

NONE

NAMED COMMON BLOCKS USED --

NONE

SUBROUTINE HIST (KTYPE, XMAX, XMIN, X, NBEG, NEND, NSIZ, IO)
DIMENSION K(140), X(NSIZ), KOLT(50)
DIMENSION NAME(3,4)
DATA NAME/4H LEN,4H GHTHS,1H ,4H FA,4H HLS ,1H ,4H GRAD,4H HENT,1H,S,4H
AZI,4H MTH,1H S/
DATA SYSOT, BLANK, STAR
DATA SYSOT, BLANK, STAR,6,1H ,1H S/
IF (KTYPE, GT, 9) GO TO 5

WRITE TITLE FOR HISTOGRAM

WRITE (SYSOT, 55) (NAME(I), KTYPE), I=1,3, IO
GO TO 10

5 KTYPE=KTYPE-9
WRITE (SYSOT, 60) (NAME(I), KTYPE), I=1,3, IO
10 CONTINUE
COMPUTE RANGE AND INTERVAL SIZE
ZERO INTERVAL COUNTER K

XMAX=AIN1(XMAX+1.0)
XMIN=AIN1(XMIN)
XTRVL=(XMAX-XMIN)/40.
DO 15 I=1,40
K(I)=0

15 K(I)=K(I)+1

NBEG= BEGINNING OF POINTS TO BE USED FOR HISTOGRAM
NEND= END OF POINTS TO BE USED FOR HISTOGRAM
ASSIGN OBSERVATIONS TO INTERVALS

DO 20 I=NBEG,NEND
 = (I(I)-XMIN)/XTRVL*1.0
K(I)=K(I)+1
WRITE (SYSOT,80)
XBEGIN=XMIN

20 XBEGIN=XBEGIN+XTRVL

FILL LINE WITH BLANKS

DO 32 I=1,50
KOL(I)=BLANK

32 MORE THAN 50 OBSERVATIONS IN THIS INTERVAL

IF (K(I),LE,50) GO TO 35
DO 30 L=1,45
KOL(I)=STAR
WRITE (SYSOT,85) XBEGIN,XEND,(KOL(I),L=1,45),K(I)
GO TO 30

BUILD LINE WITH STARS TO CORRECT HEIGHT

35 NN=K(I)
IF (NN,LT,1) GO TO 45
DO 40 L=1,NN
KOL(I)=STAR
40 WRITE (SYSOT,90) XBEGIN,XEND,(KOL(I),L=1,NN)
RETURN

WRITE (SYSOT,60)

55 FORMAT (//,1H ,21X,THI,1HISTOGRAM OF THE ,2A4,A1,1D8 OF ORDER ,13)
50 FORMAT (//,1H ,21X,THI,1HISTOGRAM OF THE ,2A4,A1,1D8 OF MAGNITUDE ,1
13)
80 FORMAT (4DX,52(1H=1))
85 FORMAT (21X,F6.3,2H =,F6.3,2H 1,45A,1,14,2H )
90 FORMAT (21X,F6.3,2H =,F6.3,2H 1,50A1,1H )
END
SUBROUTINE ZCALC

PURPOSE --
TO CALCULATE ESTIMATED ELEVATIONS OF NETWORK POINTS
USING SUPPLEMENTAL CONTOUR CROSSING POINTS THROUGH THE BASIN

USAGE --
CALL SUBROUTINE ZCALC (NS12, Z, LINK, DIST)
WHERE NS12 = MAXIMUM NUMBER OF POINTS ALLOWED TO BE READ IN
Z = ARRAY OF Z COORDINATE POINTS
LINK = ARRAY USED TO RETAIN THE POSITION, ORDER, AND
MAGNITUDE OF EACH REACH
DIST = ARRAY CONTAINING THE LENGTH OF EACH REACH

REQUIRED SUBROUTINES --
LINKFR
CALC

OPTIMAL SUBROUTINES --
NONE

COMMON BLOCKS USED --
INF
LINK

SUBROUTINE ZCALC (NS12, Z, LINK, DIST)
DIMENSION TITL(20), SOURC(20)
DIMENSION STR(50,10), ELEV(10), INF(10,2)
DIMENSION NSFEG(10), WIP(30,2)
DIMENSION Z(NS12), LINK(NS12,4), DIST(NS12)
COMMON /INF/ TITL, SOURC, NSFEG, NSEG, INF, NSFEG, NSFEG, NSFEG, NSFEG, NSFEG,
COMMON /Link/ NITL, NITOT, NITOT, NITOT, NITOT, NITOT, NITOT, NITOT, NITOT, NITOT,
COMMON /HOLD/ NSFEG, NSFEG, NSFEG, NSFEG, NSFEG, NSFEG, NSFEG, NSFEG, NSFEG, NSFEG,
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COMMON /HOLD/ NSFEG, NSFEG, NSFEG, NSFEG, NSFEG, NSFEG, NSFEG, NSFEG, NSFEG, NSFEG,
COMMON /HOLD/ NSFEG, NSFEG, NSFEG, NSFEG, NSFEG, NSFEG, NSFEG, NSFEG, NSFEG, NSFEG,
IF LINK(I,1).NE.LINK(1,1) GO TO 125
125 CONTINUE
120 NCHAN = 1
C
C -------
C FIRST THOSE POINTS ALREADY HAVING Z VALUE
C THE LAST POINT SHOULD ALWAYS HAVE A Z VALUE
C -------
C
125  L = 0
      SUM = 0.0
      KK = 0
150  KK = KK + 1
      KLINK = [ISTRINKK]
      KPT = LINK(KLINK,2)
      IF(Z(KPT),EQ.0.0) GO TO 250
      L = L + 1
      ELEV(L) = KPT
250  IF(KK.NE.1) GO TO 150
      KPT = LINK(KLINK,2)
      IF(Z(KPT),EQ.0.0) GO TO 999
      L = L + 1
      ELEV(L) = KPT
C
C -------
C CHECK FOR A MINIMUM OF TWO CONTROL(2) POINTS IN A SEGMENT.
C -------
C
C IF (L.LT.2) GO TO 620
   IK=0
   LM=0
C
C -------
C AT LEAST 2 POINTS IN ELEV TABLE LOOP THROUGH PAIR BY PAIR
C -------
C
C DO 350 KT=1,LM
   KTR=KTR+1
   I1=ELEV(KT)
   I1=I1+1
   I2=ELEV(KTR)
   ISW=1
   SUM=0.0
   YSUM=0.0
   L3=0
350  IK=IK+1
      IF(I1.EQ.I2) IK=IK-1
      ISW=ISTRINKK
C
C -------
C IS POINT BEYOND KNOWN ELEV POINT OF SEGMENT
C -------
C
C 305 IF (LINK(IROW,1).NE.LI) GO TO 310
C
C -------
C DOES THIS IROW CONTAIN SECOND CONTOUR POINT
C -------
C
C IF (LINK(IROW,2).EQ.2) GO TO 320
C
C -------
C POINT OF UNKNOWN ELEVATION FOUND BETWEEN TWO CONTOUR POINTS
C -------
C
C ISM=2
305  L3=L3+1
C -------
C MIDPOINT TABLE CONTAINS THE UNKNOWN POINTS OF SEGMENT
C FIRST VALUE IS THE POINT NUMBER
C SECOND VALUE IS THE IROW NUMBER
C -------
C
C MIDPT(1,1)=LINK(IROW,2)
      MIDPT(1,2)=IROW
      SUM=SUM+DIST(IROW)
      GO TO 300
C
C -------
C POINT OF UNKNOWN ELEVATION FOUND BEFORE FIRST CONTOUR POINT
C -------
C
C CHOOSE ARBITRARY PERCENTAGE OF FALL AND CALCULATE THE SLOPE
C..............................................................................
C
725 IF (TRY .GT. 1.0) GO TO 750
TRY = TRY**2.0
GO TO 725
750 TRY = TOY
TRY1 = TRY
PER = TRY1 / TRY
SLOPE = (PER - TRY) / DT
C..............................................................................
C ASSIGN I VALUES TO ALL POINTS IN SEGMENT
C..............................................................................
C
775 CONTINUE
950 IF (MCHAN .EQ. 0) GO TO 1000
MCHAN = 0
NO = NO - 1
940 IF (NO EQ. 0) GO TO 1001
1000 NN = NN - 1
GO TO 10
930 WRITE(6,2005)
C
2005 FORMAT(1H Income Error** I AT END OF SEGMENT IS 0.0000)
1001 RETURN
END
<table>
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<tr>
<th>Layer</th>
<th>Length</th>
<th>Width</th>
<th>Height</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1500</td>
<td>20</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>2</td>
<td>1700</td>
<td>0.0</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>3</td>
<td>1700</td>
<td>1.2</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>4</td>
<td>1800</td>
<td>1.8</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>5</td>
<td>1800</td>
<td>1.5</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>6</td>
<td>1800</td>
<td>1.2</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>7</td>
<td>1800</td>
<td>0.9</td>
<td>0.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**END**
### INPUT DATA FOR ANALYSIS REQUEST 2

*WATER
*HYPSOMETRY
*STRAHLER
*MAGNITUDE
*LENGTHS
*FAILS
*GRADIENTS
*AZIMUTHS
*ANGLES
*NETWORKS

<table>
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<th>7a</th>
<th>14a</th>
<th>7a</th>
<th>13a</th>
<th>4a</th>
<th>0a2</th>
</tr>
</thead>
</table>

*DATA*
SUBREASIN NUMBER 1 WITH OWN BOUNDARY
WATER SYSTEM TEST DATA

```
3
3212K, F3, 1.2K, F3, 1K, 12.2K, F4, DI)
076 085 5 1660 084 089 3 1566 392 084 3 1574
109 098 1 1589 094 075 3 1584 084 066 2 1598
092 096 1 1612 093 067 3 1591 100 066 2 1598
107 063 2 1608 112 059 2 1618 117 058 1 1630
096 064 3 1607 094 059 2 1610 093 069 1 1633
146 057 2 1615 106 055 1 1625 091 091 2 1572
099 083 3 1608 099 150 2 1591 103 111 3 1605
112 125 2 1618 115 127 1 1629 099 118 2 1613
099 123 3 1629 100 130 2 1627 104 140 1 1637
094 125 2 1625 091 132 1 1634 109 091 3 1586
120 089 3 1594 123 075 2 1612 126 071 1 1623
119 074 2 1618 115 071 2 1618 116 064 1 1628
115 092 2 1594 125 100 2 1605 130 105 1 1625
096 075 4 1620 073 083 4 1630 091 047 4 1635
145 024 4 1706 120 053 4 1700 132 070 4 1710
177 001 1 1928 127 100 1 1722 122 120 1 1500
127 143 4 1690 100 142 4 1675 085 130 6 1670
096 115 4 1645 085 100 4 1610 000 000 6 0
```

*END*
INPUT DATA FOR ANALYSIS REQUEST 3

*WATER
*HYDROLOGY
*STREAMER
*MAGNITUDE
*HISTOGRAM
*LENGTHS
*FALLS
*GRADIENTS
*AZIMUTHS
*ANGLES
*PROFILES
*JUNCTIONS
*NETWORKS

12 0 14 0 0 20 0 0 0 0 0 2

*DATA

MAIN BASIN WITH SUBBASINS ADDED BY *CONNECT OPTION

WATER SYSTEM TEST DATA

20000.

3

((32X,F3.3,1.2X,F3.3,1.2X,11.2X,F4.0))

14 09 5 1560 20 08 4 1600 75 30 4 1690
120 053 4 1700 132 070 4 1710 137 090 4 1690
137 160 4 1660 128 120 4 1680 119 160 4 1710
100 181 4 1730 080 199 4 1710 060 195 4 1700
047 130 4 1710 030 166 4 1730 022 150 4 1735
023 120 4 1730 011 090 4 1720 003 070 4 1700
065 030 4 1680 010 013 4 1650 015 020 2 1582
020 030 3 1517 030 029 2 1530 040 033 2 1545
045 032 2 1560 054 033 1 1590 030 039 2 1522
045 048 2 1529 051 033 3 1593 060 042 2 1592
063 062 3 1556 070 036 2 1555 076 038 1 1550
071 062 2 1561 085 047 1 1575 062 061 3 1538
056 067 2 1542 049 056 2 1554 036 057 1 1562
065 064 2 1542 068 072 2 1548 069 077 3 1552
076 085 1 1650 070 087 3 1557 063 092 2 1568
047 095 1 1577 069 095 2 1561 067 101 3 1566
074 109 2 1519 114 112 2 1592 202 113 1 1410
056 117 3 1572 060 125 1 1584 070 125 2 1577
076 130 2 1563 088 138 3 1597 038 150 2 1620
065 155 1 1642 100 148 3 1610 108 152 2 1621
117 149 2 1650 120 150 1 1641 197 160 2 1630
168 166 1 1549 000 000 0 0000 0

*CONNECT
00370001

SUBBASIN NUMBER 4 WITH OWN BOUNDARY

WATER SYSTEM TEST DATA

20000.

3

((32X,F3.3,1.2X,F3.3,1.2X,11.2X,F4.0))

056 067 5 1542 049 071 3 1547 044 084 2 1556
042 090 3 1563 050 097 2 1571 056 107 1 1582
036 103 1 1578 041 075 3 1556 035 070 2 1564
023 065 3 1570 022 056 2 1578 017 047 1 1585
012 058 1 1581 032 079 3 1565 027 085 2 1572
025 090 2 1582 022 094 1 1594 020 076 2 1580
013 072 2 1588 007 074 1 1610 060 075 4 1560
049 090 4 1585 065 110 4 1595 045 110 4 1630
020 108 4 1680 011 090 4 1720 020 070 4 1800
020 108 4 1680 011 090 4 1720 020 070 4 1800
004 050 4 1750 020 040 4 1630 050 055 4 1630

*CONNECT
00550001

SUBBASIN NUMBER 2 WITH OWN BOUNDARY

WATER SYSTEM TEST DATA

20000.

3

((32X,F3.3,1.2X,F3.3,1.2X,11.2X,F4.0))

076 130 5 1583 075 142 3 1592 065 146 3 1610
060 143 2 1627 055 140 1 1633 058 150 2 1618
053 155 2 1630 050 160 1 1665 074 147 3 1601
075 163 2 1611 081 160 3 1622 089 161 2 1633
065 165 2 1647 070 171 1 1588 066 160 2 1637
087 173 2 1649 036 177 1 1660 070 154 3 1610
064 160 2 1616 069 163 2 1627 053 170 2 1638
050 177 2 1644 052 185 2 1654 055 190 2 1661
068 160 2 1618 067 166 2 1627 067 170 3 1635
072 178 2 1644 073 183 2 1658 072 166 1 1668
064 176 2 1644 063 185 2 1666 065 190 1 1680
080 150 4 1620 086 158 4 1630 193 165 4 1660
108 174 4 1680 109 181 4 1730 330 190 4 1710
060 194 4 1700 047 190 4 1710 030 168 4 1650
065 165 4 1600 052 140 4 1595 065 130 4 1590

*END
## THE WATER SYSTEM

**COMPUTER PROGRAMS FOR WATERSHED ANALYSES**

**DEVELOPED AT**

- UNIVERSITY OF TORONTO
- PURDUE UNIVERSITY
- TORONTO, ONTARIO
- LAFAYETTE, INDIANA

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**Drainage Basin Being Analyzed Is Main Basin With Subbasins**

**Information for this Basin was Collected from Water System Test Data**

**The Scale of the Source Material Is 1/20000.**

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**Table Showing Basic Input Data**

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**Output for Analysis --**

- **WATER**
- **HYDROGRAPHER**
- **STRANGER**
- **MAGNITUDE**
- **NETRIBLES**
- **HISTORAM**
- **LENGTHS**
- **GRADIENTS**
- **ATMITHS**
- **ANGLES**
- **DATA**

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**INCOMPLETE TABLE SHOWN**
**THE WATER SYSTEM**

- Computer Programs for Watershed Analyses developed at
- University of Toronto, Purdue University, Lafayette, Indiana

DRAINAGE BASIN BEING ANALYZED IS MAIN BASIN WITH SUBBASINS
INFORMATION FOR THIS BASIN WAS COLLECTED FROM WATER SYSTEM TEST DATA
THE SCALE OF THE SOURCE MATERIAL IS 1/20000.

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DRAINAGE BASIN BEING ANALYZED IS MAIN BASIN WITH SUBBASEINS

INFORMATION FOR THIS BASIN WAS COLLECTED FROM WATER SYSTEM TEST DATA

THE SCALE OF THE SOURCE MATERIAL IS 1/20000.

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<th>AZIMUTH</th>
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<tr>
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<td>1</td>
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THIS DRAINAGE NETWORK OF ORDER 4 CONTAINS A TOTAL OF 55 SEGMENTS.
DRAINAGE BASIN BEING ANALYZED IS MAIN BASIN WITH SUBBASINS
INFORMATION FOR THIS BASIN WAS COLLECTED FROM WATER SYSTEM TEST DATA
THE SCALE OF THE SOURCE MATERIAL IS 1/20000.

LENGTHS OF ORDERED SEGMENTS

<table>
<thead>
<tr>
<th>ORDER</th>
<th>VALUES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.104  0.444  0.729  0.720  0.704  0.452  0.611  0.412</td>
</tr>
<tr>
<td></td>
<td>0.574  0.845  0.551  0.747  0.827  0.407  0.378  0.642</td>
</tr>
<tr>
<td></td>
<td>0.626  0.443  0.428  0.439  0.819  0.491  0.805  0.733</td>
</tr>
<tr>
<td></td>
<td>0.606  0.765  1.007  0.563  0.682  0.531  0.436  0.662</td>
</tr>
<tr>
<td></td>
<td>0.750  0.589  1.423  0.359  0.668</td>
</tr>
<tr>
<td>2</td>
<td>0.563  0.639  0.657  0.311  1.055  1.034  0.747  0.336</td>
</tr>
<tr>
<td></td>
<td>0.228  0.948  0.340  0.483  0.772</td>
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<tr>
<td>3</td>
<td>0.805  1.102  0.612  1.648</td>
</tr>
<tr>
<td>4</td>
<td>4.196</td>
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DRAINAGE BASIN BEING ANALYZED IS MAIN BASIN WITH SUBBASINS
INFORMATION FOR THIS BASIN WAS COLLECTED FROM WATER SYSTEM TEST DATA
THE SCALE OF THE SOURCE MATERIAL IS 1/20000.

FALLS OF ORDERED SEGMENTS

<table>
<thead>
<tr>
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<tbody>
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<tr>
<td></td>
<td>29.000 45.000 15.000 28.000 39.000 21.000 23.000 24.000</td>
</tr>
<tr>
<td></td>
<td>16.000 15.000 25.000 30.000 39.000 20.000 44.000 44.000</td>
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<td>35.000 40.000 40.000 65.000 31.000 39.000 23.000 35.000</td>
</tr>
<tr>
<td></td>
<td>36.000 38.000 51.000 33.000 45.000</td>
</tr>
<tr>
<td>2</td>
<td>23.000 16.000 14.000 9.000 36.000 39.000 18.000 18.000</td>
</tr>
<tr>
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<td>16.000 27.000 18.000 21.000 34.000</td>
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<td>16.000 28.000 20.000 29.000</td>
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DRAINAGE BASIN BEING ANALYZED IS MAIN BASIN WITH SUBBASINS
INFORMATION FOR THIS BASIN WAS COLLECTED FROM WATER SYSTEM TEST DATA
THE SCALE OF THE SOURCE MATERIAL IS 1/20000.

GRADIENTS OF ORDERED SEGMENTS

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>1</td>
<td>64,123 76,597 26,062 27,785 27,002 33,169 24,557 26,719</td>
</tr>
<tr>
<td>2</td>
<td>42,332 25,027 21,313 28,950 24,122 37,706 26,110 53,443</td>
</tr>
<tr>
<td>3</td>
<td>22,370 25,404 32,700 27,675</td>
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<td>4</td>
<td>17,150</td>
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DRAINAGE BASIN BEING ANALYZED IS MAIN BASIN WITH SUBBASINS
INFORMATION FOR THIS BASIN WAS COLLECTED FROM WATER SYSTEM TEST DATA
THE SCALE OF THE SOURCE MATERIAL IS 1/20000.

AZIMUTHS OF ORDERED SEGMENTS

<table>
<thead>
<tr>
<th>ORDER</th>
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</thead>
<tbody>
<tr>
<td>1</td>
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</tr>
<tr>
<td>2</td>
<td>165.309 78.689 283.740 32.273 290.556 14.036 300.963 214.010</td>
</tr>
<tr>
<td>3</td>
<td>130.641 143.972 337.354 11.888 236.309 121.607 236.309 81.112</td>
</tr>
<tr>
<td>4</td>
<td>241.189 196.389 157.380 197.334 174.289</td>
</tr>
<tr>
<td>2</td>
<td>312.510 159.775 60.945 113.462 336.801 0.0 288.435 81.419</td>
</tr>
<tr>
<td>3</td>
<td>123.689 233.130 111.801 206.300 163.072</td>
</tr>
<tr>
<td>4</td>
<td>206.565</td>
</tr>
</tbody>
</table>
TYPICAL HISTOGRAM
(SIX OTHERS NOT SHOWN)

THE WATER SYSTEM
COMPUTER PROGRAMS FOR WATERSHED ANALYSES
DEVELOPED AT
UNIVERSITY OF TORONTO
PURDUE UNIVERSITY
TORONTO, ONTARIO
LAFAYETTE, INDIANA

DRAINAGE BASIN BEING ANALYZED IS MAIN BASIN WITH SUBBASINS
INFORMATION FOR THIS BASIN WAS COLLECTED FROM WATER SYSTEM TEST DATA
THE SCALE OF THE SOURCE MATERIAL IS 1/20000.

HISTOGRAM OF THE LENGTHS OF ORDER 1

<table>
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<th>Length</th>
<th>Frequency</th>
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</tr>
<tr>
<td>0.1</td>
<td>0.100</td>
</tr>
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</tr>
<tr>
<td>0.3</td>
<td>0.300</td>
</tr>
<tr>
<td>0.35</td>
<td>0.350</td>
</tr>
<tr>
<td>0.4</td>
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</tr>
<tr>
<td>0.45</td>
<td>0.450</td>
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<td>0.5</td>
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<tr>
<td>0.55</td>
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<td>0.7</td>
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<td>1.05</td>
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<tr>
<td>1.1</td>
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<td>1.2</td>
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</tr>
<tr>
<td>1.95</td>
<td>2.000</td>
</tr>
</tbody>
</table>

INSUFFICIENT NUMBER OF POINTS FOR HISTOGRAM BEYOND ORDER 2
C-8
DRAINAGE BASIN BEING ANALYZED IS MAIN BASIN WITH SUBBASINS
INFORMATION FOR THIS BASIN WAS COLLECTED FROM WATER SYSTEM TEST DATA
THE SCALE OF THE SOURCE MATERIAL IS 1/200000
MAP OF DRAINAGE NETWORK SHOWING STREAMS STREAM ORDERS
THE SCALE OF THIS MAP IS 1" = 20000

LEGEND

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>ORDER</th>
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<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
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<tr>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>BOUNDARY</td>
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</tr>
</tbody>
</table>
**THE WATER SYSTEM**

**COMPUTER PROGRAMS FOR WATERSHED ANALYSES**

**DEVELOPED AT**

**UNIVERSITY OF TORONTO**  **PURDUE UNIVERSITY**

**TORONTO, ONTARIO**  **LAFAYETTE, INDIANA**

---

**DRAINAGE BASIN BEING ANALYZED IS MAIN BASIN WITH SUBBASINS**

**INFORMATION FOR THIS BASIN WAS COLLECTED FROM WATER SYSTEM TEST DATA**

**THE SCALE OF THE SOURCE MATERIAL IS 1/20000.**

**STREAM MAGNITUDE STATISTICS**

<table>
<thead>
<tr>
<th>STREAM</th>
<th>NUMBER</th>
<th>LENGTH</th>
<th>FAL</th>
<th>GRADIENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>LINK</td>
<td>OF</td>
<td>IN</td>
<td>IN</td>
<td>FEET</td>
</tr>
<tr>
<td>MAGNITUDE</td>
<td>LINKS</td>
<td>MILES</td>
<td>FEET/MILE</td>
<td></td>
</tr>
</tbody>
</table>

| 1 | 37 | 0.661 | 31.351 | 47.930 |
|   |     | 1.423 | 73.000 | 74.951 |
|   |     | 0.368 | 14.000 | 24.557 |
|   |     | 1.055 | 62.000 | 55.394 |
|   |     | 0.473 | 16.082 | 0.22424 |
|   |     | 0.211 | 12.971 | 14.974 |

| 2 | 13 | 0.426 | 14.154 | 40.970 |
|   |     | 0.457 | 25.000 | 70.292 |
|   |     | 0.212 | 9.000  | 21.313 |
|   |     | 0.445 | 16.000 | 46.179 |
|   |     | 0.20734 | 0.22424 | 0.20946 |
|   |     | 0.144 | 4.761  | 14.475 |

| 3 | 5  | 0.393 | 12.200 | 29.805 |
|   |     | 0.254 | 6.000  | 19.114 |
|   |     | 0.431 | 19.000 | 17.576 |
|   |     | 0.33333 | 0.60708 | 0.50102 |
|   |     | 0.183 | 7.191  | 14.475 |

| 4 | 3  | 0.395 | 13.000 | 32.880 |
|   |     | 0.322 | 9.000  | 31.571 |
|   |     | 0.329 | 13.000 | 2.448 |

| 5 | 2  | 0.279 | 8.500  | 41.391 |
|   |     | 0.298 | 9.000  | 55.917 |
|   |     | 0.161 | 8.000  | 25.865 |
|   |     | 0.137 | 1.000  | 29.052 |

| 6 | 2  | 0.169 | 9.500  | 24.371 |
|   |     | 0.248 | 14.000 | 23.908 |
|   |     | 0.256 | 5.000  | 19.647 |
|   |     | 0.230 | 9.000  | 9.261 |

| 7 | 2  | 0.324 | 6.500  | 19.306 |
|   |     | 0.380 | 9.000  | 21.678 |
|   |     | 0.268 | 4.000  | 14.934 |
|   |     | 0.112 | 5.000  | 8.744 |

| 10 | 1 | 0.507 | 11.000 | 21.703 |
|    |   | 0.618 | 14.000 | 22.658 |
|    |   | 0.566 | 6.000  | 11.857 |
|    |   | 0.454 | 9.000  | 19.818 |
|    |   | 0.317 | 5.000  | 15.761 |
|    |   | 0.565 | 14.000 | 24.798 |
|    |   | 0.429 | 5.000  | 11.646 |
|    |   | 1.223 | 16.000 | 13.079 |
|    |   | 0.702 | 17.000 | 26.426 |

**THIS DRAINAGE NETWORK OF MAGNITUDE 37 CONTAINS A TOTAL OF 73 LINKS.**
DRAINAGE BASIN BEING ANALYZED IS MAIN BASIN WITH SUB BASINS
INFORMATION FOR THIS BASIN WAS COLLECTED FROM WATER SYSTEM TEST DATA
THE SCALE OF THE SOURCE MATERIAL IS 1/20000.
LENGTHS OF SHREVE LINKS (MAGNITUDES)

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<td>0.626</td>
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<td>0.796</td>
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<tr>
<td>6</td>
<td>0.543</td>
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<td>7</td>
<td>0.228</td>
</tr>
<tr>
<td>8</td>
<td>0.254</td>
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<tr>
<td>9</td>
<td>0.291</td>
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<tr>
<td>10</td>
<td>0.298</td>
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<td>11</td>
<td>0.254</td>
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<tr>
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<tr>
<td>13</td>
<td>0.507</td>
</tr>
<tr>
<td>14</td>
<td>0.618</td>
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<tr>
<td>15</td>
<td>0.506</td>
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<tr>
<td>16</td>
<td>0.454</td>
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THE WATER SYSTEM

COMPUTER PROGRAMS FOR WATERSHED ANALYSES
DEVELOPED AT
UNIVERSITY OF TORONTO PURDUE UNIVERSITY
TORONTO, ONTARIO LAFAYETTE, INDIANA

DRAINAGE BASIN BEING ANALYZED IS MAIN BASIN WITH SUBBASINS
INFORMATION FOR THIS BASIN WAS COLLECTED FROM WATER SYSTEM TEST DATA
THE SCALE OF THE SOURCE MATERIAL IS 1/20000.

FALLS OF SHEAVE LINKS (MAGNITUDES)

<table>
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<th>VALUES</th>
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</thead>
<tbody>
<tr>
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<td>73,000 34,000 19,000 20,000 19,000 15,000 15,000 11,000</td>
</tr>
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<td>23,000 16,000 14,000 9,000 11,000 14,000 12,000 10,000</td>
</tr>
<tr>
<td>3</td>
<td>16,000 13,000 18,000 21,000 25,000</td>
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<td>4</td>
<td>7,000 25,000 6,000 14,000 9,000</td>
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<td>5</td>
<td>10,000 9,000 20,000</td>
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<tr>
<td>6</td>
<td>8,000 9,000</td>
</tr>
<tr>
<td>7</td>
<td>5,000 14,000</td>
</tr>
<tr>
<td>8</td>
<td>4,000 9,000</td>
</tr>
<tr>
<td>9</td>
<td>11,000</td>
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<tr>
<td>10</td>
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<td>9,000</td>
</tr>
<tr>
<td>13</td>
<td>5,000</td>
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</tbody>
</table>
THE WATER SYSTEM

COMPUTER PROGRAMS FOR WATERSHED ANALYSES
DEVELOPED AT
UNIVERSITY OF TORONTO PUI RE UNIVERSITY
TORONTO, ONTARIO LAFAYETTE, INDIANA

Drainage basin being analyzed is main basin with subbasins

Information for this basin was collected from water system test data

The scale of the source material is 1:20000.

Gradients of Shreve Links (MAGNITUDES)

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<tr>
<th>MAGNITUDE</th>
<th>VALUES</th>
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<tbody>
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<td>56.492, 53.281, 27.210, 37.564, 47.177, 51.669, 60.814, 37.374</td>
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<tr>
<td></td>
<td>28.763, 33.897, 55.476, 46.974, 47.593, 40.761, 54.687, 60.941</td>
</tr>
<tr>
<td>2</td>
<td>42.332, 25.027, 21.313, 28.950, 51.948, 46.093, 27.950, 53.664</td>
</tr>
<tr>
<td></td>
<td>70.292, 26.365, 52.949, 45.476, 46.271</td>
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<tr>
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<td>27.506, 36.490, 16.914, 30.753, 35.365</td>
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<td>0.291, 0.282, 0.612</td>
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</tr>
<tr>
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<td>0.268, 0.380</td>
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<tr>
<td>11</td>
<td>0.618</td>
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<tr>
<td>14</td>
<td>0.506</td>
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<tr>
<td>15</td>
<td>0.454</td>
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<tr>
<td>16</td>
<td>0.317</td>
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DRAINAGE BASIN BEING ANALYZED IS MAIN BASIN WITH SUBBASINS
INFORMATION FOR THIS BASIN WAS COLLECTED FROM WATER SYSTEM TEST DATA
THE SCALE OF THE SOURCE MATERIAL IS 1/20000.

### TABLE OF BASIN STATISTICS

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<th>STATISTIC</th>
<th>VALUE</th>
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<td>BASIN MAGNITUDE</td>
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<tr>
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<td>DIMENSIONLESS</td>
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<td>TOTAL LENGTH OF ALL CHANNELS</td>
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<td>MAIN STREAM LENGTH</td>
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<td>STRAIGHT-LINE LENGTH OF MAIN STREAM</td>
<td>5.85013</td>
<td>MILES</td>
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<td>WANDERING RATIO FOR MAIN STREAM</td>
<td>1.18153</td>
<td>DIMENSIONLESS</td>
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<td>AZIMUTH OF MAIN STREAM VALLEY</td>
<td>192.76318</td>
<td>DEGREES</td>
</tr>
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<td>BASIN PERIMETER</td>
<td>16.09827</td>
<td>MILES</td>
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<td>BASIN LENGTH (DIAMETER)—LONGEST DIMENSION OF BASIN FROM MOUTH TO PERIMETER</td>
<td>6.08136</td>
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<tr>
<td>BASIN AZIMUTH—ORIENTATION OF BASIN LENGTH LINE,</td>
<td>200.03389</td>
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</tr>
<tr>
<td>TEXTURE RATIO</td>
<td>3.41779</td>
<td>1/MILES</td>
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### TABLE OF BASIN STATISTICS

#### PART B -- PROPERTIES REQUIRING MEASUREMENT OF BASIN AREA.

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### TABLE OF BASIN STATISTICS

#### PART C -- PROPERTIES REQUIRING ELEVATION MEASUREMENTS.

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**THE WATER SYSTEM**

- COMPUTER PROGRAMS FOR WATERSHED ANALYSES
- DEVELOPED AT
- UNIVERSITY OF TORONTO
- PURDUE UNIVERSITY
- TORONTO, ONTARIO
- LAFAYETTE, INDIANA

**DRAINAGE BASIN BEING ANALYZED**
MAIN BASIN WITH SUBASSEMS

**INFORMATION FOR THIS BASIN HAS COLLECTED FROM WATER SYSTEM TEST DATA**

**THE SCALE OF THE SOURCE MATERIAL IS 1/20000**

A LONGITUDINAL PROFILE FROM POINT 55 TO THE MOUTH

VERTICAL exaggeration -- ONE INCH EQUALS 25 FEET

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SELECTED OUTPUT FOR ANALYSIS REQUEST 2

DRAINAGE BASIN BEING ANALYZED IS SUBBASIN NUMBER 1 WITH OWN BOUNDARY
INFORMATION FOR THIS BASIN WAS COLLECTED FROM WATER SYSTEM TEST DATA
THE SCALE OF THE SOURCE MATERIAL IS 1/20000.

TABLE OF COMPUTED STREAM REACHES

--- 21 REACHES OF ORDER 1 REPRESENT THE BASIN BOUNDARIES.

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### The Water System

- Computer programs for Watershed Analyses
- Developed at
- University of Toronto, Purdue University
- Toronto, Ontario, Lafayette, Indiana

Drainage basin being analyzed is Subbasin Number 1 with own boundary.

Information for this basin was collected from water system test data.

The scale of the source material is 1/20000.

**Strahler Stream Order Statistics**

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This drainage network of order 3 contains a total of 15 segments.
THE WATER SYSTEM

COMPUTER PROGRAMS FOR WATERSHED ANALYSES
DEVELOPED AT
UNIVERSITY OF TORONTO
PURDUE UNIVERSITY
TORONTO, ONTARIO
LAFAYETTE, INDIANA

DRAINAGE BASIN BEING ANALYZED IS SUBBASIN NUMBER 1 WITH OWN BOUNDARY INFORMATION FOR THIS BASIN WAS COLLECTED FROM WATER SYSTEM TEST DATA

THE SCALE OF THE SOURCE MATERIAL IS 1/20000.

STREAM MAGNITUDE STATISTICS

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THIS DRAINAGE NETWORK OF MAGNITUDE 11 CONTAINS A TOTAL OF 21 LINKS.
DRAINAGE BASIN BEING ANALYZED IS SUBBASIN NUMBER 1 WITH OWN BOUNDARY
INFORMATION FOR THIS BASIN WAS COLLECTED FROM WATER SYSTEM TEST DATA.

THE SCALE OF THE SOURCE MATERIAL IS 1/20000.

MAP OF DRAINAGE NETWORK SHOWING STRAHSHEM STREAM ORDERS.

THE SCALE OF THIS MAP IS 1/20000.

LEGEND

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SELECTED OUTPUT FOR ANALYSIS REQUEST 3

THE WATER SYSTEM

COMPUTER PROGRAMS FOR WATERSHED ANALYSES
DEVELOPED AT

UNIVERSITY OF TORONTO
PURDUE UNIVERSITY
TORONTO, ONTARIO
LAFAYETTE, INDIANA

DRAINAGE BASIN BEING ANALYZED IS MAIN BASIN WITH SUBBASINS ADDED BY *CONNECT OPTION

INFORMATION FOR THIS BASIN WAS COLLECTED FROM WATER SYSTEM TEST DATA

THE SCALE OF THE SOURCE MATERIAL IS 1/20000

TABLE OF COMPUTED STREAM REACHES

NOTES: 1) A REACH IS THE STRAIGHT LINE JOINING TWO DIGITIZED POINTS.
2) REACHES OF ORDER -1 REPRESENT THE BASIN BOUNDARIES.

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<th>STRAHLER</th>
<th>LENGTH</th>
<th>GRADIENT</th>
<th>REACH</th>
<th>STRAHLER</th>
<th>LENGTH</th>
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<tr>
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<td>ORDER</td>
<td>MILES</td>
<td>FT./MILE</td>
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<td>TO I</td>
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DRAINAGE BASIN BEING ANALYZED IS MAIN BASIN WITH SUBASINS ADDED BY CONNECT OPTION
INFORMATION FOR THIS BASIN WAS COLLECTED FROM WATER SYSTEM TEST DATA
THE SCALE OF THE SOURCE MATERIA IS 1/20000.

STRAHLER STREAM ORDER STATISTICS

<table>
<thead>
<tr>
<th>ORDER</th>
<th>SEGMENTS</th>
<th>STRAHLER</th>
<th>NUMBER</th>
<th>DIFICATION</th>
<th>LENGTH (MILES)</th>
<th>FALL</th>
<th>GRADIENT (FEET/MILE)</th>
<th>AZIMUTH (DEGREES)</th>
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</thead>
<tbody>
<tr>
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<td>1</td>
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THIS DRAINAGE NETWORK OF ORDER 4 CONTAINS A TOTAL OF 35 SEGMENTS.
**THE WATER SYSTEM**

*COMPUTER PROGRAMS FOR WATERSHED ANALYSES*

- UNIVERSITY OF TORONTO
- PURDUE UNIVERSITY
- TORONTO, ONTARIO
- LAFAYETTE, INDIANA

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**DRAINAGE BASIN BEING ANALYZED IS MAIN BASIN WITH SUBBASINS ADDED BY CONNECT OPTION**

**INFORMATION FOR THIS BASIN WAS COLLECTED FROM WATER SYSTEM TEST DATA**

**THE SCALE OF THE SOURCE MATERIAL IS 1/20000.**

**STREAM MAGNITUDE STATISTICS**

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<th>STREAM</th>
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<td>MILES</td>
<td>IN</td>
<td>FEET</td>
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**THIS DRAINAGE NETWORK OF MAGNITUDE 37 CONTAINS A TOTAL OF 47 LINKS.**
DRAINAGE BASIN BEING ANALYZED IS MAIN BASIN WITH SUBBASINS ADDED BY CONNECT OPTION

INFORMATION FOR THIS BASIN WAS COLLECTED FROM WATER SYSTEM TEST DATA

THE SCALE OF THE SOURCE MATERIAL IS 1/20000.

TABLE OF BASIN STATISTICS

<table>
<thead>
<tr>
<th>STATISTIC</th>
<th>VALUE</th>
<th>UNITS</th>
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<tbody>
<tr>
<td>BASIN ORDER</td>
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<td>NUMBER OF SEGMENTS OF ALL ORDERS</td>
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<td>BASIN MAGNITUDE</td>
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<tr>
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<td>MAIN STREAM LENGTH</td>
<td>6.92153</td>
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<tr>
<td>STRAIGHT-LINE LENGTH OF MAIN STREAM</td>
<td>5.85013</td>
<td>MILES</td>
</tr>
<tr>
<td>WANDERING RATIO FOR MAIN STREAM</td>
<td>1.18133</td>
<td>DIMENSIONLESS</td>
</tr>
<tr>
<td>AZIMUTH OF MAIN STREAM VALLEY</td>
<td>192.76310</td>
<td>DEGREES</td>
</tr>
<tr>
<td>BASIN PERIMETER</td>
<td>16.09227</td>
<td>MILES</td>
</tr>
<tr>
<td>BASIN LENGTH (DIAMETER)-LONGEST DIMENSION OF BASIN FROM MOUTH TO PERIMETER</td>
<td>8.08136</td>
<td>MILES</td>
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<tr>
<td>BASIN AZIMUTH-ORIENTATION OF BASIN LENGTH LINE</td>
<td>200.03389</td>
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</tr>
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<td>TEXTURE RATIO</td>
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### TABLE OF BASIN STATISTICS

#### PART A -- PROPERTIES REQUIRING MEASUREMENT OF BASIN AREA.

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<td>11018.621</td>
<td>Acres</td>
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<tr>
<td>Drainage Density</td>
<td>1.52234</td>
<td>Miles/Sq.Mile</td>
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<tr>
<td>Constant of Channel Maintenance</td>
<td>3468.33862</td>
<td>Sq. Feet/Feet</td>
</tr>
<tr>
<td>Channel (Segment) Frequency</td>
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<td>1/Sq. Miles</td>
</tr>
<tr>
<td>Link (Magnitude) Frequency</td>
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<td>1/Sq. Miles</td>
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<td>Area of Circle with Basin Perimeter</td>
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<td>Diameter of Circle Having Basin Area</td>
<td>4.68196</td>
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<td>Basin Circularity</td>
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<td>Elongation Ratio</td>
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<td>Unity Shape Factor</td>
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### TABLE OF BASIN STATISTICS

#### PART C -- PROPERTIES REQUIRING ELEVATION MEASUREMENTS.

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<td>Relief Ratio</td>
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C-26

Drainage basin being analyzed is main basin with subbasins added by connect option.

Information for this basin was collected from water system test data.

The scale of the source material is 1/20000.

Map of drainage network showing streamers, stream orders.

The scale of this map is 1/20000.

---

Legend:

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<th>SYMBOL</th>
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<td>4</td>
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PROGRAM PRERUN

PROGRAM PRERUN (INPUT, OUTPUT, PLOT, TAPE5=INPUT, TAPE6=OUTPUT)

PRERUN -- A PROGRAM DESIGNED TO PRODUCE CALCOMP MAPS OF
STREAM BASINS USING THE STREAM GEOMETRY AS RECORDED
BY THE CODE DEVELOPED FOR THE WATER SYSTEM

ONE COMPLETE DATA SET MAY CONTAIN BASIC STREAM GEOMETRY DATA
OR ORDER AND/OR MAGNITUDE DATA FOR THE STREAM SEGMENTS

THIS PROGRAM REQUIRES ONE DATA CARD TO BE PLACED BEFORE
ALL BASIN DATA SETS
THIS CARD MUST CONTAIN THE NUMBER OF BASINS TO BE PLOTTED
AND THIS NUMBER PUNCHED IN COLUMN 1 (THEREFORE LESS THAN 10)
The BASIN DATA SETS FOLLOW THIS CARD

EACH STREAM GEOMETRY DATA SET MAY BE THE SAME DATA PACKAGE
CONTAINING THE SAME CARDS AS USED TO OBTAIN A RUN ON THE
WATER SYSTEM. THE PROGRAM SCANS THESE CARDS AND OBTAINS THE
NECESSARY INFORMATION WITH NO NEED FOR ADDITIONAL
SPECIFICATION CARDS

THIS PROGRAM HAS PROVISION FOR ONE OPTION. THIS IS THE
*SCALE OPTION AND IS USED TO PRODUCE CALCOMP MAPS OF A
SPECIFIED SCALE. THIS OPTION IS OBTAINED BY THE ADDITION OF
ONE OPTION CARD TO THE DATA PACKAGE CONTAINING OTHER OPTION
SPECIFICATION CARDS. THE PLOTTING SCALE IS PROVIDED IN
ADDITION TO THE SCALE WHICH THE DATA WAS COLLECTED AT. THE
*SCALE OPTION CARD APPEARS LIKE THIS:
COL 1-6 *SCALE
COL 21-29 THE PLOTTING SCALE (REAL NUMBER)

EACH DATA SET FOR A BASIN MAP WITH THE ORDERED SEGMENTS OR
LINK MAGNITUDES WOULD NOT AUTOMATICALLY BE IN THE FORM
NECESSARY FOR A WATER SYSTEM RUN AND WILL REQUIRE SOME
ADDITIONAL CARDS

A SAMPLE DATA SET WOULD APPEAR LIKE THIS:
CARD 1 COL 1-6 *WATER
CARD 2 COL 1-5 *IDSM
CARD 3 COL 1-5 *DATA
DATA FOLLOWING IN THE FORM AS SPECIFIED
IN THE WATER SYSTEM

DIMENSION K(51), Y(51), KODE(51), 2(51), DAT(1000,41), RUNCE(20,3), FORM
11181, TITLE (20), SOURCE (20)
COMMON DAT
INTEGER HYP, USCALE
DATA NAME/4H*DAT/,.ids/4H*IDS/,;HYP/4H*HYP/,USCALE/4H*SCALE/
HYP=0

READ IN THE NUMBER OF BASINS TO BE PLOTTED

READ 15,1801 NP

CALL PLOTTING ROUTINE

CALL PLOTS (*AK, TURNT*11,*FCV0536*)
CALL PLOTX4 (190,0)
CALL PLOT (10,010,000-3)
DO 240 IP=1,NP

READ THROUGH THE DATA PACKAGE AND DETERMINE THE NECESSARY
INFORMATION FOR THE PLOT

IDSM=1
ISCV=0
HYP=0
DO 6 J=1,100
READ (5,1) INAME,TEMP
IF (INAME.EQ.'SCALE') GO TO 2
IF (INAME.EQ.'NAME') GO TO 1
IF (INAME.EQ.'SCALE') ASCALE=TEMP
IF (INAME.EQ.'IDS') IDSW=2
IF (INAME.EQ.'NMP') HYP=1
IF (INAME.EQ.'NAME') GO TO 7
A CONTINUE
GO TO 240
C
7 KOUNT1=0
KOUNT3=0
CK=6
NMP=0
XMAX=0.0
XMIN=10000.0
YMAX=0.0
YMIN=10000.0
C
READ IN THE SOURCE, TITLE, AND SCALE OF THE DATA
C
READ (5,230) (TITLE(I),I=1,20)
READ (5,230) (SOURCE(I),I=1,20)
READ (5,235) SCALE
C
READ IN THE NUMBER OF DATA POINTS PER CARD AND THE DATA FORMAT
C
READ (5,115) NPTS, FORM
C
WRITE THE HEADING
C
WRITE (6,160)
C
WRITE OUT DATA TABLE HEADING
C
WRITE (6,165)
C
READ THE DATA, STORE THE DATA IN DAT(N,N), AND WRITE OUT DATA
C
IF (HYP.EQ.0.AND.IDSW.EQ.11) GO TO 8
READ (5, FORM) (X(K), Y(K), KODE(K), Z(K), K=1,NPTS)
GO TO 9
C
INITIALIZE THE Z ARRAY IF THE DATA LACKS Z VALUES
C
READ IN THE DATA WITHOUT Z VALUES
C
DO 11 JR=1,5
   11 (JIB)= 0
READ (5, FORM) (X(K), Y(K), KODE(K), K=1,NPTS)
C
CHECK THAT THE FIRST DATA POINT IS CODE 5
C
IF (KODE(1).NE.5.AND.NUM.EQ.0) GO TO 145
   NUM=1
GO TO 25 K=1,NPTS
   KK=KODE(K)
   GO TO (10,20,15,20,30,20), KK
10   KOUNT1=KOUNT1+1
   GO TO 20
C
15 KOUNT3=KOUNT3+1

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C ----------------------------------------
C SEARCH FOR MAXIMUM AND MINIMUM X AND Y COORD.
C ----------------------------------------
C IF (X(K).GT.XMAX) XMAX=X(K)
IF (X(K).LT.XMIN) XMIN=X(K)
DAT(N,1)=X(K)
IF (Y(K).GT.YMAX) YMAX=Y(K)
IF (Y(K).LT.YMIN) YMIN=Y(K)
DAT(N,2)=Y(K)
IF (KODE(K).EQ.1) KODE(K)=KODE(K)
DAT(N,4)=KODE(K)
25 WRITE (6,170) N, (DAT(N,J), J=1,4)
GO TO 5
C
30 NTOE=N
WRITE (6,185)
WRITE (6,160)
WRITE (6,190)
XBAR=XMAX-XMIN
YBAR=YMAX-YMIN
WRITE (6,195)
WRITE (6,200) XMAX,XMIN,YMAX,YMIN
C ----------------------------------------
C CHOOSE A SCALE TO MAKE MAXIMUM USE OF 11 INCH PAPER WIDTH
C IPSW DETERMINES WHETHER THE MAP IS ROTATED 90 DEGREES TO FIT ON
C THE 11 INCH PAPER  IPSW = 1 MEANS ROTATION
C ----------------------------------------
C AX=YBAR*.525
IF (XBAR.LE.AX) GO TO 35
SF=10.0/YBAR
IPSW=0
50 RETURN
35 SF=10.0/(XBAR+2.0)
IPSW=1
40 KTEST=KOUNT+1
IF (KLOC. EQ.4) SF=SCALE/ASCALE
IF (IPSW.EQ.0 .AND. (SF*YBAR1.GT.10.3)) GO TO 275
IF (IPSW.EQ.1 .AND. (SF*XBAR1+SF*2.0).GT.10.3)) GO TO 275
MTHM=0.07/5F
IC=I
IK=K
IF (IPSW.EQ.0) GO TO 300
AX=YBAR*SF+.525
BX=XBAR+.75*SF
IF (AX.LT.100) BX=.800
PANG=90.0
GO TO 305
300 AX=XBAR+.75*SF
IF (AX.LT.100) AX=.800
BX=(YBAR*SF)+.525
PANG=-90.0
GO TO 305
305 CALL PLOT (0.,-0.25,3)
CALL PLOT (0.4,-AX,2)
CALL PLOT (BX,-AX,2)
CALL PLOT (BX,-.025,21)
AHTH=-.14
R=BX-.10
S=(AX-.375)/1.20
CALL SYMBOL (R,S,AHTH,.44)H*******************************************************************************
[****,PANG,.47)
CALL SYMBOL (999.,999.,.0,47)H THE WATER SYSTEM
1 *PANG,.47
CALL SYMBOL (999.,999.,.0,47)H COMPUTER PROGRAMS FOR WATERSHED ANALYSES
1 *PANG,.47
CALL SYMBOL (999.,999.,.0,47)H DEVELOPED AT
1 *PANG,.47
CALL SYMBOL (999.,999.,.0,47)H UNIVERSITY OF TORONTO PURDUE UNI
1VERSITY *PANG,.47
CALL SYMBOL (999.,999.,.0,47)H LAFAYETTE, INDIANA *PANG,.47
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A 490
CALL SYMBOL (999, 999, 0, 47)  
*PANG, 47)
CALL SYMBOL (999, 999, 0, 47)  
*******PANG, 47)
SCALE=SCALE/SP
IF (ISL.EQ.1) SCALE=SCALE
R=0.75
S=1.0
CALL SYMBOL (S, 5, 0, TITLE, PANG, 60)
CALL SYMBOL (999, 999, 0, 21, PANG, -1)
CALL SYMBOL (999, 999, 0, SQUARE, PANG, 60)
CALL SYMBOL (999, 999, 0, 21, PANG, -1)
CALL SYMBOL (999, 999, 0, 21, PANG, -1)
CALL SYMBOL (999, 999, 0, PANG, 29)

11
CALL NUMBER (999, 999, 0, SCALE, PANG, -1)
CALL PLOT (1.5, 0, 20, 30)
AXES(1, 3, 7, SF1=1, BAR, SF1)=2=0
CALL PLOT (0, 0, AX, -3)
CALL FACTOR (SF)
DO 10 L=1, NTOT
1000=DSM
IF (IPS, EQ, 1) GO TO 50
X=DAT(L, 1)-XMIN+0.02
Y=DAT(L, 2)-YMIN+0.02
GO TO 55
50
X=DAT(L, 2)-YMIN+0.02
Y=DAT(L, 1)-XMIN+0.02
GO TO (125, 120, 115, 75, 60, 140, 120) ID
55
IF (IK, NE, 2) GO TO 140
RUNC(L, 1)=XX
RUNC(L, 2)=YY
CALL PLOT (XX, YY, 31)
IF (DSM, NE, 1) ID=100+ID+1
CALL DTR (ID1, XX, YY, XN, YN, P)
IF (DSM, NE, 1) GO TO 40
CALL WTRC (XX, YY, TITLE, P, 1, L, 0, 1)
65
IF (IDATALL, 31, NE, 00) GO TO 70
IK=1
GO TO 135
70
IK=2
GO TO 135
75
IF (IK, NE, 2) GO TO 90
IF (IPS, EQ, 1) GO TO 60
X=DAT(L, 1)-XMIN+0.02
Y=DAT(L, 1)-YMIN+0.02
GO TO 85
80
X=DAT(L, 2)-YMIN+0.02
Y=DAT(L, 1)-XMIN+0.02
85
CALL PLOT (XX, YY, 31)
IK=1
90
CALL PLOT (XX, YY, 21)
IF (IDS, NE, 1) GO TO 95
CALL DTR (100, XX, YY, XN, YN, L, P)
CALL NUMBER (XX, YY, N1, H1, P1, 30, 0, 5, 1)
95
IF (L, EQ, MTOT) GO TO 100
100
L=1
IF (DATALL, 31, EQ, 40) GO TO 135
CALL PLOT (XX, YY, 31)
IF (IPS, EQ, 1) GO TO 105
X=DAT(L, 1)-XMIN+0.02
Y=DAT(L, 1)-YMIN+0.02
GO TO 110
105
X=DAT(L, 2)-YMIN+0.02
Y=DAT(L, 2)-YMIN+0.02
110
CALL PLOT (XX, YY, 21)
GO TO 140
C
115
IC=IC+1
RUNC(I, 1)=XX
RUNC(I, 2)=YY
RUNC(I, 3)=L
CALL PLOT (XX, YY, 21)
CALL DTR (100, XX, YY, XN, YN, L, P)
CALL NUMBER (XX, YY, N1, H1, P1, 30, 0, 5, 1)
GO TO 135
CALL PLOT (XX,YY,2)  A 658
CALL DTR (I00,XX,YY,XN,YN,LP)  A 660
CALL NUMBER (XN,YN,HTH,P,-90.0,-11)  A 662
GO TO 135  A 664

CALL PLOT (XX,YY,2)  A 666
CALL DTR (I00,XX,YY,XN,YN,LP)  A 666
CALL NUMBER (XN,YN,HTH,P,-90.0,-11)  A 666
XX=RUNC(1C,11)  A 670
YY=RUNC(1C,21)  A 672
IF (IDM+EQ.0) GO TO 130  A 674
IDM=100+1  A 676
CALL DTR (I00,XX,YY,XN,YN,LP)  A 678
IC=IC+1  A 680
CALL PLOT (XX,YY,3)  A 682

WRITE (6,259)  A 684
L=XX,YY  A 686
CALL FACTOR(1,0)  A 688
R=BX**3.0  A 690
C=CX**R  A 692
IF (C>15.0.LT.150.0) GO TO 265  A 694
WRITE (6,160)  A 696
WRITE (6,250)  A 698
GO TO 245  A 700
WRITE (6,160)  A 702
WRITE (6,255)  A 704
WRITE (6,260) (TITLE(I,I=1,20))  A 706
AX=AX+0.25  A 708
CALL PLOT (xo,ax,31)  A 710
IF (IC.EQ.0) GO TO 240  A 712
IC=IC+1  A 714
WRITE (6,210)  A 716
WRITE (6,215) (RUNCI(J,J=1,3),I=2,II)  A 718
GO TO 240  A 720

WRITE (6,220)  A 722
GO TO 240  A 724

WRITE (6,225)  A 726
GO TO 240  A 728

WRITE (6,270) (TITLE(I,I=1,20))  A 730
CALL PLOT (R,0.0,-3)  A 732

FORMAT (164,16X,F8.0)  A 734
FORMAT (1H11,12X,451H)  A 736
IF S E M T R E A S T U N I T , 13.14,143.144.145,146,147,148,149,150)  A 738
140 FORMAT (1H21,1H)  A 740
WRITE (6,270) (TITLE(I,I=1,20))  A 742
CALL PLOT (R,0.0,-3)  A 744

== TERMINATE THE PLOTTING ==  A 746

== END ==  A 748

CALL PLOTNOD  A 750
STOP  A 752

== END ==  A 754

160 FORMAT (1H11,12X,451H)  A 756
170 FORMAT (1H11,12X,451H)  A 758
180 FORMAT (1H11,12X,451H)  A 760
190 FORMAT (1H11,12X,451H)  A 762
200 FORMAT (1H11,12X,451H)  A 764
210 FORMAT (1H11,12X,451H)  A 766
220 FORMAT (1H11,12X,451H)  A 768
230 FORMAT (1H11,12X,451H)  A 770
240 FORMAT (1H11,12X,451H)  A 772
250 FORMAT (1H11,12X,451H)  A 774
260 FORMAT (1H11,12X,451H)  A 776
270 FORMAT (1H11,12X,451H)  A 778
280 FORMAT (1H11,12X,451H)  A 780
290 FORMAT (1H11,12X,451H)  A 782
300 FORMAT (1H11,12X,451H)  A 784
310 FORMAT (1H11,12X,451H)  A 786
320 FORMAT (1H11,12X,451H)  A 788
330 FORMAT (1H11,12X,451H)  A 790
340 FORMAT (1H11,12X,451H)  A 792
350 FORMAT (1H11,12X,451H)  A 794
360 FORMAT (1H11,12X,451H)  A 796
370 FORMAT (1H11,12X,451H)  A 798
380 FORMAT (1H11,12X,451H)  A 800
390 FORMAT (1H11,12X,451H)  A 802
400 FORMAT (1H11,12X,451H)  A 804
410 FORMAT (1H11,12X,451H)  A 806
420 FORMAT (1H11,12X,451H)  A 808
430 FORMAT (1H11,12X,451H)  A 810
440 FORMAT (1H11,12X,451H)  A 812
450 FORMAT (1H11,12X,451H)  A 814
460 FORMAT (1H11,12X,451H)  A 816
470 FORMAT (1H11,12X,451H)  A 818
480 FORMAT (1H11,12X,451H)  A 820
490 FORMAT (1H11,12X,451H)  A 822
500 FORMAT (1H11,12X,451H)  A 824
510 FORMAT (1H11,12X,451H)  A 826
SUBROUTINE DTR

SUBROUTINE DTR (100,XX,YY,XN,YN,L,P)
COMMON DAT(1000,4)
GO TO 15,10,151,100
5 XN=XX
YH=YY-0.03
P=L
GO TO 20
10 XN=XLAST+((XX-XLAST)/2.0)
YN=YLAST+((YY-YLAST)/2.0)-0.03
P=DOT(L,C)
15 XLAST=XX
YLAST=YY
20 RETURN
END

TYPICAL INPUT DATA

DATA SET 1 (point numbers)

DIFFERENT WATER SYSTEM TEST DATA

Y

14 09 5 1500 20 08 4 1500 75 30 4 1690
120 08 4 1700 132 070 4 1710 137 090 4 1690
137 104 4 1660 128 120 4 1680 119 160 4 1710
180 194 4 1730 080 199 4 1710 060 195 4 1700
67 194 4 1710 030 168 4 1730 022 150 4 1733
112 159 4 1730 011 090 4 1726 003 070 4 1700
200 080 4 1680 010 133 4 1650 015 020 2 1509
301 030 3 1517 030 029 2 1530 040 033 2 1545
345 030 2 1560 054 033 1 1590 030 039 2 1522
400 129 2 1529 051 053 3 1533 060 042 2 1552
403 022 3 1556 070 038 2 1565 076 038 1 1590
704 066 2 1561 085 047 1 1575 062 061 3 1538
754 066 2 1542 045 064 2 1554 036 057 1 1562
754 071 3 1547 044 064 2 1556 042 090 3 1563
754 097 2 1571 056 107 1 1582 036 103 1 1578
754 097 3 1556 035 078 2 1564 023 083 3 1570
728 094 1 1594 020 076 2 1580 013 072 2 1588
106 024 1 1610 068 064 2 1542 036 072 2 1548
200 077 3 1552 076 057 2 1560 064 063 3 1566
204 084 3 1574 109 086 1 1589 094 075 3 1586
254 088 4 1598 082 056 1 1612 093 067 3 1591
100 066 2 1598 107 063 2 1608 112 059 2 1610
111 058 1 1630 096 061 3 1602 094 059 2 1610
209 097 3 1623 100 057 2 1615 106 055 1 1629
208 091 3 1672 099 090 3 1680 059 100 2 1591
203 111 3 1695 112 120 2 1618 115 121 2 1629
028 118 2 1613 099 121 3 1619 100 130 2 1627
204 140 1 1637 094 125 2 1625 091 132 2 1634
160 091 3 1594 120 083 3 1598 123 075 2 1612
176 071 3 1523 119 076 2 1610 115 071 2 1618
116 064 1 1628 115 092 2 1594 125 106 2 1605
310 105 1 1625 070 037 3 1557 063 093 2 1568
057 095 1 1577 069 095 2 1561 067 101 3 1566
067 105 1 1578 083 113 2 1592 096 115 1 1610
068 117 3 1572 060 125 2 1584 052 126 3 1592
045 118 3 1610 040 115 2 1628 033 113 2 1637
028 113 2 1645 025 109 1 1654 040 120 2 1619
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### DATA SET 2 (orders and magnitudes)

#### WATER

#### DISW

#### DATA

ORDERED REACHES OF MAIN BASIN WITH SUBBASINS

WATER SYSTEM TEST DATA

### 2000C*

(13x2, Fb 2, Zc 2, Fb 2, Gc 0, 2x 25.0 01)

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*END
THE WATER SYSTEM

COMPUTER PROGRAMS FOR WATERSHED ANALYSIS
DEVELOPED AT
UNIVERSITY OF TORONTO, PLAQUE UNIVERSITY
TORONTO, ONTARIO, LAFAYETTE, INDIANA

ORDERED REACHES OF MAIN BASIN WITH SUB BASINS
WATER SYSTEM TEST DATA
DRAINAGE BASIN BEING ANALYZED IS SUBBASIN NUMBER 1 WITH OWN BOUNDARY

INFORMATION FOR THIS BASIN WAS COLLECTED FROM WATER SYSTEM TEST DATA

THE SCALE OF THE SOURCE MATERIAL IS 1/20000.

MAP OF DRAINAGE NETWORK SHOWING STRAHLENS STREAM ORDERS.

THE SCALE OF THIS MAP IS 1/20000.

LEGEND

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DRAINAGE BASIN BEING ANALYZED IS SUBBASIN NUMBER 2 WITH OWN BOUNDARY.

INFORMATION FOR THIS BASIN WAS COLLECTED FROM WATER SYSTEM TEST DATA.

THE SCALE OF THE SOURCE MATERIAL IS 1/20000.

MAP OF DRAINAGE NETWORK SHOWING STRAHLERS STREAM ORDERS.

THE SCALE OF THIS MAP IS 1/20000.

LEGEND

SYMBOL ORDER

1 1
2 2
3 3

BOUNDARY
THE WATER SYSTEM

COMPUTER PROGRAMS FOR WATERSHED ANALYSES
DEVELOPED AT
UNIVERSITY OF TORONTO  PURDUE UNIVERSITY
TORONTO,ONTARIO  LAFAYETTE,INDIANA

DRAINAGE BASIN BEING ANALYZED IS SUBBASIN NUMBER 3 WITH OWN BOUNDARY
INFORMATION FOR THIS BASIN WAS COLLECTED FROM WATER SYSTEM TEST DATA

THE SCALE OF THE SOURCE MATERIAL IS 1/200000.

MAP OF DRAINAGE NETWORK SHOWING STRAHLERS STREAM ORDERS.

THE SCALE OF THIS MAP IS 1/20000.
The Water System

Drainage basin being analyzed is Subbasin number 4 with own boundary. Information for this basin was collected from Water System Test data.

The scale of the source material is 1/20000.

Map of drainage network showing streamers stream orders.

The scale of this map is 1/20000.

Legend

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E-6

Drainage basin being analyzed is main basin with subbasins added by connect option.

Information for this basin was collected from water system test data.

The scale of the source material is 1/20000.

Map of drainage network showing streams, stream orders.

The scale of this map is 1/25000.

junction point

subbasin 3

connect point

junction point

subbasin 1

connect point

Legend:

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