Component-I(A) - Personal Details

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Component-I (B) - Description of Module

Items	**Description of Module**
Subject Name	Geography
Paper Name	Geomorphology
Module Name/Title	Geomorphological Models
Module Id	GEO/02
Pre-requisites	
Objectives	To comprehend the concept of Models in geography Understand Models in context of Systems Identify systems in Geomorpohology as Natural Analogue, Physical and General System Geomorphological models under each Major system
Keywords	Mathematical model, Hardware model, Analogue Model,

Models in Geomorphology

Introduction

Like any other discipline Model building in Geomorphology plays a very significant role, this was very vividly highlighted by various geographers.The progression of abridging real landscapes to manageable proportions is model building. Defined in a general way, a geomorphic model is a simplified representation of some aspect of a real landscape that happens to interest a geomorphologist. It is an attempt to describe, analyse,simplify or display a geomorphic system(Strahler, 1980). Model building in geomorphology, has been strongly influenced by the systems analysis and system approach is most suitable to provide insights and make predictions. The dynamics of different systems are explained by these geomorphic models and the major construed systems in geomorphology are identified as the **Natural Analogue system**, the **physical system** and the **general system**.

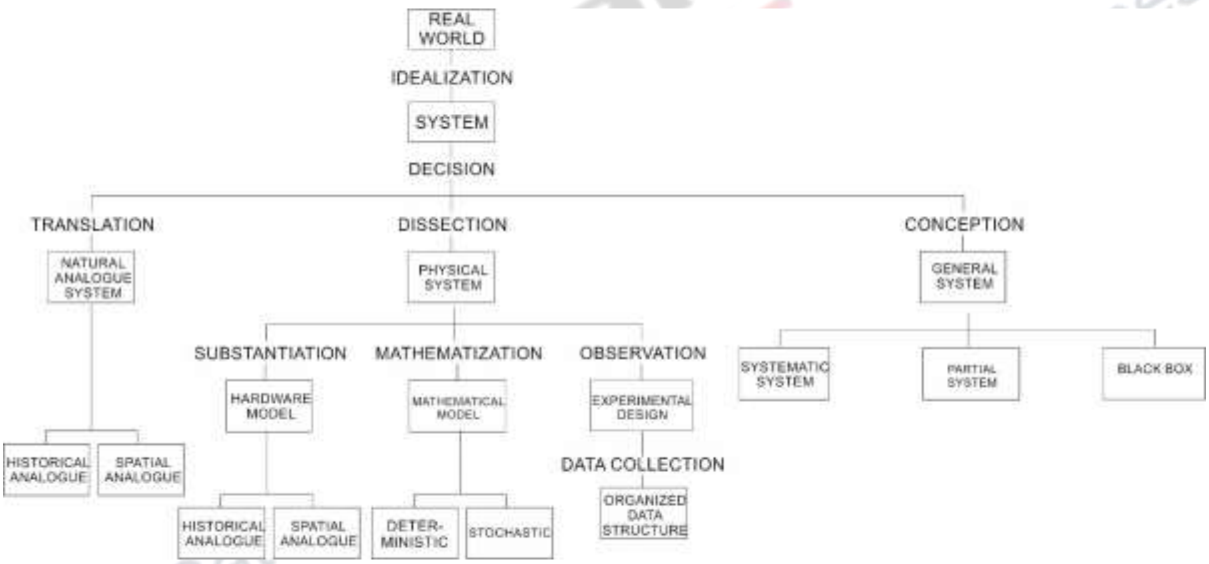

Figure 1: Geographic Activity
Source: Haggett, P and Chorley, R.J., Models in Geography

Natural Analogue Systems

One of the most widespread methods of illuminating a given geomorphological phenomenon is to interpret its significant or characteristics features through some analogous natural system that is believed to be easier, better known or in some deference more voluntarily observable than the original. By such reasoning we see how classifications (i.e. like objects grouped together for the purpose of making some general statements about all of them) outline a fundamental part of one type of model building. There are two classes of natural analogue systems-the **historical** and the **spatial**.

Historical analogues collectively explain geomorphic phenomena with respect to their assumed positions in time-controlled sequences, on the postulation that what has happened previous to the current situation will happen again, or that what existed in the past and had application and importance then has relevance to what exists now. Consequently, the phenomenon under reflection is viewed as part of a progression of real, individual but interrelated events.(Simpson,1963, p.25;see also Kits,1963).

It is after all the strongest instructive mortar of geomorphology that past landscapes can to a large extent be entirely understood with reference to present ones (Hutton,1975). Wills (1929) has efficiently used analogies with present deserts and illustrate and gives detail of the late-Carboniferous and Permian landscapes of Britain.From another point of view, it might be argued that present landscapes can be better understood with reference to past ones, and recently Ambrose(1964,.p.1850) has suggested that the sedimentary stripping of the sub-Ordovician paleoplain of the Canadian shield is reactivating an ancient topography that is practically intact.

Spatial analogues connect one set of phenomena with other, on the assumption that observations at another place are easier to make or simpler in character than those of the preliminary; or that resemblance with other areas believed to be in some way analogous will allow one to make more confident and meaningful generalizations about the original area.

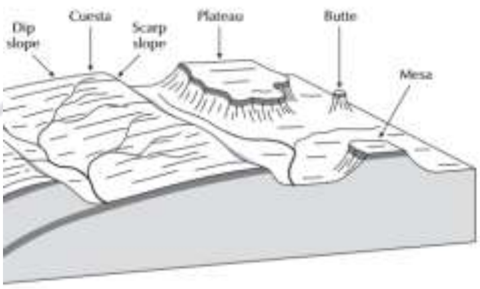

Figure 2: Spatial Analogue Model

It is in this last sense that the classificatory character of this segment of model building appears most clearly. The most widespread form of spatial analogue model is that in which adjacent flanking areas are grouped together on the assumption that each unit can be understood in terms of generalizations about some larger region of which it forms a part. Consequently, on the continental scale of morphotectonics (Hills,1961 and 1963) and on the regional scale e.g., structural Geomorphology (Melton,1959) individual landforms are grouped into tectonic or structural provinces.

An additional type of geomorphic spatial analogue is the so-called natural model in which what are believed to be characteristic assemblages of landform units are identified and presented as type assemblages.

Physical systems

The physical system approach is most perceptibly associated with conventional scientific method and was the first to be applied to quantitative data in the earth services, particularly in the 1930s and 1940s. This approach is based on the view that research can best be pursued by dissecting the geomorphic problem structure into its component parts such that the operation of each part and the interactions between the parts can be pragmatically examined showing the way to a full synthesis of the components into a working system. It is expedient to divide the physical system investigations into three, often interrelated types, those in which the significant structural elements are substantiated into a **hardware model**, mathematised into a **mathematical model**, or subjected to field observation under some expedient **experimental design**.

Hardware models

It has been seen that geomorphologist like all scientists, construct models at various levels of abstraction. The most primary level requires a modification of scale. In this case, a hardware model represents the system. There are two main kinds of **hardware models - scale models and analogue models.**

The most precious hardware models have been those which were on the whole parts of unscaled reality, tightly constrained and examined in great detail. The two most obvious instances of this are Bagnolds(1941) wind tunnel observations on sand movement and Schumm's (1956) investigation of the erosional forms and transformations of the Perth Amboy badlands. This gives the inkling to the indispensable complexity of the construction of hardware models in geomorphology, that the complications of nature compel scaling of changes of media requirements of a very high order of complexity. It is accordingly easier for an engineer to replicate a life-size man-made structure than for an earth scientist to invoke a natural complex.

Scale models are almost accurate replica of a section of the real world, which they bear a resemblance to in some very palpable respect and the similarity may from time to time be so close that the scale model becomes simply a rightfully -controlled portion of the real world.

The most understandable geomorphic benefits of the use of scale models are the elevated level of control which can be achieved over the simplified experimental conditions and the manner in which time can be compressed.

The wide-ranging problems of scaling and of dimensional similarity have been comprehensively treated by Murphy, Wilson, Duncan, Langhaar and particular references to the earth science by Hubbert and Strahler. The major issue in scale models is that the changes in scale affect the relationships between certain properties of the model and the real world invarious ways such that for example the kinematic scale ratios perform differently from linear scale ratios. Identical difficulties are involved with attempts to produce meaningful dynamic scale ratios. Such disagreements can be generally avoided in any of the three interrelated ways.

Firstly, a deformation of one significant attribute can be reduced or eradicated by the distortion of another attribute for example a deformation of the vertical linear scale of river models enables the effects due to turbulence to be more or less faithfully reproduced. The second and the most significant way in which analogous model ratios can be fashioned is by dimension less combinations of attributes. Consequently, a combination of density, velocity, depth and viscosity, permits gluey effects to be perfectly reproduced and a combination of velocity, length and the acceleration of gravity is important where gravity effects need to be accurately scaled in the model.

Thirdly, one or more of the medium can be changed in the model to aid the truer scaling of other effects but such considerations naturally lead one into the second type of hardware model-the analogue model. Problems of scaling natural geomorphic phenomena give details the malfunction of attempts to reproduce entire fluvial landform associations and their transformations and why the most successful work has involved attempts to reproduce restricted features like river meander bends and beach segments.

Scale or iconic models are diminutive, or every now and then extremely large copies of systems. They may be at variance from the systems they represent merely in terms of size. Relief models which are made out of a suitable material such as plaster of Paris, have been

used to symbolize topography as a three- dimensional surface. It is not necessary that Scale models have to be static: models fashioned by utilizing material similar to those prevalent in nature, but with the dimensions of the system scale down, can be utilised to kindle a behavior that is not static.

Put into practice, scale models of this kind replicate a portion of the real world so meticulously that they turn out to be, controlled natural systems. The distinguished benefit of this type of scale model, in which the geometry and the dynamics of the model and system are practically indistinguishable, is that the investigator exercises an elevated level of control above the simplified experimental conditions.

Other scale models use natural materials, but the geometry of the model is divergent to the geometry of the system it replicates - the size of the system is scaled down by the investigator.

The procedure of plummeting the size of the system possibly will create a number of uncomfortable situations with respect to scaling, for example, a model of the Severn estuary made at a scale of 1:10,000 can with no trouble conserve geometrical and topographical relations. On the other hand, when adding water, an actual depth of water, say, seven metres is represented in the model by a layer of water less than 0.7mm deep. In such a thin layer, surface tensions will cause massive issues, and it will be impracticable to set alight tidal range and currents uniformly; material scale down to represent sand in the real system would be so minute that a large amount of it would float. These issues of scaling are frequently surmountable, to a definite extent at least, and scale models are used to imitate the behaviour of an assortment of geomorphic systems. For example, scale models have assisted studies of the dynamics of the rivers and river systems using waterproof troughs and flumes, and supported studies of talus slopes.

Analogue models are further abstract scale models. Analogue models engage radical changes in the medium of which the model is constructed. For the largest part commonly used analogue models are maps and remotely sensed images. On a map, the surface features of a landscape are reduced in scale and represented by symbols: rivers by lines, relief by contours and spot heights by points for instance. Remotely sensed images like aerial photographs and satellite imageries represent specific properties of the landscape systems at a reduced scale.

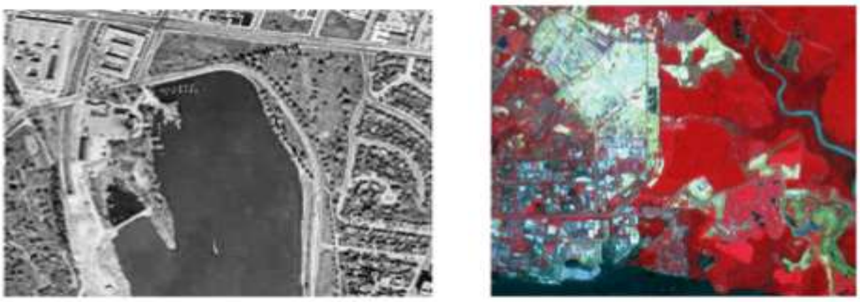

Figure 3: Static Analogue Model

Maps and remotely sensed images are, apart from where a series of them is offered for different times, **static analogue** models. **Dynamic analogue** models may also be built.

MATHEMATICAL MODELS

A mathematical model can be defined as an abstraction in that it substitutes objects, forces, event etc., by an expression containing mathematical variables, parameters, and constants involving the acceptance of a number of idealizations of variety of phenomena studied and in assigning to the assortment of entities involved some austerely defined properties. The indispensable features of the phenomena are then equivalent to the relationship between firm abstract symbols, which we can write down. The phenomena in consideration bear a resemblance to closely something enormously basic, with very few attributes. The resemblance is so accurate that the equations are a kind of working model, from which we can forecast features of the real phenomena which we have never observed.

Figure 4 : Mathematical Model
Source: Drainage Basin Network, Leopold and Langbein, 1962

The general type of geomorphic mathematical model is the one which concerns some simplified statement of definite significant features of the real world, which can be transformed according to assumptions concerning the fundamental operation of the system yielding by checking the model forecasts against the proper real-world situations. Some information about the primary mechanisms engaged and the sequence of geometric changes to which the earth's surface experiences with the passage of time are integral to this model. Consequently, mathematical examination follows the symbolic statement of the assumed primary static and dynamic relationships and the logical mathematical conclusions then are tested against the real world and the effects envisaged by the model point toward the success which we have had in building the original model. The dissimilarities exposed then might lead to the unearthing of auxiliary causes and these observed facts may be understood in greater detail. Mathematical models are frequently divided into categories like **deterministic** and **stochastic**.

Those based on classical mathematical notions of exactly predictable relationships between independent and dependent variables(that is, between cause and effect) are called **Deterministic mathematical models** and comprise of a set of exactly specified mathematical assertions from which exceptional consequences can be deduced by logical mathematical arguments. Such models are very closely concerned with relationships and driving forces between the factors identified in the simplified model. The most widespread type of deterministic geomorphic model engages the transformation of slope profiles under a variety of assumptions.

Stochastic mathematical models include random components that permits different possible results emanating from given set of initial conditions. An example of stochastic model is one in which simulation of individual streams originating under varied conditions or forces operating at random link forms stream network (Summerfield, 1991)

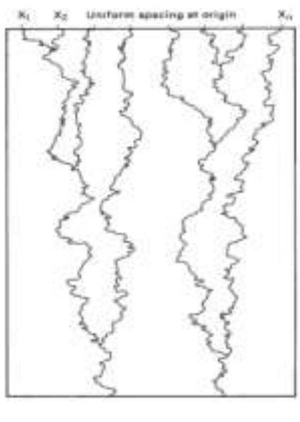

Figure 5 : Stochastic mathematical Model, Wolman and Miller, 1964
Development of rill on hill slope

EXPERIMENTAL DESIGN MODELS

In terms of the contributions made to geomorphology, the foremost aspect of the physical systems approach engages the understanding that within a given range of observational data lies definite meaningful component parts that can be recognised by making use of a suitable experimental design. On the basis of the experimental design, constructed with reference to some conceptual model of the nature of the difficulty and appropriate operational definitions of its component parts, the numerical data are collected, checked with respect to their scalar and number-system distinctiveness and a 'data matrix' is composed. This data structure is frequently analysed by regression type statistical techniques to construct a simple variable system which workable correlations are acknowledged engaging the course and strength of assumed causation.

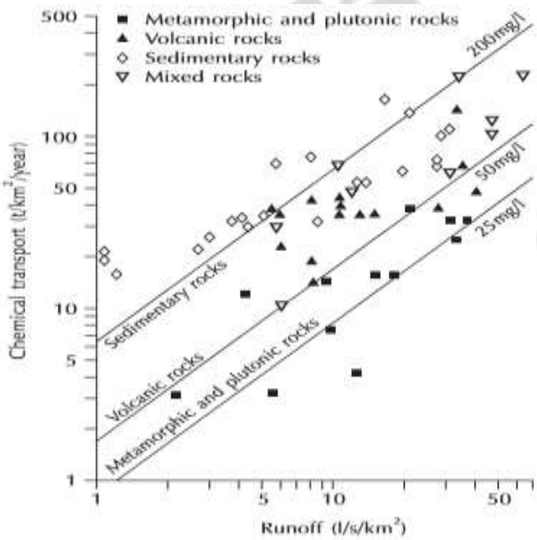

Figure 6: Experimental Design Model

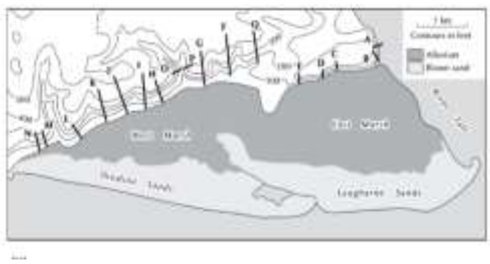

Figure 7: Experimental Design Model

GENERAL SYSTEMS

The general system approach to the study of landforms rests upon some extensive attitude to groups of geomorphic phenomena which is obtained as the consequence of experience or insight. For this reason, the prominence lies in the organisation and operation of the system as an entire system or as linked components, to a certain extent,rather than in detail study of individual system elements.

A geomorphic system is an inclusive composite of landforms which operate together according to some apparent pattern, energy and matter input into the system giving rise to a predictable system response in terms of internal organization and the consequential energyand matter output. Geomorphic systems can be regarded as part of the 'supersystems and as being comprised of subsystems. Subsystems are consequently the indispensable components of a system and can be acknowledged as distinct input-output linkages.

In geomorphology subsystems are generally united by pouring the output of one of the subsystems into an additional subsystem to form its input. When interest in the subsystem operations is extremely detailed, the systems approach is substituted by the experimental design model. Two systems are said to have 'similarity' when there is precise equality of all components, and to have equivalence when they transform the same inputs in to indistinguishable outputs. **Synthetic system, partial system and black box** are components of **general system** and dealt with in detail.

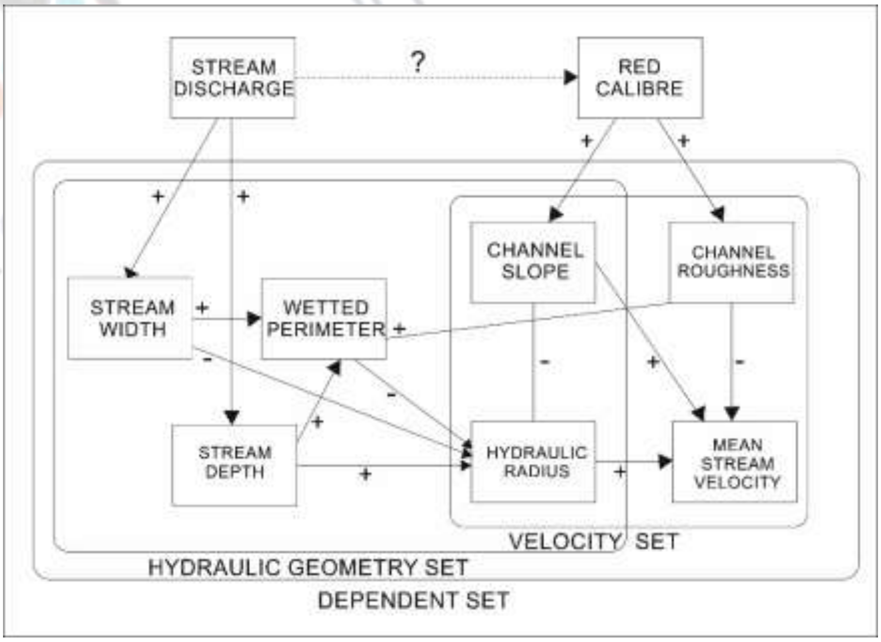

Figure 8 : General System – Hydraulic Geometry

Source: Source: Haggett, P and Chorley, R.J., Models in Geography

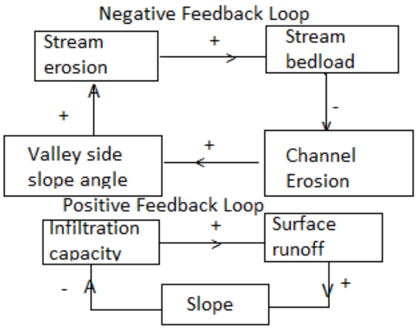

Figure 9: Feedback Relation in System
Source: Hugget, R.J, Fundamentals of Geomorphology

Synthetic Systems

Synthetic systems in their preliminary phases exhibit similarity with experimental design models, being involved with recognizing allegedly critical features of the structure of geomorphic phenomena, together with their sampling and analysis.The purpose of synthetic systems research, on the other hand, goes further than this in that its objective lies in the synthesis of the analysed structure and the extension and generalization of conclusions to the point of making process-response models.

The modus operandi for building up synthetic systems starts with the recognition of definite vital structural elements in a given geomorphic complex, together conceivably with some views as to the potential relationship between these elements (involving direction of causation and which variables change together).

Partial systems

The partial systems is one which have been first and foremost associated with the resolving of fundamentally practical problems in the earth sciences. It has been related to the establishment of workable relationships between often randomly grouped sets of factors or subsystems. Detailed knowledge on the subject of the internal functioning of these subsystems is not regarded as obligatory, but the attainment of precise information about the interrelationships between these subsystems allows one to recognize and forecast the behavior of the entire systems under different input conditions .This information may come from diverse sources, but the object is always to set up mathematical relationships between the system inputs and outputs, without any effort to illustrate unambiguously the internal mechanisms of the system. The consequential behavior pattern are then used to envisage, and to a smaller extent to comprehend, the behavior patterns in other similar systems or in same system at different times.(Amorocho and Hart,1964)

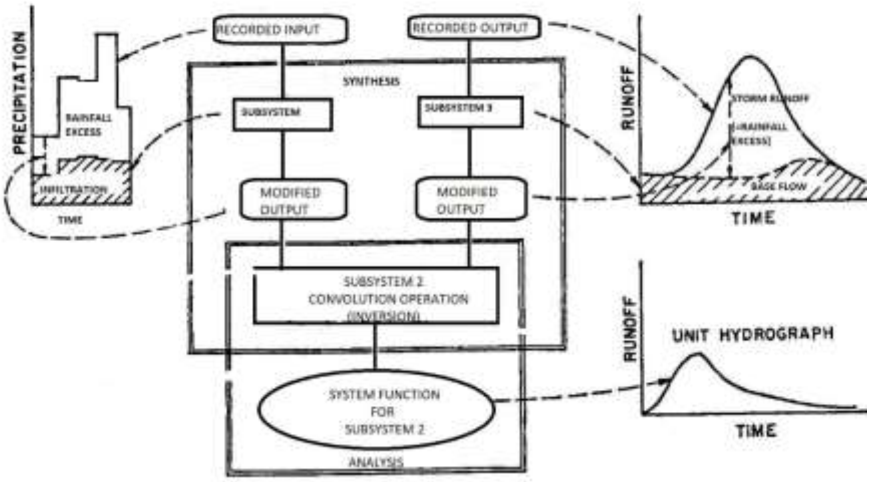

Figure 10: Partial System

Source: Haggett, P and Chorley, R.J., Models in Geography

The black box

On the whole intense application of general systems models engages the concept of the 'black box'. This necessitate modest or no detailed information concerning the system components or subsystems within the black box system, interest being focused upon the nature of the outputs which result from differing outputs. Consequently, the black box is equivalent to the grey box of the partial system and the 'white box' of the synthetic system.

In geomorphology, the black box approach has supported much of the significant work of the last one hundred years.Such work has been characterized by broad perceptive leaps wherein decisions are taken on the subject of the supposed dominant characteristics of broad landform assemblages. Even though there has been much guesswork and assumption on the subject of the detailed nature of the progression at work, the characteristic patterns of landform transformations through time, and the rates of operation of geomorphic processes.

Testing the Model

The testing of the patterns, relationships and process/responses estimated by geomorphic models engages reappraisal against the real-world conditions. Even though such testing is undoubtedly the generally significant single step in successful model building, definite types of models have proved more vulnerable to reappraisal than others.

The most testable models are present in the midst of the hardware, partial system and experimental design models. Engineering–type hardware models are continuously checked against reality through construction to allow for adequate representation of present conditions; they are over and over again ‘moulded’ to known past conditions and as to their reproduction of known historical progression of events; and, finally, forecasts from the model usually form the basis for engineering works which themselves form expensive tests for the appropriateness of the model. In the same way, the building of partial system models engages the unvarying checking of real world inputs and outputs so that the concluding model can usually replicate a limited characteristic of reality with authenticity. Experimental design models can also be eagerly tested by collecting new data which are statistically checked against the relationships resulting from the original model.To a certain extent more difficult to test are the process-response models consequential from the synthetic system approach, and the mathematical models. This is because of the higher level of generality presumed by these models and the complicatedness of unscrambling local complications from authentic errors in the model.With respect to deterministic mathematical models little effort has been made to test their inferences in the field.

The most difficult type of models to check are some of the natural analogue system and the black box general system, since their construction in the past has engaged such immense leaps in to generality, based upon decisions concerning the dominant system characteristics, the origins of which may be incomprehensible. Consequently, for example, definite denudation chronology models and the cycle of erosion engage so many built-in assumptions that any testing to which they have been subjected usually develops in to circular reasoning (Chorley,1965). On the other hand, an example of a simpler type of black box model which received outstanding field support after a hundred years was Darwins’ theory of the development of atolls from fringing and barrier reefs by the slow subsidence of reef foundations.This model was deductively supported by Davis after more than a few unsuccessful attempts to drill deep ocean trolls. The reappraisal of geomorphic models is infrequently completely unambiguous but checking, discarding and remodeling have got to become the centre of geomorphic concern, as the subject is to enlarge from a subjective catalogue of phenomena in to a rational and cogent discipline.