PUBLIC INVESTMENT, PRIVATE INVESTMENT AND FINANCIAL CROWDING-OUT: AN EXERCISE FOR THE INDIAN ECONOMY

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CERTIFICATE

This is to certify that the dissertation entitled **"PUBLIC INVESTMENT, PRIVATE INVESTMENT AND FINANCIAL CROWDING-OUT : AN EXERCISE FOR THE INDIAN ECONOMY"** submitted by **Binod Bihari Bhoi**, in partial fulfilment of the requirements for the award of the degree of Master of Philosophy (M.Phil) of this university, has not been previously submitted for any degree of this or any other university.

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Dedicated to

MY LATE FATHER

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CHAPTER - 1
INTRODUCTION

INTRODUCTION

In the macroeconomic literature of the post 1930s economic policy making has assumed great significance both in developed and developing economies. While growth assumed the pivotal role in the developed world, it is development which has been the mainstay of developing countries. But with the pace of time the developing countries have universally resorted to development planning as a viable strategy for accelerating the rate of economic growth, with their hope of fast catching up with the developed world.

Although the nature of the economy on macroeconomic fundamentals are relatively different in these economies, the study in macroeconomics has essentially remains the same, that is, the study of the behaviour of large economic aggregates, their (inter) relationship and their determinants. So when we talk of growth and development the most obvious question that confront us is-what are the instruments of macroeconomic policy that may be used to influence the magnitudes of these aggregates? With whatever degree of faith economists have on market mechanism, nobody strictly prescribed for price level fluctuations to do the job of maintaining full-employment equilibrium (which has been the long-run goal of all economies) because it is expected that fiscal and monetary policy will do the job more efficiently and less disruptively. According to Keynes and his followers erratic price fluctuations distort the information content in money as an unit of account thereby allowing economic agents to formulate expectations about the future in an uncertain environment. So uncertainty leads to instability in the economy, because it is unlikely that such expectations about the future will always be met. And economists being generally averse to such signals in the economy look for alternatives to price fluctuations as tools to maintain full employment equilibrium. The search for such tools is based on the criteria that it should be less distortionary and more effective in maintaining macroeconomic equilibrium. So as a natural outcome the most obvious answer to such question, in modern day democracies (mostly mixed economies), is the single most instrument of government budget, including its allocation of revenue and its

expenditure streams. Within the heads of revenue expenditure the kind of taxes raised and expenditure made may have significant macroeconomic implications. More so, to strike a balance between the two is an important determinant of aggregate level of demand in these economies. When, as is usual, expenditure exceeds revenue (i.e. in case of deficit) and the government must borrow, the form in which it borrows (i.e. by money creation or interest bearing debt issuance) and from whom it borrows. (foreigners, the domestic banking system or the public) become important policy variables. In other words, the methods and source of financing the gap[1] assume significance which, in recent period, is of alarming magnitudes in developing countries.

The level of public expenditure and the size of the deficit (i.e. the excess of expenditure over receipts) has been a most controversial topic in academic discussions over these years. The debate has a long history starting from the days of classicals who were championing the cause of laissez-faire policy. Keynesians while justifying their arguments relied heavily on the demand side of the problem while the modern rational expectation schools relied heavily on the supply side of the problem. So the question which confronted economists is how effective an increase in government expenditure can be in expanding total expenditure or effective demand and with it total employment, if the money supply is held constant and the additional expenditure is financed by capital market borrowings. This is behind the crowding-out debate, which in modern time is intensely debated by the Keynesians and the monetarists, which led to what is called the 'mainstream synthesis' that gave a new dimension to the problem with their emphasis on the time horizon - fiscal policy in the medium term.[2]

Meaning and Nature of Crowding out :

A long standing problem in macroeconomic theory and policy making is on the question - Does public expenditure crowds out private expenditure in economic (production) activities? Crowding-out is a multidimensional concept, having different

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[1] Economists emphasized on different gap analysis to substantiate their view on stabilization and adjustment policies prescribed for developing countries. See Taylor (1993)

[2] The debate of the 1970s, between the two schools which was mainly on the time horizon was closely associated with that of rules vrs. discretion

interpretations at different levels. But most generally it is understood as the displacement of private economic activity by public economic activity or private spending by public spending. The monetarist and the Keynesians confronted on this issue most rigorously. However, over these years economists have differentiated between 'complete' and 'partial' crowding-out, real (or resource) and financial crowding out, ex-ante (direct) and expost (indirect) crowding out. Such differentiation, in our view, is based on the operational transmission mechanism on the one hand and the time horizon on the other, that facilitates for the comparison between the short-run and long-run effect of various economic activities.[3]

Real Vs. Nominal Crowding Out : According to the Keynesians with their emphasis on underemployment equilibrium 'complete crowding out' is a rarest possibility. But to the monetarists, with their presumption of full or near full employment in the economy, any sizeable increase in government expenditure can only be possible at the cost of real private expenditure (in a closed economy). This is what they called real crowding out.[4] In the literature mostly the LS-LM framework is in use to explain their view under both fixed and flexible price setting, taking exogenously determined nominal money supply. There argument is that under fixed price setting nominal and real crowding out amounts to the same thing, while under wage-price flexibility real

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[3] The short-run - long-run dichotomy differentiate between the impact effect and steady state effect of changes in Government activity When Stocks and expectations adjust fully to the changes in Government policy, neo Keynesian literature has dealt mainly with short-run crowding out. Few recent papers like Tobin & Buter (1976), Blinder and Solow (1973b) deals with long-run crowding-out. See Buiter (1977) for more references on the subject

[4] In the conventional discussion on fiscal policy this inflation induced crowding (sometimes called "forced saving") was termed as real crowding out. On the other hand, the demand induced stimulating effect (accelerator effect) or Government spending on private investment was termed as 'Crowding-in'. Thus both the two terms reflect the real sector effect of increased public spending and not on the means of financing that spending and therefore may follow ; suit even if it is tax financed. By contrast to it, current literature on crowding-out stressed not merely on deficit spending but more so on deficits financed by other means than money. See B.M. friedman (1978) for extensive discussion on related subjects.

crowding-out may occur even if there is no or no full, nominal crowding out, with the pigou effect[5] (real balance effect) in operation.

Direct Vs. Indirect Crowding-Out :

In the mainstream economics much emphasis has been given to the transmission mechanism that may cause nominal crowding out and categorised broadly into two groups:

i) mechanisms that act via the rate of interest called indirect or expost crowding out.

ii) mechanisms that do not act via the rate of interest called direct or ex-ante crowding-out, which can be full or partial, depending on the nature of the economy.

In the IS-LM model, under a closed economy framework, full crowding out occurs (i.e. no effect on real income of changes in public spending) when the LM curve is vertical-implying that both the money supply and money demand are interest inelastic. So the rate of interest rises to such an extent that private expenditure is reduced by the same amount as government expenditure is increased. Full crowding out also occur when the IS curve is horizontal. Again with a given money supply total expenditure cannot increase and any increase in government spending takes place at the cost of a decrease in private spending. These two theoretical possibilities did not garner empirical support[6] and with the usual shape of the IS and LM curve i.e. a downward sloping IS curve and an upward slpoing LM curve, crowding-out can of course only be partial. This phenomenon (partial crowding out) is close to reality and

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[5] Under a situation of full employment any positive fiscal impulse (like increase in public expenditure) is reflected in increased prices, consequently the real balances fall, with given money supply. This cause LM curve to shift to the left. A lower real balance means a fall in the private sector's wealth which may curbe reduction in spending, so that the IS curve also may shift to the left, till the intersection is reached at the full employment level. This is the pigou effect.

[6] See Buiter (1977) for an extensive discussion on this topic.

is the concern of economists in more recent time. Thus crowding out is not an all-or-nothing phenomenon, what matters is the sign and magnitude of the public policy multiplier for effective planning. This degree of crowding out facilitates for the comparision between the short-run (impact effect) and long-run (steady state) consequences of fiscal and monetary policy.

Direct (or Ex-ante) Crowding Out :

The degree of direct crowding out (or ultrarationality) is the extent to which an increase in government expenditure immediately meets with a fall in private expenditure ' ; in explaining the structural relationships of the economy. In other words, it takes various dimensions and is based on how far public consumption, public investment and public bonds are treated as substitutes for their private sector counterparts in behavioural economic decisions made by private agents (or households) in private utility functions. Under the IS-LM model it results from the mechanisms that prevent the IS curve from shifting to the right at the first instance, due to a positive fiscal impulse. Thus it reflects the inability of fiscal policy actions to shift the IS curve. In this case a higher volume of Government debt is absorbed in the public portfolios without affecting the rate of interest (or without causing the rate of interest to rise). So what is implicit in this case is that the increase in available private funds is fully devoted to government bonds. And if it is so then it will change the composition of portfolios that may bear on interest rates and cause portfolio crowding-out. This possibility is neglected in the literature on direct crowding-out.[7] This phenomenon of direct crowding out, in our view, is less evident in developing economies because of the lack of minimum provision of public services on the one hand and under-utilisation of real resources on the other, with general shortage of funds (financial repression). Under such a situation expost or indirect crowding out can be seen as more relevant in this context.

[7] This point will be made more clear while reviewing the existing literature in the second chapter.

Indirect (or ex-post) Crowding-Out :

Indirect or ex-post crowding out refers to the displacement of private economic activity by public economic activity that results from the working of the whole model of the economy without there being any 'ultrarationality' of the level of the individual structural relationships. In other words, it is caused by changes in prices and interest rates resulting from increased government spending (or more generally due to changes in some government policy instrument). Under the IS-LM framework it results from various mechanisms (price and non-price) that reverse the increase in national income caused by the rightword shift of the IS curve consequent on increased Government spending. In a closed economy, full short-run indirect crowding out can occur under the full employment version of the IS-LM model with a classical labour market. In a fully employed economy, if crowding out occurs then that may be the result of competition for scarce resources between the public and private sector and under such a situation an expansionary monetary policy can only be inflationary. Again, under such situation, competition between the two is not limited to the demand side of the market for final goods and services only, if the Government directly engage itself in production activity then there can be competition in the factor markets also like markets for labour, capital and other intermediate products.

But if crowding out occurs in a closed economy with unemployed real resources (i.e. in a situation of under-full employment equilibrium), then it can be argued as due to competition for limited funds in the economy and an expansionary monetary policy can help bring the economy to its production possibility frontier where the scarcities for real factors become the binding constraint. Thus, the short-run indirect crowing-out has great implications in macroeconomic theory and policy making as explanation to business cycle fluctuations and hence needs careful treatments. So the policy makers should be able to identify the cause properly and then prescribe accordingly. For example, if scarcity of funds is identified as a plausible explanation for crowding out, which is mostly the case in developing economies with unemployed real resources, then policy prescriptions should be on the mode of financing of Government spending programmes, irrespective of their specific content.

The implicit assumption in this analysis is that the rate of interest acts as the equilibriating mechanism with the assumption that supply of funds are interest elastic. But this specifically pose a problem particularly in the case of developing countries because of the regulated nature of the interest rate and is unlikely that it will reflect the true effects of the forces operating on both sides. Therefore, it is necessary to find some alternative mechanisms which can capture the effects of supply and demand forces properly and can be thought of as a tool of crowding-out analysis. In this direction we have chosen the availability theory or credit rationing[8] approach in our model. Because in developing countries extensive financial interventions like interest controls, directed credit programs and inflation control are often employed to promote the growth of key sectors, which yield revenue to the Government and appease antiusuary sentiments. There is no doubt that such policies do have some of their intended effects, but it is to be seen how far such a regime mattered for capital formation.[9] Therefore to gauge the extent of crowding out we will employ the availability of credit approach in our model that will suit the case of a developing country like India, because of its administered interest rate regime and a repressed financial market.

Crowding-out: A New Dimension:

From this broader notion on crowding out (as discussed above), the current debate has shifted to the specific content of public expenditure and their likely consequences on private economic activities which has both short-run and long-run implications for growth and development. One such long standing issue in macroeconomics and development economics which has attracted the attention of economists in recent years is on the relationship between public and private investment. This shift in emphasis in

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[8] See Patnaik (1995), p. 13, Argument on the possibility of credit rationing in India and how it acts to explain the neo-Kenesian monetarist dichotomy.

[9] See McKinnon (1973), for concrete discussions on the effect of credit rationing on investment in the case of a developing country. McKinnon's Proposition is that when such poor financial intermediation faster credit rationing, investment projects are highly unlikely to exhibit uniform returns at the margin and it differentiate between firms in terms of their access to credit, from favoured firms reap the benefit at negative real costs while offers rely exclusively on internal funds. In his view the resultant distinction in terms of technological choice, capacity utilization and employment hinder economic progress.

reexamining the relationship can be attributed basically to two factors, which are product of macroeconomic thinking on stabilization and adjustment as explanations of business cycle theory. Traditionally the term stabilization was used in relation to the level of overall economic activity, which emphasized primarily on the application of fiscal and monetary policy (demand management) to reduce the amplitudes of business cycle fluctuations. And this sort of reasoning was prevalent till the later part of 1970s, starting from the Keynsian prescription in the 1930s. But now a days, it is no more understood in that conventional sense. Basically the development of the 1980s can be considered as behind such an understanding. In our view, three points are worth mentioning here. First, the recognition that by virtue of its large size in the economy, modern day Government can impart a considerable degree of stability to aggregate demand. The available tools in the hand of the Government being great command over resources and (operationalising) the automatic fiscal stabilizers. Economists in this tradition are of the view that, it should not, however, be taken to mean that aggregate demand cannot fluctuate from its trend, it can and it does, but they argue that only in exceptional circumstances that such fluctuations will really pose serious problem. Secondly, the recognition that different shocks originating on the supply side (like oil shocks, exchange rate shocks etc.) which are exogenous in the sense that the domestic economy has no control over them, are likely to have an impact on the economy. Again such shocks are likely to be recurrent in nature and for that reason take precedence, when negative such shocks are liable to cause an increase in unemployment and fall in output. Therefore, it is argued that in such case aggregate demand (stabilization) policy is less likely to solve the problem. In the event of such recurrent problem, modern day concern is how to minimize the adverse repercussions in the wake of a shock and is to have an economy that is able to adjust quickly, smoothly and without undue inflation. Therefore, as usual, the policy prescriptions fall on the supply side operation of the economy. Mostly these supply side measures fall under the 'resource allocation' aspect of Government policy, that can be regarded as playing a role in stabilization also. Thirdly, the worldwide shift in the 1980s towards a growth strategy emphasizing upon the role of market and private sector attributed mainly to the collapse of centrally planned economies - led in many countries to a retrenchment of the public sector from production and to a redefinition of its role

in the development process. This redefinition of the role of public sector in economic development is guided by the principle that the public sector should concentrate in areas where it complements rather than displace private sector activity. This guiding principle alongwith the changed economic scenario (supply based stabilization) has paved the way for a reexamination of the relationship between public and private investment for economic growth. so the consensus is that stabilization policy along with its prime concern with inflation control should also facilitate growth adjustment to shocks.

All this discussion at the policy level amounts to the emphasis on medium-term considerations in the framing of monetary and fiscal policy for economic growth. In other words, the shift in emphasis from demand based adjustment (which is essentially a short-run phenomenon - Keynesian analysis) to supply based adjustment has led the argument in favour of long term fiscal and monetary policy. To make this point clear, we can refer to the debate of the 1970s between the Keynesian and monetarists approaches on setting of policy. The debate which was mainly on the time horizon and was closely associated with that of rules vs. discretion in the setting of policy. Monetarists generally viewing that economy operates usually at or near full employment, rejected the efficiency of discretionary policy in stabilizing short-term fluctuations in output in favour of a rule for the rate of growth of money supply that would stabilize inflation in the medium term. On the other hand, Keynesians, subscribing to the impracticability of a rule-based approach to monetary policy argued that discretionary policy could effectively offset cyclical fluctuations in output. In the 1980s, a decade of recovery, however, the terms of this debate changed with each side relaxing on their stances, that led to the emergence of 'mainstream synthesis'. In this new paradigm, a discretionary use of policy instruments was recommended not so much to remove fluctuations as to preserve the credibility of the medium term objectives in the face of very often volatile private sector expectations and reactions. Thus it seems reasonable to assume that introduction of some sort of policy variables into the analysis is a must, for a sound and effective study of aggregate economic behaviour like the study of investment behaviour in the economy.

This analysis is of particular importance in developing countries, like India, which are confronted with institutional and structural constraints. The traditional macroeconomic thinking in developing economies viewed that these economies are supply constrained so that Keynesisn type of macroeconomy is not relevant. But current situation in these economies makes it clear that deficiency in aggregate demand can also be a problem, particularly where there is a linkage effect between different sectors of the economy (most prominent being the linkage between industry and agriculture).

Tobin and Buiter (1982) also supported the argument that even when output is supply constrained, issues concerning aggregate demand remain. Their analysis hovered around the question- does expansionary fiscal policy work? In their analysis of long run effects of fiscal and monetary policy on aggregate demand they pointed out that, it depends on the extent to which this expansion (in aggregate demand) evokes an increase in supply, which in turn, depends on how close the economy is to its productive capacity. This means that the effectiveness of fiscal policy depends on the productive efficiency of resource use which is a reflection of the institutional structure and the general economic environment. So how responsive is supply to demand has a bearing on the multiplier effect in the economy. In case of structural and supply bottlenecks it is not unlikely to expect a lower value of the multiplier for real output as part of the increased demand (due to a positive fiscal impulse) will manifest itself in price rise (inflation). Thus the policy package has to have an appropriate balance between measures intended for demand management and supply management.

The real economic issues being that most of the developing countries, including India, assigned an important role to public investment in their planned policy formulation, with the notion that it will act as a stimulus to private investment and thereby will serve as a powerful instrument of stabilization and growth policy. Though this belief has been on the mainstream economics for several years no proper attempt has been made on its empirical dimension except few aggregative studies and that too the question of public investment heterogeneity was completely neglected while studying the relationship between public and private investment which is the key

determinant of growth in these economies. Therefore it is imperative to have a disaggregative study, mostly because, in these economies the state is often involved, through public enterprises, in diverse economic activities such as manufacturing, banking, commerce and so on, in addition to its conventional role as provider of public goods and basic infrastructure services. Therefore it is likely that different types of public investment may have different (opposing) effects on private sector activity: public investment in areas such as basic infrastructure and human capital formation presumably tend to raise the profitability of private production and thereby boost private investment, while involvement in more conventional activities - where public enterprises basically replicate the actions of private firms - might be expected to have the opposite effect by competing with the private sector for scarce funds and resources. Again, since most of these public enterprises run on losses, their diverse activities put pressure on the government budget, thereby leading to excessive fiscal pressure in the economy. Now when Government adopts fiscal stabilisation measures, the brunt of such action falls generally on Government's. productive expenditure, since they involve long gestation lags, like investments in social and economic infrastructure, which has long run consequences for growth.

Moreover, when the size of deficit (fiscal gap) increases, then the way Government finance the deficit, i.e. through deficit financing or market borrowings has also implications for private economic activities. So it is important to study the relationship between public and private investment, when public investment is financed through various modes like taxation, market borrowing and money creation (or deficit financing). Because it is likely that different modes will have differential effect on private investment because of an underdeveloped financial market which is subject to various controls by the Government and therefore it is imperative to judge the degree of positive or negative effect each mode may have on private investment.

For the purpose of our study we will deal with the Indian case, which is one of the developing countries that resorted to economic planning as a viable strategy for growth since her independence. Therefore, before setting our objectives, a brief

introduction to the economic thinking behind planning and the current terms of the debate would be in order.

Economic Thinking Behind Indian Planning: An Overview

Indian planning basically subscribing to a supply side view of the planning problem did not pay much attention to the fact that domestic demand can possibly be a constraint on the growth process. The economic rationale behind such a notion was that, with an active state policy on investment (higher public investment) any possible slacks in the economic system would be utilized. The underlying idea behind such a scene was Nehru's philosophy on economic development, of which the first three plans and especially the second plan is an outcome. The following features were identified as the underlying causes of structural lagardness in the planning process -

i) shortage of material capital

ii) low capacity to save due to low per capita income

iii) Structural limitations like an underdeveloped financial market preventing conversion of savings into productive investment.

iv) high sectoral interlinkages with surplus labour.

Consequent upon the above anomalies, the planners stressed the need to achieve growth in aggregate investment via rapid growth in public investment. And dispropertionalities apart, they were of the view that so long as it grows rapidly, it was unlikely that the growth process lose momentum. Their aim was to deploy it fruitfully in such areas as infrastructure, agriculture and in areas promoting industrial development, with the hope that, in the long run, it will enable to balance supply with demand along a growing trend line. Accordingly faster growth of capital goods sector were accorded primacy with the hope that it will convert growing (generated) savings into additional real investment. With these arowed objectives of Indian planners, the pre 1970s saw the era of inward looking policies like import substitution and self-reliance.

A new growth paradigm emerged in the mid-1970s as economists started realising the benefits of an open economy. The weak industry-agriculture linkage caused a switch from import-substituting industrialisation to export led growth. Thus it seems, it supports

Kaldor's argument of shifting emphasis to international trade for acceleration of growth in industrial production, once the demand constraint for agricultural product is overcome. The aim of the new strategy was to attract large volume of foreign capital and make the balance-of-paymnts (BOP) position strong, which failed to succeed despite considerable diversification of export basket and a faster rate of growth of non-traditional manufacturing over total exports. Many ascribed the failure to inappropriate package of policy measures which kept the Indian export environment unfavourable domestically. Though the issue has been intensely debated in the 1970s, no common consensus emerged as a result. But economists more or less agreed that problems like tied-aid, the import of old technologies, poor maintainance and replacement of infrastructural bottlenecks, inability to raise productive capacity significantly along with non-realization of scale factor led India to be a high cost economy and hence a fall in its competitiveness in the world market. Now with recently adopted liberalization measurs in the context of import policy, it was believed in some circles that, with liberal imports of capital goods and technology, it would energise the Indian economy to reap the benefits of national international division of labour, which the inward looking strategy of the past has prevented so far. Many economists, therefore, are of the view, whether the learning effects did not take place because of - wrong projection of demand, inappropriate technology or whether it was the general slowing down of the rate of increase of real public and private investment which prevented the scale economies being reaped can only be very approximately established.

A similar debate followed the post-1965 stagnation in industrial growth in India. Economists gave different explanations to support their hypothesis on a general industrial slowdown. While Srinivasan and Narayana put the blame on the decline in public investment, Nayyar gave explanations in terms of a shrinking home market for industrial output, i.e. demand constraint on growth. Prabhat Patnaik, on the other hand, made responsible the speculative activities of the private sector comprising of the agricultural landlords and the industrial capitalists, while in Desai's view, it was the inefficiency in resource use in the public sector that caused stagnation. Thus, it can be discerned from the above analysis that a lot of factors might have operated in varying degrees in explaining growth in the economy during the 1970s. In our view, the factor which has a greater explanatory power for such laggardness is the nature of public investment and its capacity

to raise total investment in the economy. So under liberalised atmosphere, if public investment will not crowds-in private investment to avoid any infrastructural bottlenecks and raise productive capacity in the economy, i.e. if such laggardness continues, then it may lead to balance of payment (BOP) crisis instead of raising the marginal rate of domestic savings. Again technological development being the major concern of the government for achieving a higher rate of growth, the study of relationship between public investment and private investment under various constraints hints at the productive capacity in the economy and the accelerated rate of overall investment for facilitating productive accumulation and hence growth in the economy.

There has been a great deal of discussion in recent years on the efficiency of resource use in the Indian economy. As an indication to it, many Indian planners hinted on the sharp increase in the incremental, capital-output ratios (ICOR) from the mid-1950s to the early sixties. The recent studies by scholars like V.K.R.V. Rao, Sukhamoya Chakravarty and K.N. Raj are worth noting in this direction. While Rao has considered the time series of gross domestic savings as a percentage of GDR at market prices and the concomitant acceleration in growth, Chakravarty considered the marginal percentage rate of gross savings as an indication of the growing maturity of the economy and pointed out that the rate of growth of GDP has not displayed a corresponding acceleration. While Chakravarty's inference runs in terms of declining investment productivity, Rao attributed it to an erroneous policy on capital formation that could not produce the desired impact on growth. Similarly, to K.N. Raj such a rise in ICOR has been an almost universal phenomenon for many developing countries, including India. Therefore, he stressed on the need to study it more sectorally to get a true picture of the economy.

Added to this, the debt crisis of 1991 and the underlying fiscal crisis was viewed by economists as the product of wrong economic policies accumulated through the 1980s. The acute fiscal deficit caused high internal borrowings. On the resource mobilisation front, there was a shift from direct taxes to indirect taxes in tax revenue collection which is said to be inflationary. Again the 1980s and begining of 1990s become a deficit period due to high interest payments, growth of unproductive public expenditure and financing of consumption expenditure by borrowed funds. This can be seen from the fact that the small

but consistent revenue surplus of the 1970s transformed into a revenue deficit averaging at more than 2 percent of GDP in the second half of the 1980s. So all these developments led the govt. to feel lack of fiscal flexibility in its expenditure decisions.

On the external front the balance of payments (BOP) situation was also in the making for a long time. The trade liberalisation of the 1970s and more open industrial policies of the mid 1980s, jointly, though created an environment for rapid industrialisation, led to disproportionate growth in imports and increased import intensity of production in general. But export performance remaining modest, the high demand for foreign exchange led to continuous increase in external debt. So both high internal debt and high external debt due to macroeconomic imbalances, with more emphasis on indirect taxation, led to the fear of serious inflation. Consequently, as a unilateral solution to all these problems, followed the macroeconomic restructuring based on structural adjustment and stabilisation policy under the guidance of Fund/Bank prescriptions.

Thus, it is evident from the above analysis that, in the Indian planning process public investment throughout was the driving force behind the general strategy of import substitution industrialisation. The planners and policy makers were of the view that investment played a crucial role not only as a component of final aggregate demand, but also in terms of determining the size of the country's capital stock thereby its future source of growth and employment opportunities. It was also generally believed that private investors would be reluctant to channel needed resources to key industrial projects because of the region's lack of social and economic infrastructure, as well as the absence of fully developed markets for equity, insurance and information. Therefore, government. investment in infrastructure and basic industry with their attendant positive spillover effects, were viewed as necessary by policy makers for achieving optimal rates of investment and growth.

However, with the onset and aftermath of the debt crisis in 1991, there has been a radical change in the overall development strategy. Instead of concentrating on inward-oriented growth strategy, under the guidance of state directed investments, the new growth model is outward-oriented in nature and more importantly, heavily reliant on market forces

as evidenced by the ongoing deregulation of product and factor markets and the privatisation of most state owned enterprises. Again as a stablisation prescription there is calls for public expenditure cut. This unprecedented move in streamlining the role of public sector can, in part, be attributed to the limited internal and external resources available to the govt. during the 1980s, but more importantly, it is also viewed as the result of past inefficiencies and failures generated by the public sector's attempt to indulge in too many investment activities through public enterprises in direct production of goods, competing with the private sector.

Thus the unending debate has both demand and supply dimensions, and economists emphasizing on the one or the other aspect prescribe differently for macroeconomic stabilisation. Therefore, in this light, it is necessary to study the relationship between public and private investment basically emphasizing on the financing of public investment and their consequences on private investment decisions. So as a natural outcome our objective falls on this line of establishing true relationship between the two i.e. to judge on the extent of net crowding-out or crowding-in effect of public investment on private investment, taking into account the financial constraints on private investment decisions, which to a great extent is contingent upon public investment the pattern of its financing through the use of fiscal and monetary tools.

To capture the whole gamut of the problem, in this dissertation, we proceed as follows:

In the second chapter, we review some of the existing literature on crowding-out debate. Since the topic is very confusing, first, we have reviewed some important theoretical literature to clarify the meaning of crowding out and its specific dimensions. Second, we have critically reviewed some case studies both international and national to highlight on the role of transmission mechanism and the consequent approach to modelling private investment which is important to judge the extent of crowding-out. The third chapter deals specifically on the formulation of the model based on the credit rationing approach. A flexible accelerator framework has been chosen to specify the private investment function and has been modified to take into account the institutional and structural characteristics specific to developing economies. We hope that such a model will

help us to judge the extent of crowding out of private investment due to the financing of public investment.

In the fourth chapter, first we give a brief introduction to the extent of public sector in Idia and its performance over time. Then we estimated the model for the Indian economy covering the period 1960-61 to 1990-91 and interpret the results. Also to judge the differential effect of public investment (if any) it has been disaggregated into two components- core infrastructure and non-infrastructure.While estimating the reduced form equation for private investment.

In the concluding chapter, we present the summary of our discussions from the view point of macroeconomic policy making in India.

CHAPTER - 2
REVIEW OF LITERATURE

Faster economic growth is a major objective of economic policy in most developing countries, which normally requires a higher quality and quantity of investment. The real issue being that, most economies during their initial stages of development placed emphasis on public investment with the hope that it will act as a stimulus to private investment activities and hence will enable the economy to attain a higher rate of investment which is a prerequisite in any growth theory - in Harrodian tradition. So the argument was that it will crowd-in private investment and will raise the productive capacity in the economy and also help maintain stability in aggregate demand which is considered very important under Keynesian tradition - which unquestionably has a positive effect in production and hence investment demand (desired capital stock). But, now with little faith on the relevance of Keynesian constraint on growth (demand constraint) the emphasis has shifted towards the supply side of the argument for adjustment, i.e. how smoothly economies can adjust to exogenous shocks without altering the growth momentum on the one hand and with the least amount of adverse repercussions (inflation) on the other. So as a natural outcome Government budget emerged unilaterally as the most important policy tool in the hands of the policy makers.

But excessive reliance on this as a tool of economic stability has also raised the question of sustainability which implied the balancing of the budget. This question has implications in two directions one monetary and the other is real effect. While monetary dimensions prescribed for the short-run stability, the real effect calls for long run stability- the growth in productive capacity. More interestingly this long-run implications is very much determined by the short-run consequences. In other words, it has posited itself in the interaction between the monetary and real effects in the economy which in equilibrium prescribes for a balance budget for sustainable growth. To put it otherwise, it amounts to determine and define the true relationship between public and private investment, that may have both the above mentioned short run and long-run consequences in the economy.

Therefore while studying the relationship between the two, it is necessary to proceed the analysis by first defining public investment and then identifying its determinants with the financing constraints on it, that can have financial implications on private investment decision in the economy.

In this light we would like to review few of the existing literature on this topic, which will through some light on the terms of the debate in more recent time. We will review it under three sub heads:- first, that broadly covers the theory behind the crowding out controversy; second section review few international studies in this topic and lastly, few existing studies in India.

Theoretical Literature on Crowing-out:

Now a days, there is an increasing concern among policy makers on the ever increasing size of the budget deficit. In the academic arena this has led to an intense debate between the Keynesians and the monetarists on the issue of the financing of the deficit and their economic consequences. It is generally viewed that economic consequences of deficits can be inflationary (in the sense of raising prices) or deflationary (in the sense of depressing investment) or both which depends on the time horizon (i.e. the time lag involved in each case to have an effect on the economy). Consequently the debate has also taken from the efficacy of fiscal policy in the short-run and long-run when the monetary policy is unaccomodative. In other words, the terms of the debate has shifted from deficit financing to financing of deficits through means other than money and their consequences upon the economy. Hope the following literature will clarify this point.

Blinder and Solow (1973), in a reply to the monetarists re-statement of the quantity theory and the renewed belief on the conventional wisdom on crowding-out reexamines the effectiveness of fiscal policy in raising the level of output and employment in the short-run. The conclusion which emerged from their theoretical argument follows that fiscal policy is potent in an economy with unemployed resources. They have differentiated between the crowding-out that may result from government's direct involvement in productive activities to that may arise from deficit spending unaccompanied by money creation, i.e. due to

competition in the financial markets for more funds with debt floating. This competition for funds may push up the interest rate and may depress private expenditure which are interest elastic. The degree of crowding-out, thus depends on the degree of rise in interest rate in response to the growth demand for money and supply of bonds engendered by the government spending on the one hand and the interest elasticity of investment on the other. Thus recognizing the interest induced wealth effects with bond financing, their empirical findings rejected the monetarist's view that a bond financed government spending multiplier is approximately zero - fiscal importance. But what is crucial to their analysis is the stability of the economy and once that is satisfied effectiveness of fiscal policy then is an empirical question, in principle. Under various conditions their findings support partial crowding-out, rendering fiscal policy to be effective in the short-run.

David and Scadding (1974), distinguishes between two types of crowding out ex-ante and ex-post with their notion of ultra-rationality in which households subsume corporate and government spending and saving in their budged decisions which is used to explain the stability of gross private saving rate (GPSR) despite important changes in its composition. Their general conclusion from this observed stability is that, under full employment, fiscal policy can neither affect aggregate expenditure nor alter the ratio of investment to consumption. The model views households as ultrarational in the sense that they view the corporate sector as an extension of themselves which implies that corporate and private savings are perfect substitute in their behavioural decisions.

As to the public sector ultrarationality implies that tax-financed Government services, such as schooling or medical care, are seen as full substitutes for individually bought services, which may render a free rider problem with the paying customer indulging in tax avoidance by not revealing their willingness for public services, but actually substituting it in their behavioural decisions. So private agents lower their spending to the full amount of the tax increase and the private savings ratio as a fraction of GNP, therefore, remains stable.

Regarding investment spending, they presuppose that, consumption expenditures by the government are financed by taxes and that government investment is financed by

bonds. Hence the private sector treats government deficits as public investment. Ultrarationality at this level implies public investment and private investment as perfect substitutes. therefore, any increase in bond financed public spending reduces private spending by a similar amount. This is what they call ex-ante crowding-out, explained fully by untrarationality. which ruled out any ex-post crowding out in the sense of having no effect on interest rate mechanism. Their argument is that private saving ratio remaining constant, the extra funds become available in exactly sufficient volume to absorb the new Government bonds and hence the interest rate need not increase in order to draw funds away from other uses. In this way it rules out expost crowding out, that occurs via rise in the relative effectiveness of fiscal and monetary policy for macroeconomic stabilisation depends crucially on the form of crowding out ex-ante or ex-post, but for long-run growth such a distinction seems immaterial.

But the problem is that, even without such far fetched assumption like perfect substitutability between public and private investment (which follows from the assumption that taxes finance only government consumption expenditure) and constancy of private savings ratio, one can see that, a battle for scarce investment funds will follow on an increase on government spending, that drive up the rate of interest and may cause crowding-out of private investment, which is not due to ex ante effect.

Barro (1974), discussed the equivalence between taxes and debt as sources of finance for government expenditures. This results from full tax discounting: government debt is not seen as net wealth by the private sector because, he hypothesized that households are rational enough to anticipate the future taxes entailed by present government borrowing, when with a given level of public expenditure, the public sector substitutes bond financing for taxes, private agents will increase their savings out of their increased disposable income in order to provide for these future taxes and the higher volume of government debt is taken up by the public without any need for the interest rate to rise. Thus interest rate remaining constant the bond sales do not crowd out investment. private expenditure and consequently aggregate expenditure remain unchanged. He considered that a Government could follow the monetary rule regardless of the size of its deficit. Bonds sales would allow large deficits without inflation. The additional savings

would allow investment, capital accumulation and growth to be unaffected. To him, this might be suboptimal but is better than the misinformation generated by excessive money creation. He based his argument on a number of conditions like private agents are immortal and they have perfect foresight about the future; there is no interest rate differentials between the public and the Government and that taxes and transfer are lump-sum. Thus, these conditions seems to be very restrictive in a real world situation and can therefore be questioned on their validity. The second inference that can be made from his analysis is that it is the level of expenditure not the way how it is financed that matters for the determination of national income. This can be questioned on the ground of efficiency of those expenditure, leaving aside the financing problem. Third, if government debt is seen as net wealth by the public, then it may affect the portfolio composition and with more wealth demand for money will increase which in turn will lead to a rise in interest rate. Such rising interest rates will decrease the value of financial assets held by the public, and hence may reduce private spending. Thus, crowding-out may occur due to this interest induced wealth effects.

Buiter (1977), considered crowding-out as a multidimensional concept and made a difference between direct and indirect crowding-out. He defined direct crowding out (or ultrarationality) as the extent to which the Government sector is subsumed by the private sector in specifying the structural behavioural relationship. While indirect crowding out is defined as the extent of substitution of private spending by public spending without altering the structural relationship at the individual level and both have a time dimension. Using a full employment IS-LM model he tried to show the extent of direct crowding under various dimensions like investment, consumption, income and wealth i.e. how far the private agents view the Government activity, in each case, substitutes their own in its decision to finance the deficits by alterative modes like taxes and interest bearing debt issuance. So it all depends on how the private agents treat taxes and debt in their utility functions. He stated that for increased public spending to have no real effect in the long run would require full direct crowding out on the one hand and full equivalence between taxes and public sector deficit on the other. Ruling out full direct crowding out he stressed on the degree of crowding out along each dimensions which needs empirical testification to be useful in policy formulation.

Friedman (1978), deals extensively on the question of crowding out under various modes of financing of government deficit and their economic consequences. He has basically differentiated between two concepts associated with non-money (bond) financing of government deficits - one the transaction crowding out and the other is portfolio crowding out. By transactions crowding out it is understood that the deficit caused by increased government spending (or tax cut) also increases money demand for transactions purposes and under conditions of fixed money supply (unaccomodative monetary policy) money market equilibrium requires that interest rate must rise to balance money demand with fixed money supply. And to the extent that aggregate private spending is negatively related to the interest rate, it will affect some of the expansionary effect of increased government spending which is called transactions crowding out. This is only partial except under conditions of a vertical IS curve (where there is no crowding out at all) and a vertical LM curve (in which case there is full crowding out). His point is that the magnitude of transactions crowding out is sensitive to the rate of interest used to measure the elasticity of money demand and the interest elasticity of private spending. He concludes that the elasticity of money demand with respect to short term interest rate (like yields on time deposits, commercial papers or treasury bills) being small compared to long term interest rate (like yields on Government bonds and securities) and being less volatile, crowding-out in the short-run will be smaller than in the long-run. Again this basically follows, because in the long run the interest elasticity of money demand increases faster than does the income elasticity and also the interest elasticity of private spending tends to be larger. Consequently his argument follows that because of the different income elasticities of the public's demands for time and demand deposits, the offset (or crowding out) will be greater if monetary policy controls M_2 than if it controls M_1.

Using a model with three assets - money, government bonds and real capital and criticising the conventional understanding on the effects of bond financing of government deficits (which generally admits crowding out) he allowed for the possibility of both crowding-in and crowding-out. His argument is that, the conventional view that a decrease in investment is the only possible result of debt financed government deficits was due to their failure to consider adequately the public portfolio behaviour, that is about their

assessments of the risk and returns associated with holding different assets like money, bonds and real capital. Using a three assets model-money government bonds and real capital - his analysis showed that the sign and magnitude of the portfolio effect of bond financing of deficits on private investment depends on the relative substitutabilities among these three assets in the public aggregate portfolio - that is, whether bonds are closer substitutes for money or for capital. He derived one substitutability index (from the symmetry condition) which is the ratio of the substitutability of bonds for money to the substitutability of bonds for capital which is always positive and lies between two extremes 0 and μ . It takes the value 0, when bonds and capital are perfect substitutes and μ when bonds and money are perfect substitutes. In between there lies all the possibilities. There is portfolio crowding out if bonds are more substitutable for capital and less substitutable for money than the ratio of the respective wealth coefficients of the demands for money and capital and portfolio crowding-in incase of just the opposite, i.e. if bonds are more substitutable for money and less for capital than their respective wealth coefficients, that determine the critical value for the index. Two points can be noted here - (i) If money demand is independent of wealth (i.e. wealth elasticity of money demand is zero) portfolio crowding out cannot occur and the only possibility is portfolio crowding in. (ii) If bonds and capital are perfect substitutes portfolio crowding in cannot occur and the only possibility is portfolio crowding out. Blinder and Solow's analysis on the possibility of crowding-out with variable capital falls under this category.

But the problem with his analysis is that it depends crucially on the assumption that demand for money is a function of both income and portfolio wealth, in other words, on the assumption that people hold money balances for both transactions and portfolio (speculative) purposes, a topic which is prone to much debate. Second, both forms of crowding-out can happen at the same time, therefore no generalization on the net effect of a positive fiscal impulse supported by bond finance is possible. In other words the relative substitutability index has an empirical dimension and thus needs verification.

On the crucial substitutability hypothesis that differentiates between crowding-out and crowding-in, his view is that, when monetary policy is unaccomodative, the government debt management policy should take precedence in operationalizing the

stimulative fiscal policy. In this aspect his attention was focussed on term structure (time horizon) of different Government bonds and as a generalization his argument was that 'short-term' bonds can be thought of as closer substitutes for capital than money. Once this holds, based on his relative substitutability index, policy prescription on debt management easily follows. That is replacing long term bonds by short term bonds causes portfolio crowding-in, while crowding-out occurs when short term bonds are replaced by long term bonds. Given the heterogeneity of government bonds and their relative substitutability, the debt management policy then determines crucially the effect of fiscal policy, i.e., the fixed trade off between short-term stimulation and investment for growth. The final outcome of expansionary fiscal policy (i.e. whether it will be inflationary or deflationary) involves substantial time lags and thus has crucial implications for growth. Therefore, it is argued that assessment of the fiscal policy should start with the behaviour of real sector rather than that of financial sector. What matters for efficacy of fiscal policy is, how responsive is supply to demand that has important long run consequences for growth.

This analysis is run purely under the assumption of unaccomodative monetary policy but do provides some insight into the debate on stabilization and growth, which can be observed from the statement that what matters prices is not only the money stock but some combination of money plus the outstanding interest bearing government debt. But what is not fully clear from his analysis is a dynamic interpretation of crowding-out, i.e. the possibility that in one time period there may be crowding out but in another crowding in may prevail. Thus it is necessary to study the more plausible case of coordination between fiscal and monetary policy which best reflect the real world phenomenon.

Tobin (1979), in his analysis of deficit spending and crowding-out in shorter and longer runs raised the question - does accumulation of public debt (non monetary debt) over the passage of time offset the expansionary effect of increased public spending, making the fiscal policy important. He argued that, assuming, with given wealth of the public, a negative relationship between demand for money and rate of interest if exists would also imply that the initial (impact) effect of a positive fiscal impulse is expansionary. His argument is that even though money supply is unchanged its velocity will arise along with interest rates. Therefore, how the impact (expansionary) effect will behave over time

is contingent upon the change (if any) of the observed negative relationship between response of money demand to interest rate i.e. whether it becomes zero or positive over time, which can happen only if wealth effect on money demand dominates the substitution effect. In other words, it amounts to say that the public demand for wealth and their saving, are positively related to interest rates and that part of the accumulation induced by higher interest rates on assets other than money is held in money. The issue of the effectiveness of expansionary fiscal policy unaccompanied by money expansion, commonly termed as 'financial crowding-out' refers to a situation of under employment in which displacement is not necessary to release resources for the use of government or its transfer. He ruled out the possibility of full crowding-out which can happen if investment is perfectly interest inelastic (horizontal IS curve) or demand for money is perfectly interest inelastic (vertical LM curve), on the ground that adjustment of capital stock is not instantaneous (involves lags) and there can be substitution possibility between money and interest bearing assets. He tried to show the possibility of partial crowding-out under a short-run discrete time model and under conditions of longrun stationarity. The conclusion that follows from his analysis is that effective fiscal stabilisation required a responsive monetary policy for maintaining macroeconomic equilibrium.

The above literature review shows that these studies mostly dealt with the short run consequences of financing of public expenditure and their impact, both direct and indirect, on private spending and hence on employment and output in the economy. And on the basis of the assumptions about the economy like full employment or underemployment, the prescription on financing of a positive fiscal impulse differs. In both cases, however a general conclusion is that, a positive fiscal impulse combined with accommodative monetary policy may crowd-in investment, because to some extent the pressure on interest rate is eased with increased money supply. But with fixed financing or bond financing the result is ambiguous and has differential effect under the two assumptions - under full employment. While there is possibility of full 'crowding-out in an unemployment model it can only be partial because along with the pressure on interest rate increased public spending also adds to output and profits of the private sector (acceleration effects). Though there are some hints at the long run consequences associated with government

expenditure the studies were highly aggregative. The following points which has received little attention, therefore, needs a mention.

(i) What is important for long-run growth and stability is investment. So with the increasing size of the government deficit and the consequent prescriptions on stabilization should not adversely affect investment, per se. Therefore, there is a need to study the relationship specifically between public investment and private investment, so that it can give some insight into the widely held view on stabilization that a contractionary fiscal and an expansionary monetary policy favours investment.

(ii) Secondly, it is important to distinguish between situations in which output is limited by resources and investment is limited by potentially available savings (funds) - supply constraint- from cases when both output and investment is limited by demand - demand constraints, signs of which are high unemployment and excess capacity.

(iii)Thirdly, the general view that in underemployment situation any crowding out that occurs is the result of a tight monetary policy also needs a verification. Because increased public spending (or tax cut) if financed by money creation may raise the inflation expectations about the future. The immediate effect which is apparent is that it will boost private investment, to the extent that the nominal interest rate is not fully indexed with respect to the rate of inflation which results in a low real rate of interest. But one possibility that cannot be ignored is that, it may affect the composition of capital in favour of inventory accumulation. Again such a positive effect on private investment cannot be generally concluded, because if higher rates of inflation were systematically accompanied by increased uncertainty about the future in which case, the private agents can be assumed to be rational enough to expect a tight monetary and fiscal policy and hence in this sense may depress private investment. Thus, a proper policy mix, i.e. effective coordination between fiscal and monetary policy might be warranted.

Case Studies:

Cebula (1978) tried to capture the effects of debt financed government spending on private investment directly without the detour via interest rates, by including the change in the outstanding volume of government debt in the investment function. His intention was to directly capture the actual crowding out effect of government budget deficit and he found crowding-out to a significant degree in the United States and Canada. Another objective was to judge the impact of crowding out on inflation and found that crowding out has important inflationary impact in both the economies. The conclusion that followed from his analysis emphasised on the inflationary potential of fiscal policy that derives from supply considerations, against the traditional demand considerations. But the problem with this study is that it does not take into account a functional relationships between macro variables and simply considered the negative coefficient of the budget deficit as crowding-out.

Aschauer (1989b), considered the possibilities of both crowding-out and crowding in effect of public capital accumulation on US private investment and output and empirically found the net effect to be positive in both cases. He pointed out that at a superficial level an increase in public investment may be expected to reduce private investment by a similar amount, but more specifically one can see that public infrastructure capital crowds in private investment by raising the profitability of private capital stock, but other form of capital may crowd-out private investment. Thus, this paper emphasized on the possibility of differential impact of different types of public capital on private investment, that followed a lot of work in the field. But his analysis is under a neoclassical framework, whose strict application generally posed problem in developing countries due to lack of appropriate data on the one hand and due to the specific structural and institutional characteristics specific to these economies like as underdeveloped financial market and strategic role of public investment in economic planning. Thus, it requires a more coherent study incase of developing economies.

SPECIFIC STUDIES IN INDIA:

Sundararajan and Thakur (1980) deals with the specific issues of crowding out of private investment by public investment in terms of a growth model, covering the period

1960-76, under a comparative study of India and South Korea. This is a study which came at a time when there was increasing concern among economists about the applicability of the neo-classical theory of investment and the transmission mechanism operating in developed countries in its strict sense to the case of developing economies. Though they highlighted on this particular problem, that is, on the possible consequences in applying the standard neo-classical model in the case of a developing country, their study is basically a modified way of applying the neoclassical model to take into account some of the institutional and structural factors inherent in these economic systems.

The problem with their study is that they have taken the rate of return variable (rate of interest) as the linking variable between the real and monetary sectors of the economy (as in the IS-LM model) which basically is based on an implicit assumption of well functioning factor markets. But due to general market imperfections in LDCs (including India) in terms of price and non-price rationing (i.e. an administered interest rate regime and various quantitative controls) it is difficult to expect the rate of return variable (the rental wage ratio) to act as the equilibrating mechanism and therefore it is unlikely that it will capture the effect of any crowding-out (since the private investors, under such rationing framework, will no longer equate the rate of interest (r) with the marginal efficiency of capital (MEC) in their investment planning and also it cannot reflect the effect on private investor's credit demand functions.

Therefore, we would like to introduce the volume of credit (credit availability to the private sector) in the private investment function which will capture the crowding out effect, if any, by restricting the flow of credit to the private sector due to any increase in public investment and judge how the various modes of financing public investment will affect the flow of credit to the private sector and hence on the extent of crowding- in/out associated with each. Along with neglecting the differential impact of financing public investment, it also does not make any difference between the various types of public investment like infrastructure and non-infrastructure which may have differential impact in private investment.

Krishnamurty (1984), allowing for both complementarity and crowding out effects of public investment on private investment and on output, has shown a sectoral analysis that give insights into the very structure of the Indian economy and their involvement overtime. His findings (Simulation results) on a one shift increase in public investment shows that in Agriculture Complementarity prevails (which is basically due to his specification in the sense that it did not allow for the possibility of (crowding out). However in industry and tertiary sector crowding outweigh complementarity effect in the year of increase in public investment and private investment recovers thereafter. At the aggregate level his findings are similar to that obtained by Sundararajan and Thakur (1980). But regarding its effect on output he got contrary results - while in Sunderrajan and Thakur, due to crowding out aggregate GDP also suffers for a longtime, in this case a gain in public sector output and its favourble impact on productivity on other sectors more than compensate for the loss in private output, even in the first year. In short, though public investment crowds out private investment in some sectors and for some years at no stage does aggregate real GDP suffers, that is to say the final outcome favours growth of output. This model suffers particularly in the context of dealing with the issue of crowding out because there has been no stress on the nature of investment function that can capture the structural and institutional factors and their consequences on the operational transmission mechanism that explains crowding out or crowding in.

Krishnamurty, Pandit and Sharma (1989) emphasized on the supply side as explanations for growth performance and dealt broadly with the issues of capital formation, resource mobilization, crowding out and inflation under a macroeconometric model. Regarding the relationship between the public and private investment their findings show generally crowding in phenomena which had its stronghold till mid 1970s and weakening thereafter under the changed scenario. Secondly, it shows that resource crunch in the public sector (public sector resource gap) adversely affects private investment by preempting resources for its use. Thus it shows crowding out through financial channels and due to price effects dealing with the two modes of financing, i.e., resource gap being financed through deficit financing which has inflationary consequences or through domestic borrowings in which case by increased interest rates or by rationing.

Thus it is not clear from this study about the operational transmission mechanism, though they have referred to the interest rates which may not perform well in explaining crowding in or crowding out under a controlled interest rate regime as is the case in India. Secondly, going to emphasize on supply factors neglecting demand factors is in no way warranted. Therefore a proper model should take into account both constraints private on investment decisions.

Pradhan,Ratha and Sarma (1990) is an extensive study on the mode of financing of public investment and the possible impact of it on private investment, under a computed general equilibrium framework. They have concluded that crowding-out may not be so harmful when other objectives like income distribution is taken into account along with growth consequences of public investment. On the various modes of financing their conclusion is that crowding-out of private investment is the highest with direct taxation as the mode of financing and lowest when the mode of financing is money creation. But compared to money creation, market borrowing mode of financing public investment results in more crowding-out of private investment.

But the problem with this study is that they have not made any difference between the infrastructure and non-infrastructure component of public investment and any differential impact each type may have on investment, output and growth. Secondly, to make suggestions on fiscal and monetary policy or broadly on stabilisation, we need to consider the macroeconomic factors like total public sector investment and their consequences on private investment with various modes of financing it.

Mehta (1993), in a paper attempts to analyse the effects of public capital on the productivity of private capital in non-agricultural sector and the substitution possibility between private and public capital, employing Cobb-Douglas and Translog Production function approaches. His conclusion is that public capital in both infrastructure and non-infrastructure sectors are not complementary to private sector capital. Again he concludes that an unit increase in private capital brings a larger rise in the productivity of public capital than a unit increase in public capital on the productivity of private capital. The problem with this study is that first by excluding the agricultural sector in his analysis he has omitted

the possible linkage effect of it on industry, i.e. he has not considered the possible demand and supply constraints operating in the economy, which to a great extent affects the private investment decision. Secondly, it completely ignores the mode of financing of public capital and the possible effect there of on private investment, and thus cannot be used to make any suggestion on policy front with this study.

Thus it is clear from the brief review that none of the studies deals extensively with the mode of financing and different types of public investment together to prescribe something on macroeconomic policy making in India.

Therefore, to overcome this deficiency, we formulate our objectives as follows:

Objectives:-

(i) To study the relationship between public and private investment, i.e. whether public investment complements or crowds-out private investment, by specifying an appropriate investment function in the economy, considering the various modes of financing of public investment

(a) market borrowings, an

(b) money creation.

(ii) To study the above relationship when public investment is disaggregated into its infrastructure and non-infrastructure components and see the offsetting effect each categories may have on private investment, to broadly suggest something on macroeconomic stabilisation.

Methodology:

We will use Ordinary Least Square Regression for estimation, covering the period 1960-61 to 1990-91.

The next chapter develops a model to study the relationship between public and private investment under a modified flexible accelarator framework.

CHAPTER - 3
THE MODEL

THE MODEL

Economists often question the validity of the standard neoclassical investment function in developing countries[1] due to the presence of structural and institutional factors specific to these economies which cause general imperfections in the factor and product markets, leaving aside the data problem regarding the capital stock. Again these economies (as in India) depict a dismal performance in the sense that demand constraint and supply constraint may both be binding on private investment. Therefore it is necessary to formulate the model in such a way as to accomodate all these factors, that can allow us to judge on the extent of net crowding-out or crowding-in effects of private investment, which has a bearing on long-run growth and development. Keeping all these factors in mind, we have chosen a modified flexible accelerator framework in our model.

I. Public Investment and the Crowding-Out Hypothesis :

A long standing debate in the macroeconomic literature has been on the controversial question of whether public and private investment are complements, substitutes or as assumed in most macroeconomic models, independent of one another. Many endogenous growth theory has also focussed attention on the potential impact of public investment on long-term economic growth.[2]

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[1] See Tun Wai & Wong (1982), Blejer & Khan (1984), for more references on the argument. For reference on neoclassical models see Jorgenson (1971).

[2] See Easterly (1992) and Barro's discussion on it. And also Barro (1990). It is argued that public spending has two effects-one distortionary due to its financing pattern (distortionary taxes) and the other is complementary effect by raising the marginal product of private capital. Incase of productive government expenditure (like infrastructure) the complementary effect dominates the distortionary effect. In otherwords, if government infrastructure is small the rate of growth rises with an expansion of government. But in the case of a larger government the distorationary effect dominates and hence growth declines. But for non-productive government expenditure (which might enter into household utility functions) the predicted relation is

The economic rationale behind most of these studies rest on the idea that public investment is confined to such areas where private sector will be unwilling to enter (as they cannot produce in optimal amounts) because, it is both difficult to ration their use and benefits to paying customers (the free rider problem) and due to the lumpiness and indivisibilities in production - the required initial investments are very high and lumpy in nature with long gestation lags. However, these goods are considered as important for the proper functioning of a market system because they tend to generate large and widespread spillover effects. For example, public investment in infrastructure (social and economic) tend to complement private capital formation by facilitating the implementation and realization of private agent's investment plans by overcoming supply bottlenecks in the economy (through their elimination of transportation, communication and educational bottlenecks). Public investment also indirectly affects private investment because it not only augments overall aggregate demand for privately produced goods and services, but also influences private investor's future profit and sales expectations, (the income effect). Lastly, public investment in roads, highways, airports, ports, electricity and gas facilities, water and sewers, health facilities and education services increases the productivity of capital and labour used in private production technology. Thus, in these ways, public investment complements private investment in production.

On the otherhand, public investment used in the production of those goods and services which competes with the private sector may crowd-out private investment.[3] This is particularly the case if these investments are undertaken in markets with high rates of effective protection. Again financing of public investment heavily through taxation, market borrowing and money creation in an economy with a weak financial system (i.e. financial repression) as is the case in many developing countries (including India) may crowd-out

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negative throughout. Thus, it is generally concluded that the size of the government and the nature of capital (infrastructure/non-infrastructure) has important long-run effects on growth.

[3] See Blinder and Solow (1973) for a detailed discussion on it

private investments by restraining them from profitable investment outlets. The combined negative effects of these price and quantity constraints can, in developing countries, become binding in nature very quickly, thus outweighing any positive direct and indirect effects, as claimed by its supporters.

Thus the final impact of public investment on private capital formation is uncertain, complex and as indicated above, is subject to a number of intricate relations. Therefore, it is necessary to formulate a model in such a way as to accomodate both the possible crowding-in and crowding-out effects on private investment and is to be seen that the final outcome (total effect) depends on the relative strength of these two opposing effects which are inversely related.

II. Public Investment from the Budget Relation: A Policy Determined Variable :

The level of public investment and the way it is financed has a bearing on the availability of finance to the private sector which affects the speed of adjustment (λ) with which the private sector adjust its investment to the gap between the desired and actual level. So to deal with the various mode of financing we determine the public investment as follows.

From the budgetary transactions of the government at various levels and public sector undertakings for their plans, we know that the total public sector resource gap (total expenditure - Revenue Receipts i.e. TE-RR) which we call here public sector fiscal deficit (FD) given as -

$$FD = TE - RR$$

$$= RE + CE - RR \quad \text{---------- (1)}$$

Where, RE = Revenue expenditure

CE = Capital expenditure

RR = Revenue receipts (Tax + non-tax)

But this capital expenditure (CE) is composed of two terms - public investment (IG) and current transfers which can be added to the revenue expenditure to give the total consumption expenditure. Because from the central government budget CE is composed of one capital formation part plus current transfer plus capital transfers, but this capital transfers is nothing but loans to States, UTs and public sector undertakings for capital formation. So when we deal with the public sector as a whole, we can write,

Total expenditure (TE) = consumption expenditure (G_C) + investment or public sector Gross domestic capital formation i.e. public investment (IG) where current transfers is added with RE to give total government consumption expenditure.

Therefore from (1) we can write

$FD = G_C + IG - RR$ ---------- (2)

Where FD = public sector gross fiscal deficit

G_c = public sector (or total government) consumption expenditure

IG = public investment

RR = revenue receipts (tax + non-tax)

Again we know that this FD is financed from various sources like

i) Domestic borrowings (DB)

ii) Foreign borrowings ($\overline{FB}$)

iii) Deficit financing

So the resource gap (FD) uncovered by these borrowings (domestic plus foreign, which is called gross capital receipts GKR) is termed as the high powered deficit (HPD), i.e.

$HPD = FD - GKR = FD - DB - FB$

and by the balance sheet constraint, then, this high powered deficit (overall budgetary deficit, as defined in economic survey) brings about an equivalent change in the net RBI credit to the government[4] Which is called monetisation of deficit or money creation.

So we write $\Delta RBCG = FD - DB - FB$ .....(3)

This net change in RBI credit to government (ΔRBCG) reflects the monetary sector's integral link with the fiscal sector and modelled as under. Here according to the formulation (3) we assume that the external borrowings ($\overline{FB}$) as exogenous, because the external sector is not explicitly introduced into our model. However, the domestic borrowing requirements by the public sector (DB) outside of RBI, are endogenous to the model. Therefore, we write, from relation (2) and (3)

$IG = DB + \overline{FB} + \Delta RBCG + (RR - G_c)$ ---------- (4)

In developing economies, it is a common phenomenon that expenditure increases faster than receipts and it is often said government meets its current (or consumption) expenditure from its revenue, because politically it is unrewarding to control current expenditure. Hence most part of revenue goes to meet the current expenditure and these economies often encountered a deficit on this front also. Therefore it is quite reasonable to assume that most part of the capital formation is financed out of the government's gross capital receipts, which includes both internal and external borrowings and the deficit which remained uncovered by these two, leads to an equivalent amount of money creation in the economy. Again this (ΔRBCG) being rasidually determined as in (3) also gives insight into the government's expenditure and revenue side, thus giving a dynamic interpretation to the

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[4] Actually, RBI gives loans to the central government to monetise this deficit, but because most of the borrowings by state government UTs and public sector enterprises (PEs) are channelised through the central government, it can be reasonalbly viewed as RBI credit to the government as a whole to meet the overall budgetary deficit as defined in economic survey. See Economic Survey (1994-95), pp. 20, 21 and 33 for greater details on budgetary transactions of all levels of government and PSUs.

gross fiscal deficit (FD) term taken alone for consideration or jointly with public investment in our model, as can be seen subsequently.

III. Financial Sector and the Equilibriating Mechanism : The Rationing of Credit

Our analysis is based on the availability theory which emphasises that under imperfections in the financial market (i.e. under financial repression) the equilibriating role of the interest rate is hindered (which works properly under the assumption that supply of funds are interest elastic) and hence any disequilibrium in the financial market (particularly lonable funds market) is eliminated by non-interest mechanism (i.e. credit rationing). According to this theory the financial determinants of aggregate demand are represented by the availability of funds rather than their costs.[5] Whether monetary actions are effective or not, depends upon the elasticity of aggregate demand to changes in the supplied volume of lonable funds. Such a framework is very much suited to the case of a developing country due to the presence of structural and institutional rigidities like a controlled interest rate regime, as in India. McKinnon (1973) is of the view that, in contrast to developed countries, one of the principal constraint on investment in developing countries is the quantity rather than the cost of financial resources. Even if the rate of return on investment tend to be high, the rate of interest on lonable funds are kept low by the Government for a variety of reasons - controlled interest rate regime. Therefore any effect exerted by the rate of interest on private investment is not direct within this rationing framework, rather occurs via the channel of financial savings.

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[5] See David and Scadding's (1974, pp. 241-43), argument on ex-ante crowding out. To explain this their presupposition was that consumption expenditures by the government are financed by taxes and that government investment is financed by bonds. Hence private sector treats government deficits as public investment. But in our formulation we are not going to such an extreme; just we have emphasized upon the point, as can be seen later on in our formulation how the linking variable ΔRBCG allows a dynamic interpretation to the fiscal deficit term, that takes care of the possibility of tax revenue financing public investment.

[6] See Nassef (1972) for further discussions on a similar line.

Therefore our contention is that under such financial market imperfections (a fund shortage situation) the banking system embraces a substantial portion of lending and borrowing operations and hence the availability of funds, rather then their costs, is the appropriate linkage between the real and financial phenomena; and the manipulation of bank credit is of prime importance for the effectiveness of monetary policy in a developing country like India.

So the task of proper modelling under such a situation requires a proper specification of the analytical purpose of the study which in turn necessiates the assessment of the financial behaviour of different actors involved in the fund market, the linkage variables and the impact of the linkage variable on aggregate demand. The assessment of monetary impacts on the level of real economic activity is a prerequisite to design the level of policy actions needed to achieve given targets on the real side of the economy. The design of such actions is possible only within the framework of an economic system in which spending behaviour is integrated via the linkage variables with the financial behaviour of different actors of the economy.

IV. Mode of Financing Public Investment:

For our analytical purpose, in our economic system, two actors are involved[7] - the Government (broadly public sector) and the private sector. One interesting thing in our frmework is that one of the actors, the Government is more powerful, in the sense that using different monetary and fiscal tools (like the statutory liquidity ratio (SLR)/or various tax incentives) it is able to preempt its share of the credit to meet its demand for credit)

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[7] In this Paper public sector and government has been used interchangably, though public sector is usually used in a much broader sense. But in our formulation it makes no difference beause specific to our approach the financing decisions is broadly undertaken by the government. So we often write government in place of public sector for sharpness which amounts to the same thing. So one should not get confused with it.

from the domestic market - banks and the public (on the households) which are prime suppliers of credit and the rasidual is available to the private sector to meet its investment demand. On the external front, neither of the actor is able to extract funds substantially due to a host of internal and external factors specific to their decisions and therefore we consider the external borrowing ($\overline{FB}$) requirements as exogenous to our model.

Taking into consideration all these factors we try to model our economic system as follows :

Since our main aim here is to judge on the Financial Crowding-Out, if any, due to increase in government spending to finance increased public investment, we write the exogenously determined public investment (IG) as a function of all financing variables, that also affects the private investment decisions, finance being rasidually made available to the private sector. This is termed in the literature as short-run crowding-out effect of public investment on private investment, which we view is basically contingent on the mode of financing of public investment and process as follows:

The households (H) and the banks (B) are the major suppliers of credit in the domestic market to both the private sector (P) and public sector (G). The household gives loans to the public sector (C_H^G), to the private sector (C_H^P) and to financial institutions[8] (C_H^{FI}) like IDBI, ICICI, IFCI, LIC, GIC, UTI etc. But this household credit to financial institutions (FIs) again get channelised to the private sector (P) and public enterprises (PEs). So we can write

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[8] The reason behind setting up DFIs (Development Financial Institutions) was to plug the perceived gaps in the provision of medium and long-term finance for investment. And over the years they have gained a prominent position in India's financial structure, with assets in the region of 50% of the assets of commercial banks. See Joshi & Little (1996), Chap IV, for more on it. But our concern here is mainly with investment institutions (like LIC, GIC, UTI etc) which get their funds directly from the public and term lending institutions (like IDBI, IFCI etc) which could borrow cheaply sharing in the allocation of SLR funds, along with raising public money through floating of bonds. So both the private sector and public enterprises running on commercial lines demand the C_H^{FI} and therefore will not affect our analysis, if we club C_H^{FI} with C_H^G and C_H^P with C_H^P and write HFS = $C+D+C_H^G+C_H^P$.

$$C_H^{FI} = C_H^{P} + C_H^{PE} \text{ ---------- (*)}$$

But public enterprises being included in the public sector, for simplicity we can broadly say the resources of the FIs get used to finance the demand for credit by the public and private sector. Therefore we can write, without loss of generality,

$$C_H^{FI} = C_H^{P} + C_H^{G} \text{ ---------- (**)}$$

So households total (net) financial savings (HFS) which goes to finance the credit requirements in the economy is over and above their currency holdings (C) and deposit with banks (D). Therefore we write

$$HFS = C + D + C_H^{G} + C_H^{P} \text{ ---------- (5)}$$

$$\Rightarrow C_H^{P} = HFS - C - D - C_H^{G}$$

Thus the household credit to the private sector (C_H^{P}) is derived rasidually by subtracting the credit demanded by the public sector (C_H^{G}) from the net financial savings of the household. The government utilises the fiscal tools (e.g. various tax concessions) to get the demanded credit from the households and hence preempts its share.

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[9] Actually household credit to government should, more specifically, be a function of rate of return on government securities (r_1) and rate of return on competing assets like industrial securities (r_2). So $C_H^{G} = f(r_1, r_2)$ with $f_1 > 0$ and $f_2 > 0$. But for simplicity we do not introduce it in functional form, because in our formulation this only acts as a linking variable, as can be seen later on. Again it is difficult to get data on rates of return on different types of securities also. Again under a repressed financial system it is likely that household may behave as risk averters and consider government securities as riskless, thereby enabling the government to extract a sizeable amount of credit with small tax concessions.

[10] In India, under section 80 and 80L of the Income-tax Act, many tax concessions are declared in respect of interest income from Government securities ,to make it attractable.

Similarly total commercial bank credit (C_B) is divided between the public and the private sector. So simply we write.

$$C_B = C_B^G + C_B^P \text{ ---------- (6)}$$

The bank credit to the public sector (C_B^G) is a function of SLR (the statutory liquidity ratio) and total bank deposits (BD), but for simplicity we write it linearly as

$$C_B^G = SLR \times BD = \Gamma \times BD \text{ ---------- (7)}$$

where Γ = SLR (statutory liquidity ratio)

The SLR stipulates the propertion of deposits that banks must hold in the form of government and other approved securities, that carried considerably lower interest rates then were available on commercial lines.[12]

So under this simplified notation, the supply of credit to the private sector by banks (C_B^P) is then rasidually determined and can be written as

$$C_B^P = (1-\Gamma) \times BD \text{ ---------- (7.1)}$$

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[11] A more concrete formulation would have been $C_B = C_B^{GG} + C_B^{PE} + C_B^P$ where $C_B^G = C_B^{GG} + C_B^{PE}$, i.e. disaggregating the public sector (G) into pure government (GG) and public enterprises (PE_s). And government generally utilies the various monetary tools like SLR, CRR to get its demanded credit from banks. But clubbing them together as C_B^G will not affect our analysis and is also justified (or reasonable) on the ground that most of the borrowings by the public sector is directed through the central government as can be observed from the statement that central government outstanding liabilities (non-RBI) in 1993-94 would have been 32.7% lower if state government UTs, and PSEs had borrowed directly, instead of through the central government Economic Survey 1994-95, pp. 20-21.

[12] Indian banks are obliged to satisfy not only SLR, but also CRR, which requires banks to hold part of their deposits with RBI and thus form part of rationing - the equilibriating mechanism under financial repression. Though there are limits set by the monetary authority for CRR at 3 - 15% and SLR at 25 - 40%.

where Γ is stipulated SLR

and BD - total commercial bank deposits.

So C_H^G and C_B^G basically constitutes the domestic borrowing by the public sector which is mostly done through the central government. So the domestic borrowing requirements by the public sector (DB) is written as

$$DB = C_H^G + C_B^G \text{ ---------- (8)}$$

which fits into equation (4).

Assuming public investment (IG) as a policy determined exogenous variable and its financing as endogenous to our model, in the sense that it is financed through the usual mode of taxation, market borrowing and money creation, which are detemined within the model, we write public investment (IG) from eq. (4) through (6) as a function of all financing variables as -

$$IG = F(C_H^G, C_B^G, \Delta RBCG) \text{ ---------- (9)}$$

and for simplicity, opting a linear representation, we write

$$IG = a_1 C_H^G + a_2 C_B^G + a_3 \Delta RBCG \text{ ---------- (10)}$$

where $a_1, a_2, a_3 > 0$

With foreign borrowing assured as exogenous to the model, this net change in RBI credit to government (ΔRBCG) then reflect the monetary sectors integral link with the fiscal sector. On the other hand the C_H^G and C_B^G are endogenous to the model, as defined above and reflects the linkage between the real and financial phenomena .

Now substituting (8) into (3), we obtain

$$\Delta RBCG = (FD - C_H^G - C_B^G - \overline{FB}) \text{---------- (11)}$$

Now substitutiong (11) into (10), we get

$$IG = a_1 C_H^G + a_2 C_B^G + a_3(FD - C_H^G - C_B^G - \overline{FB})$$

$$= a_1 C_H^G + a_2 C_B^G + a_3(FD - \overline{FB}) - a_3 C_H^G - a_3 C_B^G$$

$$= (a_1 - a_3) C_H^G + (a_2 - a_3) C_B^G + a_3 (FD - \overline{FB})$$

Now substituting for $C_B^G = \Gamma \times BD$ from eq. (7), we obtain,

$$IG = (a_1 - a_3) C_H^G + (a_2 - a_3) \Gamma \times BD + a_3 (FD - \overline{FB})$$

$$C_H^G = \frac{IG - (a_2 - a_3) \Gamma \times BD - a_3 (FD - \overline{FB})}{(a_1 - a_3)} \quad \text{..... (12)}$$

This C_H^G links the public sector's financing pattern with that of the private sector.

V. Specification of Private Investment Function:

It is often argued that the standard neoclassical model of investment cannot be applied properly in the case of a developing economy due to the presence of institutional and structural factors specific to these countries - like the absence of a well developed financial market, strategic role given to public investment in capital formation and an administered interest rate regime, that is, due to general imperfections in the capital and labour market. So such financial and factor markets due to excessive control by the government prevents investors from following the strict neoclassical rule of equating the marginal cost of their capital to its rental price. These features are typical to the case of India also as public sector was assigned the pivotal role in domestic capital formation throughout the planning period and also interest rate is controlled by the government (the monetary authority) and has been kept low to channelise investment into strategic sectors. Thus the availability of resources, rather then their costs or price tends to be the binding constraint. This has been particularly the case in the allocation of financial resources where

the central bank have relied excessively on changing the statutory liquidity ratio (SLR) of commercial banks to mobilise funds for financing various government projects. Therefore, our choice of the modified accelerator over the standard neoclassical model of investment falls in line with that of Tun wai & Wong (1982), Sundararajan & Thakur (1980), Blejer & Khan (1984), to take account of all these institutional and structural factors, i.e. all the constraints faced by private investors in their investment decisions. Again the advantage of such a formulation is that we can introduce the effects of different modes of financing of public investment that have a bearing on private investment to judge on the net effect, i.e. whether it crowds-out or crowd-in private investment and how it vary with the specific mode chosen.

Moreover, with such a formulation we can disaggregate public investment into infrastructure and non-infrastructure component and can know the effects of each type of private investment. In this way it will accommodate both the objectives of our study - how the crowding-in or crowding-out effect get affected with the different modes of financing of public investment and with the different types of public investment.

Since it takes time to plan, build and install new capital, we write the adjustment of actual investment in period t (ΔKp_t) to the difference between the desired private capital stock in period t (KP^*_t) and the actual stock in the previous period (KP_{t-1}) under a partial adjustment framework as.

$$\Delta KP_t = \lambda (KP^*_t - KP_{t-1}) \quad \text{---------- (13)}$$

or, $$KP_t = \lambda KP^*_t + (1 - \lambda) KP_{t-1} \quad \text{---------- (13.1)}$$

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[13] See Chakraborty Commitee report 1985, on the working of the monetory system.

Where λ is the coefficient of adjustment, with $0 \leq \lambda \leq 1$, ΔKP_t is the change in private capital stock or simply net private investment, KP^*_t is the capital stock desired by the private sector to have in period t. Thus eq. (13) postulates that net private investment in any given time period t is some fraction λ of the desired change for that period. Although theoretically it is possible for the actual capital stock to adjust instanstaneously to its desired level ($\lambda = 1$) or for no-adjustment to take place at all ($\lambda = 0$), in actual practice it lies somewhere between 0 and 1, implying the various constraints faced by private investors in their investment decisions. On the other hand the formulation (13.1) shows actual capital stock in period t as a weighted average of the desired capital stock in that period and the actual stock in the previous period.

This formulation is in terms of net investment, but we need it to be in gross terms to judge the relationship between public and private investment, as per our specification of the problems, and therefore write gross private investment (IP_t) as equal to net investment plus depreciation of the previous period's capital stock, that is,

$$IP_t = \Delta KP_t + \delta KP_{t-1} \quad \text{----------} \quad (14)$$

where δ is the rate of depreciation of private capital stock.
Using standard lag operator notation, we can write (14) as

$$IP_t = [1 - (1 - \delta)L] KP_t \quad - - - - - - - - - - - - - - - \quad (15)$$

where L is the lag operator with $LKP_t = KP_{t-1}$.

By inverting relation (15) we can relate private capital stock to gross private investment as

$$KP_t = \frac{IP_t}{[1-(1-\delta)L]} \quad \text{----------} \quad (16)$$

and substituting for KP_t and KP_{t-1} in eq. (13.1) by using (16), we get

$$\frac{IP_t}{[1-(1-\delta)L]} = \lambda KP^*_t + (1-\lambda)\frac{IP_{t-1}}{[1-(1-\delta)L]}$$

which has the solution.

$$IP_t = [1-(1-\delta)L]\,\lambda KP^*_t + (1-\lambda)\,IP_{t-1} \quad \text{---------- (17)}$$

Now under long-run representation of the accelerator model it can fairly be assumed that the desired capital stock is proportional to the level of expected output and we write

$$KP^*_t = \beta Y^*_t \quad \text{---------- (18)}$$

where β is a constant.

Where Y^*_t is the expected level of output corresponding to KP^*_t . This is quite a standard formulation and can be rationalised by assuming that the underlying production function has (technologically) fixed proportions among factor inputs, so that factor prices do not enter into the specification. If we now substitute (18) into (17) we can get an expression for a basic accelerator model for gross private investment as -

$$IP_t = \beta\lambda[1-(1-\delta)L]\,Y^*_t + (1-\lambda)\,IP_{t-1} \quad \text{---------- (19)}$$

An alternative and more convenient way for deriving eq. (19) is by directly specifying a partial adjustment function for gross priate investment IP_t, rather then KP_t, so we write.

$$\Delta IP_t = \lambda(IP^*_t - IP_{t-1}) \quad \text{---------- (20)}$$

where IP^*_t is the desired level of private investment. In the steady state, desired private investment is given by.

$$IP^*_t = [1-(1-\delta)L]\,KP^*_t \quad \text{---------- (21)}$$

Combining equations (20) and (21) and solving for IP_t than yields an equation exactly the same as equation (17) and substituting for KP^*_t from (18) than yields (19), the same as above. So in this formulation (17), to incorporate the effect of public investment and the various modes of financing of public investment on private investment, one can proceed in two ways -

(i) either viewing that these factors affect the speed of adjustment (λ) with which the private sector adjusts its actual investment to the gap between the desired level and previous period's actuals, that is, by influencing the ability of private investors to achieve the desired level of investment as given in eq. (20). In case of crowding-out we will expect a smaller coefficient of adjustment, whereas in case of crowding-in effect of public investment we would expect the coefficient (λ) to be higher.

(ii) the other way is public investment and the various ways in which it is financed affecting the desired level of private investment in the first place. Therefore in this case the desired level of private investment is expressed as a function of the level of public investment and the various financing variables rasidually made available to the private investors along with the expected output. So in estimation of the final equation both the methods will give similar result, the only difference will be in interpreting the results.

So to study the effect of public investment and the various modes of financing of it, we follow the first approach suggested by Coen (1971) and mostly used by many studies on private investment behaviour in developing countries like Sundararajan & Thakur (1980), Blejer & Khan (1984) etc.

So we hypothesize that the response of private investors as represented by the adjustment coefficient (λ) depends on the following factors:

i) the level of public investment

ii) the availability of finance to the private sector, which is affected by the way of financing of public investment, like

a) $C_H{}^P$ - the household credit to the private sector

b) $C_B{}^P$ - bank credit to the private sector as has been rasidually determined by relation (5) and (7) respectively.

So with a linear formulation, we write the adjustment coefficient (λ) to get systematically affected by the above variables as

$$\lambda_t = b_0 + \frac{1}{IP_t^* - IP_{t-1}} (b_1 IG_t + b_2 C_H{}^P + b_3 C_B{}^P) \text{ ---------- (22)}$$

with $b_1, b_2, b_3 > 0$

We expect that the real level of public investment raises the productivity of capital and by providing critical infrastructure to be used in private production complements private investment and hence b_1 is expected to be positive i.e. $b_1 > 0$.

Secondly, the higher the availability of finance to the private investors from various sources - i.e. from households and Banks, the more the private investment will be. Hence we expect positive signs for b_2 and b_3. Thus $b_2 > 0$, $b_3 > 0$.

Now substituting eq. (22) into (20), we get

$$\Delta IP_t = b_0 [IP_t^* - IP_{t-1}) + b_1 IG_t + b_2 C_H{}^P + b_3 C_B \text{ ---------- (23)}$$

Now substituting for IP_t^* from (21) $KP_t^* = \beta Y_t^*$ from (18) into (23) and solving for IP_t, we obtain,

$$IP_t = b_0[1-(1-\delta)L]\beta Y_t^* + b_1 IG_t + b_2 C_H^d + b_3 C_B^d + (1-b_0) IP_{t-1} \quad \text{---------- (24)}$$

With β a constant, and $b_1, b_2, b_3 > 0$.

Now substituting for C_H^d from eq. (5) and C_B^d from eq. (7.1) into eq. (24) we get,

$$IP_t = \beta b_0 [1-(1-\delta)L]Y_t^* + b_1 IG_t + b_2 (HFS - C - D - C_H^d) + b_3(1-\Gamma)BD + (1-b_0) IP_{t-1}$$

$$= \beta b_0 [1-(1-\delta)L]Y_t^* + b_2 IG_t + b_2 (HFS - C - D) - b_2 C_H^d + b_3 (1-\Gamma) BD + (1-b_0) IP_{t-1}$$

Now substituting for C_H^d from (12), we get

$$IP_t = \beta b_0 [1-(1-\delta)L] Y_t^* + b_1 IG_t + b_2 (HFS - C - D)$$

$$- b_2 \left[\frac{IG - (a_2 - a_3)\Gamma \times BD - a_3(FD - \overline{FB})}{(a_1 - a_3)} \right] + b_3(1-\Gamma)BD + (1-b_0) IP_{t-1}$$

$$= \beta b_0 [1-(1-\delta)L]Y_t^* + b_1 IG_t + b_2 (HFS - C - D)$$

$$- \frac{b_2}{a_1-a_3} IG + \frac{b_2(a_2-a_3)}{a_1-a_3} \Gamma \times BD$$

$$+ \frac{b_2 a_3}{a_1-a_3} (FD - \overline{FB}) + b_3(1-\Gamma) BD + (1-b_0) IP_{t-1} \quad \text{---------- (25)}$$

Now assuming that only a fraction of total public investment is financed from bank credit, we can write the demand for credit by the public sector (C_B^d) as a constant fraction of IG.

$$C_B^d = \gamma IG \quad \text{---------- (26)}$$

Where γ is a constant

Again we know from (7) that $C_{13} = \Gamma \times BD$.

So combining these two, we can write $\Gamma \times BD = \gamma . IG$ ---------- (27)

Now substituting for $\Gamma \times BD$ in (25) through (27), we get

$$IP_t = \beta b_o[1-(1-\delta)L]Y_t^* + b_1 IG_t + b_2(HFS - C - D)$$

$$+ \frac{b_2 a_3}{a_1 - a_3}(FD - \overline{FB}) + b_3(1-\Gamma)BD$$

$$+ \frac{b_2(a_2 - a_3)}{a_1 - a_3}\gamma IG - \frac{b_2}{a_1 - a_3} IG + (1 - b_o) IP_{t-1}$$

now taking IG common, we can write,

$$IP_t = \beta b_o[1-(1-\delta)L]Y_t^* + b_1 IG_t + b_2(HFS - C - D) + \frac{b_2 a_3}{a_1 - a_3}(FD - \overline{FB})$$

$$+ b_3(1-\Gamma) BD + \left[\frac{b_2\gamma(a_2 - a_3)}{a_1 - a_3} - \frac{b_2}{a_1 - a_3} \right] IG + (1-b_0) IP_{t-1}$$

or $IP_t = c_o[1-(1-\delta)L]Y_t^* + b_1 IG_t + b_2 (HFS-C-D) + c_1 (FD-\overline{FB}) +$

$b_3(1-\Gamma)BD + c_2 IG + (1-b_o) IP_{t-1}$ ---------- (28)

where $c_o = \beta b_o$, $c_1 = \frac{b_2 a_3}{a_1 - a_3}$ and $c_2 = \frac{b_2\gamma (a_2 - a_3) - b_2}{a_1 - a_3}$

In the above equation, $(1-\Gamma)BD$, where Γ = SLR, is nothing but the flow of bank credit to the private sector, so the only unobservable variable is the expected level of output (Y_t^*) and it can be generated in a number of ways like - using a generally distributed lag formulation, or using an adaptive expectations model or by fitting an autoregressive process and taking the predicted values as expected output. We have taken the average of current real GDP and its past four years GDP as expected output, because in India there is evidence of abnormality each alternate years either in the form of droughts or wars or political instability or some other exogenous shocks like oil shocks, which affects the GDP, expecting that it will perform better than the above mentioned methods of deriving expected output.

So now writing, $[1-(1-\delta)L]Y_t^* = \Delta GDP_t$

where δ is the chosen rate of depreciation and L is the one period lag operator.

HFS-C-D = H1, FD-$\overline{FB}$ = FD_1, $(1-\Gamma)$ BD = FBC, i.e. the flow of bank credit to the private sector and substituting in (28)

We can write

$$IP_t = c_0 \Delta GDP_t + b_1 IG_t + b_2 H1_t + b_3 FBC_t + c_1 FD1_t$$

$$+ c_2 IG_t + (1-b_0) IP_{t-1} \quad \text{---------- (29)}$$

Where the expected signs of the coefficients are as follows- the coefficient of ΔGDP_t i.e., the accelerator coefficient as positive - $c_0 > 0$.

$b_1 > 0$ - which gives the crowding-in effect of public investment, in the sense that public investment by providing basic infrastructure reduces the cost of production in the private

sector, thereby increasing the profitability on the one hand and increases the productivity of capital and labour on the other.

$c_2 < 0$ - which gives the crowding out effect in the sense that financing of public investment also put pressures in the scarce investible funds and thereby limits the credit availability to the private sector.

$b_2 > 0$ - which means the more the household credit, the more will be the private investment.

$b_3 > 0$ - which implies that the higher the bank credit available to the private sector, the higher will be the investment.

$c_1 < 0$ - which implies that a higher fiscal deficit net of foreign borrowings means the more the domestic borrowing requirements by the government on the one hand and is also viewed by private agents as implying more future taxes on the other and thus depress private investment. So with these signs we can write (29) as

$IP_t = c_o \ \Delta GDP_t + (b_1-c_2)\, IG_t + b_2\, HI_t + b_3\, FBC_t + c_1 FDI_t + (1-b_o)\, IP_{t-1}$

or $IP_t = \alpha_0\, \Delta GDP_t + \alpha_1\, IG_t + \alpha_2\, HI_t + \alpha_3\, FBC_t + \alpha_4\, FDI_t + (1-b_o) IP_{t-1}$ ---------- (30)

with $\alpha_0 > 0$, $\alpha_1 >$ or < 0, depending on whether $b_1 > c_2$ or $b_1 < c_2$, $\alpha_2 > 0$, $\alpha_3 > 0$, $\alpha_4 \gtrless 0$ or < 0

Interpretations:

1. So it is evident from formulation (30) that the total effect of public investment on private investment depends on the relative strength of the crowding-in (b_1) and crowding out (c_2) and appriori we cannot say which effect is stronger this needs to be empirically tested.

2. But by disaggregating public investment into infrastructure and non-infrastructure components, we can expect that in case of infrastructure, investment, b_1 will be stronger than c_2, compared to its non-infrastructure component, so that the total effect will be positive, or at least can be expected that the positive effect is large enough to compensate for the negative effect.

The next chapter deals with these issues with its empirical dimension in India over the period 1960-90.

CHAPTER - 4
EMPIRICAL FINDINGS

EMPIRICAL FINDINGS

Before estimation, a brief introduction to the role of the public sector and its performance over time is necessary for a proper understanding of the relationship between the public and private investment. Mostly, because the public sector, over the years, has entered into almost all areas of economic activities through the public enterprises, thereby rendering itself to competition with the private sector. So with the increase in the size of the public sector, its performance has a bearing on the economy, in the sense that, its performance has a say in shaping the monetary and fiscal policy to be pursued in future. Again, these policies affect the private sector investment activities to a great extent and hence have long run implications for growth and stability.

I. The Role and Performance of the Public Sector in India :

The Indian development strategy since the inception of planning has been to achieve growth with social justice. Therefore, in an effort to achieve the declared objectives in the presence of the pervasive private sector, greater emphasis was placed on public sector. It can be seen in the context of the Mahalanobis strategy of the second plan which specifically focused on long term growth. The long term growth orientation in an import-substitution dominated strategy required that the domestic capacity creation be biased in the direction of producing capital goods to produce more capital goods. Consequently, there was considerable acceleration in public investment in infrastructure and indirectly, productive investments in universal intermediates like steel, coal, power and heavy electricals machinery. The dominant theme under such an

approach has been the growth orientation and the complementary role that the public sector was experted to play vis-a-vis the private sector. Such state intervention was expected to operate through the following instruments:

(i) aggressive fiscal and monetary policies,

(ii) market intervention without undertaking direct production.

(iii)undertaking directly productive economic activity through the public sector - essentially an extension of the public ownership of means of production.

So utilising all these instruments, the public sector has grown alarmingly over the years, particularly through indulging in direct production activities. With such development it was hoped that the public sector would be able to generate enough resources from such large scale operation. But this growth in ownership is accompanied by the institution of comprehensive controls; taken together this has resulted in a rapid increase in public administration also.

Public sector comprises of

(i) government administrative departments (ADS),

(ii) departmental enterprises like, the railways, posts and telegraphs and other communication enterprises and other departmentally-run enterprises, and

(iii) non-departmental enterprises consisting of (a) financial and (b) non-financial, which are wholly or mainly government owned companies and public corporations. Administrative departments including defense services are said to constitute the general government comprising central and state govts., Union territories (UTs) and all layers of local level institutions. The currency issue function of the RBI is said to be a sovereign function and hence its issue department is treated as part of the general government, with the other banking departments forming part of non-departmental

enterprises. So a fair description of the extent of public sector and its performance can easily be ascertained from (Table 1). In describing the extent of public sector activity, we shall usually mean the extent of public activities at all levels - central, state and local governments - but these will also be distinguished. So in table 1, we give a disaggregative statement by including public enterprises, non-departmental enterprises, that are supposed to be run on commercial lines, as well as, those departmental enterprises (like railways, post and telegraphs etc.)which are not.

It is evident from Table - 1 that there has been acceleration in capital formation of the public sector which has mainly come from the public enterprises. Starting with an average of around 19percent in 1960s, it has risen to more than 26percent in the 1980s. Similarly capital formation in government administration (ADs) has also kept pace with the overall increase. But the capital formation by Departmental Enterprises (DEs) has not been commensurate increase, which is contrary to the perceived development strategy in the sense that - most of the basic infrastructure provision is provided through various departments like Railways, Posts and telegraphs etc. Instead it has actually fallen from an average of about 18 percent to less than 10 percent by the end of the 1980s. Thus it is clear that the increase in the pattern of capital formation in the public sector has been the result of growth in ownership through public enterprises and comprehensive controls which is reflected in the increase in capital formation by the administrative departments. This can also be discerned from the industrialization policy pursued through the 1960s - which saw nationalization on a large scale starting with the nationalization of 14 major commercial banks in 1969.

But if we observe the performance of public sector in terms of its share in aggregate gross domestic product at factor cost and its saving as percentage of gross

domestic product at market price and contrast it with the investment shares in total investment than an interesting point emerge. That is there has been a generally rising trend in the share of public sector in total GDP but a general loss of saving momentum in the public sector with the exception in the 1980s when the aggregate was at its highest at more than 4 percent of GDP. But if we analyse at a disaggregative level, then it gives even more interesting results - the ADs share has declined and became negative in the later part of the 1980s averaging at 15percent of the GDP and the DE's share in total public savings had increased considerably starting from a very low figure, with the DE's shares being very small, i.e. less than one percent throughout.

In case of its share in aggregate GDP, the major share was by the ADs till the end of 1970s and though it has increased thereafter also, the contribution by NDEs has outweighed it from 1980 onwards with the share of DEs remaining almost stable at around 4 percent. But during the pre-1980 period the non-departmental enterprises did not fare well even with a high share in total investment of the public sector.

Thus, one thing that is clear from such a disaggregative analysis is that contrary to the planner's expectations the savings generated in the public sector has actually declined, more so due to dissavings by the pure government sector. From 1960-65 the government saving rose above the levels attained in earlier periods, primarily due to increased tax efforts. But in the second half of the decade, it actually fell. This reflected the fall in tax revenue (Table - 2) - (Tax-GDP ratio declined to 10.5percent of GDP from 12.2percent in the first half of the decade) during a period of recession combined with the fact that expenditure cuts were directed at investment, which can be seen from the drastic reduction in capital formation by DEs. In the 1970s government savings rose even during the crisis years (droughts) of 1973/74 and 1974/75 because in

Table-1: THE EXTENT OF PUBLIC SECTOR:A DISAGGREGATIVE STATEMENT
Capital Formation(GDCF), Savings and Output (at current prices)
(in percent; period averages)

Years	Administrative Departments	Departmental Enterprises	Non-Departmental Enterprices	Total Public Sector
	GDCF in public sector as percentage of total GDCF			
1965-70	8.2	14.1	19.4	41.4
1970-75	9.7	12	19.2	41.1
1975-80	7.7	11.6	25.8	45.3
1980-85	10.9	11.8	26.3	49.1
1985-90	10.1	9.9	26.2	44.2
1990-91	7	7.3	21.6	36
	Gross Saving in Public sector as percentage of GDP at Market prices			
1960-65	1.5	1	0.5	3.1
1965-70	1.1	0.7	0.7	2.5
1970-75	1.4	0.5	1	2.9
1975-80	2.4	0.7	1.4	4.5
1980-85	1.3	0.3	2.2	3.8
1985-90	-1.5	0.6	3.2	2.3
1990-91	-2.5	0.7	3.1	2
	GDP from Public Sector as percentage of aggregate GDP at Factor costs			
1960-65	5.2	3.9	1.9	11
1965-70	5.7	3.7	2.9	12.3
1970-75	6.1	3.4	4.9	14.3
1975-80	6.7	3.7	7.9	15
1980-85	7.7	3.4	10.7	21.7
1985-90	9	4.2	13.1	26.3
1990-91	9.2	3.9	13.1	26.3

Source: Government of India, CSO (Various Years) National Accounts Statistics.

these years there were drastic cuts in current expenditure. But since the second half of the 1970s there is sizeable increase in public expenditure, a trend which still persists. But since government revenue also rose strongly (Table-2 - it rose to an average of 14.6percent of GDP during the period 1975-80 from 12 percent during the first half). Consequently, there was little change in government savings.

In the 1980s there was sharp deterioration in government saving, which become increasingly negative after 1984-85, leading to the fear of fiscal crisis. This basically happened despite the increase in tax revenue to 16.9percent of GDP on an average for the period 1985-90, which jointly with a decline in the share of public investment in total investment reveals the fact that government expenditure rose sharply. These changes consisted of a move toward more populist style of government at all levels.

On the other hand, though public enterprises' saving increased it was not adequate to finance a significant increase in public enterprise investment, which implies that the public sector is to a great extent capturing private savings for its use (see table - 1). From 1960-61 to 1974-75, public enterprises saving hovered around 1percent of GDP, apart from a very low level for few years after the droughts of 1965-66. However, there was a slight increase to around 2.2. percent of GDP during the second half of the 1970s, partly resulting from bank nationalization and consequently higher recorded savings in financial enterprises. Savings of non-financial enterprises showed no growth trend as a proportion of GDP until the 1980s. However the savings of other enterprises (NDEs) doubled from around 1.5 percent of GDP in the late 1970s to an average of 3.2 percent of GDP in the second half of the 1980s, a plausible explanation for which can be that, during that period it was the oil sector which was

Table-2: FINANCING OF PUBLIC INVESTMENT,1960/61 TO 1990/91

(Percentage of GDP at current Market Prices, with period averages in brackets)

Years	Total GDCF 1	Gross Savings 2	Public GDCF 3	Public Savings 4	Tax Revenue Direct 5	Indirect 6	Total 7	Fiscal* Deficit 8	Foreign Borrowing 9	Domestic Borrowing 10	Deficit Financing 11	M3** Growth 12	Inflation*** Rate 13
1960-61	15.7	12.7	7.1	2.6	2.5	5.8	8.3	5.5	1.8	2.6	0.9		
1961-62	14.2	12.2	6.7	2.9	2.6	6.4	8.9	5.7	2	2.9	0.6	1.9	0.2
1962-63	15.8	13.4	7.8	3.1	3.3	7.1	10	5.2	1.9	2.6	0.7	9.9	3.8
1963-64	15.4	13.3	7.9	3.4	3.2	7.7	10.9	5.8	1.4	2.5	0.8	8.8	6.3
1964-65	15.1(15.2)	12.7(12.9)	7.9(9.3)	3.3(3.8)	3(3.6)	7.5(6.8)	10.6(12.2)	6.4(7.2)	2.6(2.7)	3.2(3.5)	0.5(0.9)	10.3(7.7)	10.8(5.2)
1965-66	16.8	14.5	8.5	3.1	2.8	8.4	11.2	6.7	3	3.4	0.2	10.2	7.7
1966-67	18.4	15.3	7.2	2.2	2.6	8.4	11	4.3	1.9	2.2	0.1	11.2	18.9
1967-68	15.4	13	6.7	1.9	2.2	7.7	10	4.8	2.8	1.8	0.2	9.2	11.6
1968-69	13.9	12.8	5.9	2.3	2.3	8	10.2	4.8	2.3	1.6	0.8	10.7	-1.2
1969-70	15.6(16)	15(14.1)	5.6(6.8)	2.6(2.4)	2.4(2.4)	8(8.1)	10.4(10.6)	4.5(5.0)	1.4(2.3)	3.0(2.4)	0.1(0.3)	13.2(10.9)	3.8(7.1)
1970-71	16.6	15.7	6.5	2.9	2.3	8.7	11	5.1	0.8	3.4	0.9	13.3	5.5
1971-72	17.3	16.2	7.1	2.8	2.5	9.5	12	6.6	0.8	3.9	1.6	14.5	5.6
1972-73	15.9	15.4	7.3	2.6	2.6	10	12.6	6.2	0.5	3.9	1.6	16.4	10.1
1973-74	19.1	18.4	7.7	2.9	2.5	9.4	11.9	5.2	0.7	3.5	0.8	19.8	20.1
1974-75	18.3(17.4)	17.4(16.7)	7.6(7.2)	3.6(3)	2.5(2.5)	10.1(9.5)	12.6(12)	5.4(5.7)	1.0(0.8)	3.4(3.6)	0.9(1.2)	13.6(15.5)	25.1(13.3)
1975-76	18.8	19	9.6	4.2	3.2	11	14.2	6.1	2.2	3.4	0.4	12.5	-1.1
1976-77	19.7	21.2	10.1	4.9	3.3	11.5	14.5	6.4	1.6	4.6	0.1	19.8	2.1
1977-78	19.5	21.1	8.1	4.3	2.8	11	13.8	6.2	0.7	4.4	1	20.1	5.2
1978-79	23.3	23.2	9.5	4.6	2.7	12.2	14.9	7	0.6	6	0.6	20.3	0.2
1979-80	22.1(20.7)	21.6(21.2)	10.3(9.5)	4.3(4.5)	2.7(2.9)	12.7(11.7)	15.5(14.6)	7.5(6.6)	0.7(1.2)	4.3(4.6)	2.3(0.9)	20.3(18.6)	17.1(4.6)
1980-81	20.9	21.2	8.6	3.4	2.4	12.2	14.6	9	1.2	5.2	2.5	16.3	18.2
1981-82	23.8	19.8	9.5	4.5	2.6	12.5	15.1	8.3	0.8	5.9	1.6	17.4	9.8
1982-83	22.5	19	11.3	4.4	2.5	12.8	15.3	9.5	0.8	7.3	1.3	14.3	2.6
1983-84	21.1	18.9	9.8	3.2	2.4	12.8	15.2	9.5	0.7	6.9	1	17.4	9.5
1984-85	21.2(21.9)	18.2(19.4)	10.8(10)	2.8(3.7)	2.3(2.4)	13.2(12.7)	15.5(15.3)	11.1(9.5)	0.8(0.9)	8.1(6.7)	2.2(1.7)	18.2(16.7)	7.1(9.3)
1985-86	24.2	19.8	11.1	3.2	2.4	14.1	16.5	10.3	0.7	8.3	1.3	17.1	5.7
1986-87	23.2	18.7	11.6	2.7	2.3	14.6	16.9	12.3	0.8	8.3	3.1	17.6	4.3
1987-88	22.5	20.9	10.4	2.2	2.2	14.8	17.1	11.6	1.1	8.8	1.6	17	8.2
1988-89	22.4	21.4	9.9	2	2.5	14.4	16.9	11.2	0.7	9.1	1.2	17.4	7.5
1989-90	24.1(23.3)	22.2(20.6)	10(10.6)	1.6(2.4)	2.4(2.4)	14.6(14.5)	17(16.9)	12.0(11.5)	0.7(0.8)	8.9(8.7)	2.2(1.9)	19.6(17.7)	7.4(6.6)
1990-91	24.2	23.6	9.7	1	2.5	14.1	16.4	12.3	0.8	9.3	2.1	16.6	10.3

* The Public sector resource gap as defined in Economic Survey

** Annual growth percent

*** Annual percentage change in WPI for all commodities

Source: First four colomns from Government of India, CSO (1989 new series, 1991 and 1996), National Accounts Statistics
Columns (5, 6, 7) from Government of India(GOI),Ministry of Finance(1994), Public Finance Statistics;
Columns(8,9,10,11) from GOI, Ministry of Finance (various years),Economic Survey;
Column (12) from Singh,Shetty and Venkatachalam (1982) and RBI (various years), Report on Currency and Finance;
Column(13) calculated by using WPI data from Chandhok,H L(1990) and GOI , Ministry of Finance (various years), Economic Survey.

very profitable and not the other enterprises. For the general low profitability of the public enterprises, one explanation can be fostered in terms of excessive bureaucratic control, protection from outside competition and an administered pricing policy deliberately undertaken by the government in line with the declared objectives of achieving growth with justice. With this sort of performance in terms of savings, however, any acceleration in public investment could only be financed out of the budget, thus putting fiscal pressures in the economy. Consequently, the government's monetory and fiscal policies were extensively used to serve the purpose of economic planning with a poorly performing public sector. Thus one can say that on the resource mobilisation front there was a big gap in projection and achievement. Inspite of this plan after plan, there was a sense of optimism concerning savings and a faith in the ability of the economy to sustain high level of investment rate (driven by a high rate of public investment), which has been central to India's economic philosophy.

For financing economic development in developing countries, while the economic dictum placed responsibility upon the government sector to mobilise savings in India, actually there was little success in this direction. Therefore, the burden of financing development fell upon the private sector also in terms of various price and non-price rationing. This can be seen from Table-2, which shows the pattern of financing of public investment; size of the deficit and growth in money supply which has implications for the private sector activities.

Indian plans have strongly emphasized the role of public savings as a support for public investment. In practice, public savings as a proportion of GDP has stagnated except for an upward move in the second half of the 1970s. However, after 1981-82 there was a sharp fall, which contributed to rising public deficits. And public savings

Table 3 Saving/investment behaviour of the private sector
(percentage of GDP at current market prices, with period averages in brackets)

Year	Total GDCF	Gross saving	Private GDCF	Pvt. Corp. GDCF	Household GDCF	Private saving	Pvt. Corp. saving	Household Saving: Total	Household Saving: Physical assets	Household Saving: Financial assets
1960-61	15.7	12.7	8.9	3.3	5.6	10.1	1.7	8.4	5.6	2.8
1961-62	14.2	12.2	8.9	4.3	4.6	9.2	1.7	7.5	4.6	2.8
1962-63	15.8	13.4	8.7	2.9	5.8	10.3	1.8	8.5	5.8	2.7
1963-64	15.4	13.3	8.7	4.1	4.6	9.9	1.8	8.1	4.6	3.5
1964-65	15.1(15.24	12.7(12.86	8.5(8.74)	3.6(3.64)	4.9(5.1)	9.3(9.76)	1.5(1.7)	7.8(8.06)	4.9(5.1)	2.9(2.94)
1965-66	16.8	14.5	8.5	2.7	5.8	11.4	1.5	9.9	5.8	4.1
1966-67	18.4	15.3	10.8	2.1	8.7	13.0	1.4	11.6	8.7	2.9
1967-68	15.4	13.0	9.7	2.3	7.4	11.1	1.2	9.9	7.4	2.5
1968-69	13.9	12.8	9.2	2.1	7.1	10.5	1.2	9.3	7.1	2.2
1969-70	15.6(16.02	15.0(14.12	10.4(9.72)	1.6(2.16)	7.8(7.56)	12.4(11.88	1.3(1.32)	11.1(10.56	8.8(7.56)	2.3(2.8)
1970-71	16.6	15.7	10.6	2.4	8.2	12.8	1.5	11.3	8.1	3.2
1971-72	17.3	16.2	11.4	2.8	8.6	13.8	1.6	11.8	8.5	3.4
1972-73	15.9	15.4	9.8	2.6	7.2	12.7	1.5	11.2	7.6	4.2
1973-74	19.1	18.4	10.6	2.6	8.0	15.5	1.7	13.8	8.0	5.8
1974-75	18.3(17.44	17.4(16.62	12.2(10.92	3.7(2.82)	8.5(8.1)	13.8(13.64	1.0(1.66)	11.8(11.98	8.5(8.14)	3.2(3.96)
1975-76	18.8	19.0	11.2	2.7	8.5	14.6	1.3	13.3	8.4	5.0
1976-77	19.7	21.2	10.8	1.5	9.3	16.4	1.4	15.0	9.2	5.7
1977-78	19.5	21.1	11.6	2.4	9.2	16.7	1.4	15.3	9.2	6.1
1978-79	23.3	23.2	12.8	2.2	10.6	18.5	1.5	17.0	10.6	6.4
1979-80	22.1(20.68	21.6(21.22	12.5(11.78	2.6(2.28)	9.9(9.9)	17.3(16.7)	2.1(1.54)	15.2(15.6)	9.9(9.46)	5.3(5.7)
1980-81	20.9	21.2	12.2	2.5	9.7	17.8	1.7	16.1	9.7	6.3
1981-82	23.8	19.8	13.4	5.7	7.7	15.3	1.6	13.7	7.7	6.0
1982-83	22.5	19.0	11.5	5.7	5.8	14.5	1.6	12.9	5.8	7.2
1983-84	21.1	18.9	11.1	3.4	7.7	15.6	1.5	14.1	7.7	6.4
1984-85	21.2(21.9)	18.2(19.4)	10.4(11.72	4.4(4.34)	6.0(7.38)	15.4(15.72	1.7(1.62)	13.7(14.1)	6.0(7.38)	7.7(6.72)
1985-86	24.2	19.8	13.0	5.5	7.5	16.6		14.6	7.5	7.1
1986-87	23.2	18.7	11.5	5.3	6.2	16	1.8	14.2	6.2	8.0
1987-88	22.5	20.9	12.5	3.6	8.9	18.7	1.7	17.0	8.9	8.0
1988-89	22.4	21.4	14.4	4.0	10.4	14.3	2.1	17.2	10.4	6.9
1989-90	24.1(23.28	22.4(20.6)	14.1(13.1)	4.2(4.52)	9.9(8.58)	20.(18.24)	2.6(2.04)	18.1(16.2)	9.9(8.58)	8.1(7.62)
1990-91	24.2	23.6	15.5	4.3	11.2	22.6	2.8	19.8	11.2	8.7

Source: Government of India, CSO (various years), National Accounts Statistics.

deteriorated and touched the periods low at 2.3 percent of GDP during 1985-90. Table - 2 presents information on the financing of public investment by public savings, public domestic borrowings and public foreign borrowings. Along with it, it shows the tax revenue collection of the government and its composition over time. Again, it also depicts the deficit financing of the public sector which is the major source of money supply in India.

From Table-2, it can be discerned that, over these years, there has been a shift towards indirect taxes in tax revenue collection, which is often termed as inflationary. So a declining public savings which has increased the size of the deficit has resulted in increased savings requirements by the government, but with declining foreign assistance which was a major source of financing during the 1970s, there has been increased reliance on domestic borrowings. Therefore, domestic borrowing as a percentage of GDP has increased from a low of 2.5 percent of GDP in the second half of the 1960s, has gone up to more than 8.5 percent of the GDP in the second half of the 1980s. Similarly, deficit financing as a tool of financing public investment which was around 1 percent of GDP in the first half of the 1960s, it touched the period's low of 0.32 percent of GDP in the second half of the 1960s and then has increased to more than 1 percent of GDP. The deficit financing has dual effects in the economy. On the one hand, while increased deficit financing ease the credit availability to the private sector by reducing the borrowing requirements of the public sector in the economy, it can also be inflationary in the sense that supply may not keep pace with the increased demand pressure generated in the economy.

So the beneficial effects of deficit financing depends on the nature of the economy, i.e. how close the economy is to its productive capacity. If the objective is to

increase the aggregate investment inthe economy, then under situations of underdeveloped financial market, deficit financing may be preferred over market borrowings to facilitate the availability of investible resources to the private sector. Because, both money supply as well as bank credit being related to the same monetary base (or reserve money), are subject to some controls and movements.[1] Consequently, any restraint on money supply also restrains credit in the economy and vice-versa. Again, it is also difficult to control exactly the supply of money or credit because the monetary base is partly determined by the government's fiscal operations and partly depended on other endogeneous factors including the portfolio choice of the public. For example, expansion of bank credit is depended on the banking habits of the people. Therefore, a continuous monetary policy may also be warranted in the event of the economy experiencing large fiscal deficit, as in India, because credit is both demand determined and supply-determining. So with an active fiscal policy, monetary policy needs to be pursued to achieve the twin objectives of price stability and adequate supply of bank credit to the productive sectors of the economy. The specific features of the Indian economy imply that a restrictive monetary or credit policy may lead to recession (lower growth) by forcing a downward movement in both aggregate demand as well as aggregate supply. Secondly, to the extent that a credit sqeeze is sought to be achieved by directly or indirectly raising the interest rates, there would be a tandency towards an increase in prices. Thus, monetary squeeze combined with high interest rates may be stagflationary,[2] severity of which depends on the relative strength of demand and supply constraints. Thus, the government shouldering the responsibility of mobilising savings should generate savings in its own right and utilise policy tools to generate more savings in the economy.

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[1] Gupta (1986).

[2] Taylor (1983).

Table 4: Saving/Investment Balances, Sectoral GDP* and Inflation (in real terms)**
(Percentage of Real GDP at Market Prices,unless otherwise stated)

Years	Gross Investment	Gross Savings	Total Gap	Public Investment	Public Saving	Public Gap	Private Investment	Private Saving	Private Gap	Public Infrastructure	Public Sect GDP	Private Sect GDP	Inflation Rate
1960-61	18.4	12.7	5.7	7.1	2.6	4.5	11.4	10.1	1.3	2.2	8	92	
1961-62	17.6	12.2	5.4	6.8	2.9	3.9	10.8	9.3	1.5	3	8.7	81.6	0.18
1962-63	18.9	13.4	5.5	7.9	3.1	4.8	11.1	10.3	0.8	3.6	10	90	3.8
1963-64	19.3	13.3	6	8.4	3.3	5.1	11	10	1	3.9	10.4	89.6	6.3
1964-65	19.9(18.8)	12.7(12.9)	7.2(5.9)	8.2(7.7)	3.3(3.0)	4.4(4.6)	11.7(11.2)	9.4(9.8)	2.3(1.4)	3.6(3.3)	10.5(9.5)	89.5(88.5)	10.8(5.3)
1965-66	20.9	14.5	6.4	9.1	3.1	6	11.8	11.4	0.4	3.7	12	88	7.7
1966-67	21.4	15.3	6.1	8.1	2.3	5.8	13.3	13	0.3	3.3	12.6	87.4	13.9
1967-68	19.9	13	6.9	7.6	1.9	5.7	12.3	11.1	1.2	2.9	12.4	87.6	11.6
1968-69	18.3	12.8	5.5	6.6	2.3	4.3	11.7	10.5	1.2	2.6	13.1	86.9	-1.2
1969-70	18.8(19.9)	15.0(14.1)	3.3(5.6)	6.2(7.5)	2.6(2.4)	3.6(5.1)	12.6(12.3)	12.4(11.7)	0.2(0.7)	2.5(3)	13.3(12.7)	86.7(87.3)	3.8(7.2)
1970-71	19.2	15.7	3.5	6.9	2.9	4	12.3	12.8	-0.5	2.8	13.8	86.2	5.4
1971-72	20.6	16.2	4.4	7.4	2.8	4.6	13.2	13.5	-0.3	2.8	14.5	85.5	5.6
1972-73	19.5	15.4	4.1	8.8	2.6	6.2	10.7	12.7	-2	3.1	15.4	84.6	10.1
1973-74	21.5	18.4	3.1	8.5	2.9	5.6	13	15.5	-2.5	3.7	16.3	83.7	20.1
1974-75	21.6(20.5)	17.4(16.6)	4.2(3.9)	8.2(8.0)	3.7(3.0)	4.5(5)	13.4(12.5)	13.7(13.7)	-0.3 (-1.1	2.9(2.9)	16.4(15.3)	83.6(84.7)	25.2(13.3)
1975-76	20.9	19	1.9	9.5	4.2	5.3	11.4	14.7	-3.3	3.3	16.4	83.6	-1.1
1976-77	21.6	21.2	0.4	10.5	8	5.5	11.3	16.3	-5.0	3.4	17.9	82.1	2.1
1977-78	20.9	21.1	-0.2	8.2	4.3	3.9	12.7	16.7	-4	3.3	17.5	82.5	5.2
1978-79	22.6	23.2	-0.6	9.3	4.6	4.7	13.3	18.6	-5.3	3.3	17.8	82.2	0.1
1979-80	23.0(21.8)	21.6(21.2)	1.4(0.6)	10.2(9.5)	4.3(4.5)	5.9(5.1)	12.8(12.3)	17.3(16.7)	-4.5(-4.4	3.6(3.4)	19.6(17.9)	80.4(82.1)	17.1(4.7)
1980-81	20.9	21.2	-0.3	8.7	3.4	5.3	12.3	17.7	-5.4	4.5	19.7	80.3	18.2
1981-82	24.8	19.8	5	10.5	4.5	6	14.3	15.2	-0.9	3.8	19.3	80.7	9.3
1982-83	22.6	19	3.6	11.1	4.4	6.7	11.5	14.6	-3.1	3.9	20.6	79.4	2.6
1983-84	20	18.9	1.1	9.6	3.3	6.3	10.4	15.7	-5.3	4.1	20.3	79.7	9.5
1984-85	19.9(21.6)	18.2(19.4)	1.7(2.2)	10.5(10.1	2.8(3.7)	7.7(6.4)	9.4(11.6)	15.4(15.7)	-6(-4.1)	3.8(4)	21.2(20.2)	78.8(79.8)	7.1(9.3)
1985-86	22.3	19.8	2.5	10.3	3.2	7.1	12	16.6	-4.6	3.7	22.3	77.7	5.7
1986-87	20.8	18.8	2	10.7	2.7	8	10.1	16	-5.9	4.5	23.4	76.6	4.3
1987-88	20.9	20.9	0	9.7	2.2	7.5	11.2	18.8	-7.6	4.2	24.2	75.8	8.2
1988-89	23.2	21.5	1.6	9	2	7	14.2	19.4	-5.2	3.8	22.6	76.4	7.5
1989-90	22.3(21.9)	22.2(20.7)	0.1(1.2)	9.1(9.8)	1.6(2.4)	7.5(7.4)	13.2(12.1)	20.6(18.3)	-7.4(6.1)	3.9(4)	24.1(23.5)	75.9(76.5)	7.4(6.6)
1990-91	23.7	23.6	0.1	9	1	8	14.7	22.6	-7.9	3.8	23.7	76.3	10.3

* Sectoral GDP figures are at factor costs and therefore are expressed in propertion to real GDP at facor costs

** Disaggregated data on capital formation at 1980/81 prices is not readily available for the whole period, therefore investment deflator has been used to generate the break-up data in real terms

*** Annual percentage change in WPI for all commodities (with base 1980-81=100)

Source: Government of India, CSO(various years,new series), National Accounts statistics

For column on Inflation Chandhok,H I (1990), India Data Base and Government of India,Ministry of Finance(various years),Economic Survey.

Households, the private corporate sector and the government are the main sources of domestic savings. While in developing countries, the undistributed profits of the corporate sector and the budgetary surpluses of the government constitutes a major source of saving, it is the household sector which accounts for a major source in gross domestic savings. Table 3 shows the private sector's savings and investment behaviour over the period. But a more disaggregated analysis shows, household saving accounts for 60 to 80 percent of domestic savings. Further break up gives household savings in terms of physical assets and financial assets. And household physical savings is defined as identically equal to household investment, though erroneous, but it can show the trends. The household savings rate increased from around 8 percent of GDP in the early 1960s to over 15 percent in the late 1970s, then dipped to around 13 to 14 percent from 1982-83 to 1986-87. But it again rises to over 17 percent in the closing years of the decade. Within the total, the component of financial savings and physical savings (investment) shows different patterns. As is shown in table-3, household financial savings as a percentage of GDP shows a tendency to stagnate or fall during or immediately following instances of inflation or recession, when real interest rates turn sharply negative, for example, during 1966-68, 1973-75 and 1979-82. But with these exceptions, a notable feature over the whole period is the rapid growth of financial savings in the 1970s, particularly in the second half of the decade which can be thought of as explained by the spread of banking following bank nationalisation, a positive bank deposit rates for some periods and rapid rise in worker's remittances from the Gulf Countries.

Household's physical saving has also increased, without showing tendency to stagnate during periods of high inflation, like financial savings. This may be due to the

Figure-I : INVESTMENT LAVELS(1980-81 PRICES)

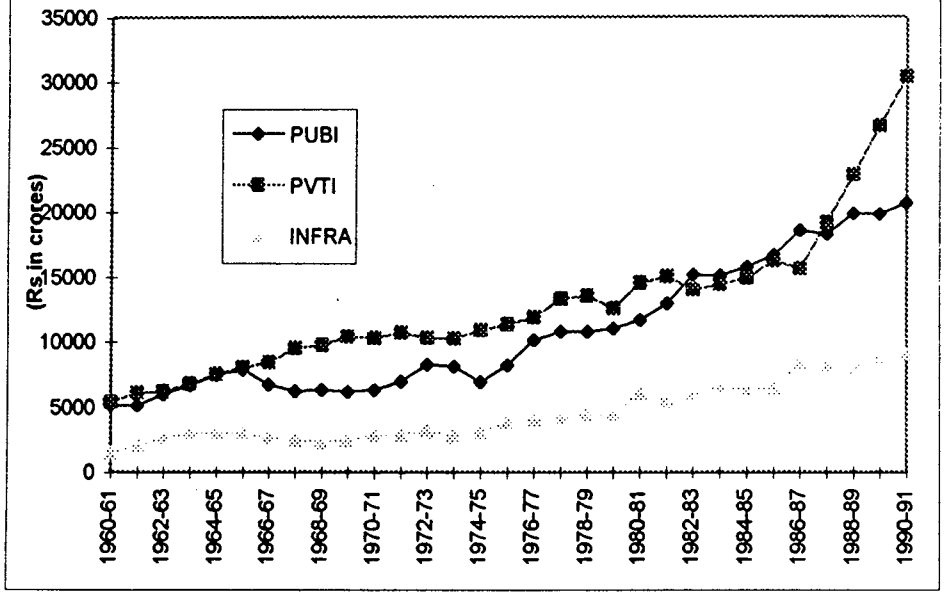
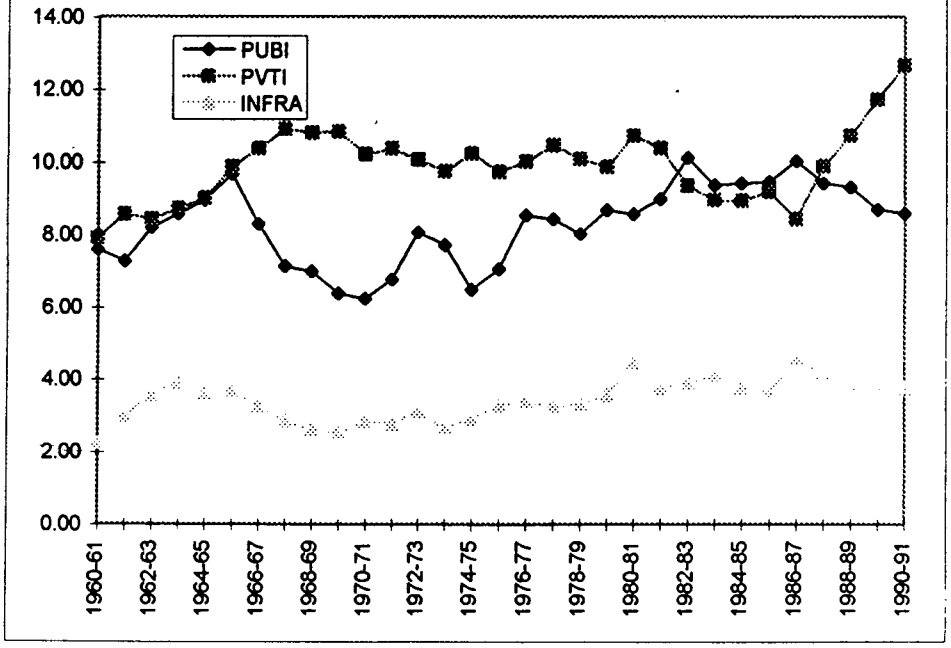


Figure-II: REAL INVESTMENT SHARES IN GDP AT MARKET PRICES



possibility of substitution of real assets for financial assets at such times. Although this do not fully explain the developments over the sample period. But it can be seen that there was no mere substitution between the two, because the overall rate of saving in the household sector has also increased. Again with the spread of banking, government has also exercised controls interms of fixing the nominal rate of interest (administered interest rate regime); so how the rate of interest is indexed against inflation explain the behaviour of financial savings and investment, and with government's objective of price stability, proper care was taken on not to allow a trend rise or fall in real rate of interest. But with high public borrowings (Table 2) during the period, it may have created an environment for crowding-out of small scale investment.

In the private corporate sector there has always been a deficit, because its own savings could not finance an increasing rate of capital formation by it, which can be seen from table-3. Thus, lending this sector to rely on borrowed funds to finance investment. Again with declining public savings and consequent increase in public deficit, with declining foreign borrowings (at concessional rates) there was increasing pressure on the domestic market for funds from both the government and the private sector, which might have resulted in controlling the flow of credit to the private sector. Because, it can be discerned from the fact that under such an unstable environment, with its avowed objective of maintaining price stability followed a tight monetary policy which can be seen from a constant increase in the statutory liquidity ratio (SLR) which starting from a low of 25 percent in the 1960s has increased to around 38 percent by the end of the decade. This along with utilisation of Cash Reserve Ratio (CRR) as a tool of short-run monetary management, created an environment for credit rationing, partly depressing private investment. This has been the response of the private sector

to various policies pursued by the government in response to public action, which provides the ground for the possibility of financial crowding-out.

This being the general tendency in the economy, it is necessary to explain their performance in real terms. Table-4 presents the saving- investment balances in the economy and sectoral contribution to GDP, with a hint at inflation rate, which is taken as an indication of macroeconomic stability. At constant prices also similar tendencies are noticed and most of the savings investment gap is explained by the public sector's deficit. As can be seen from Table 4 that starting from around 4.6 percent in the first half of the 1960s, it rose to around 7.5 percent of GDP by the end of the decade. But in case of private sector, there was a small deficit till the end of the 1960s, and then there has actually been a surplus in that sector. So the rate of increase in investment has been more or less stable in the private sector compared to the public sector. Because in its aim to check inflation and to achieve a higher growth rate in the economy, public investment has been very responsive to all sort of shocks (like draught, trade shocks etc.). We actually see that a surplus in the private sector come to appear after the year of bank nationalisation and consequently due to increased financial savings by the household sector. We can notice that it has been responsive to the rate of inflation, during period of inflation there has been substitution towards physical savings. Therefore, in aggregate, private investment represents a more stable pattern than public investment.

Again, if we see the pattern of real private and public investment, there we can see that during periods of declining investment, actually private investment has increased and vice-versa, which casts doubt on the complementarity between the two, which was the major concern of the debate of the 1970s. It can be seen that when

public investment actually fell on an average from the first half of the 1960s, there was an increase in the public investment from 11.2 percent to 12.3 percent of GDP. And core infrastructure investment has hovered around 3 percent of GDP in the first two decades, with an actual decline from 1966-67 to 1974-75. Consequently, the increase in private investment was not sharp. But no long term trends in the response of private investment is observable from the data. But if we see year to year fluctuations than it gives interesting results, in the sense that increased public investment with increasing deficit in its resource mobilisation front, might have caused financial crowding out, by putting pressure on the limited available resources. An as we have seen in table 2 the financing pattern of public investment, which has shifted in favour of domestic borrowing. Therefore, we guess the instance of financial crowding out in the economy, which will be made clear in estimation.

It we observe the performance of the public sector in terms of its contribution to aggregate output, then we can seen that with such a high share in total investment around 40 to 45 percent on an average, its contribution to output has been very low, i.e. only 16.5 percent and in the pre 1974-75 period it was less than the average and in the post 1974-75 period it consequently improved and reached to the peak of around 24 percent by the end of the 1980s.

Finally, a look at the policy on growth-both fiscal and monetary: about fiscal policy, it needs no further explanation. Regarding monetary policy, we can say that the main aim was to maintain price stability and in this direction there was a fair degree of success except few abnormalities in some years, in response to exogenous shocks. But we can fairly say one thing, that, it is private investment which is more sensitive to monetary policy, not the public investment. Therefore one question that confronts

economists is whether greater monetary ease (and therefore higher inflation) over the whole period would have increased the rate of growth by permitting higher public investment (financed by the inflation tax) or higher private investment (less crowding out). Though there is a limit to inflation tax as a method of knowing growth. Therefore, it requires a very cautious approach, in the sense of effective co-ordination before the fiscal and monetary policy. A priori consideration about a generally tight monetary policy would suggest that it could adversely affect long term growth. Indian monetary system, thus has been subject to various controls like high cash reserve ratios with below market interest rates on bank reserves, forced government borrowing from commercial banks at low interest rates, preemption of credit through stipulated SLR, and a controlled interest rates on bank deposits and loans with directed credit programmes. In this setting one should expect slow growth of private financial savings and inefficient investment and hence a reduction in long run growth. It created an environment for crowding out through rationing of credit, thus reflecting it to be essentially a financial phenomena. Though the spread of banking can hostened some position effects, it may be neutralised by the adverse impact of large public deficit. Therefore a test on crowding out is in order.

But as a preliminary view of the score of public and private investment and their inter-relationship we can refer to figure 1 and figure 2, which shows the time series on real fixed investment in the two sectors, both as levels and as percentage to GDP. We can see fairly divergent movements in public and private investment, particularly since 1965/66 - a general decline in public investment accompanied by an acceleration in private investment. During the subsequent recovery, the growth in private investment declined, a tendency which persisted till early 1980s and when public investment actually surpassed private investment, that is, during 1982/83, private

investment actually fell below public investment, a tendency which continued till 1987/88 and then with the increase in public investment, private investment has also shown a rising trends, a period which coincided with the long term fiscal policy (1985), with lesser controls exercised by the government. Thus, it implied a negative correlation between the two.

Another interesting thing is about the pattern of core infranstructure (defined as transport and communication, water supply, electricity and gas and construction) investment as a component of public investment, when infrastructure investment was rising initially, i.e., during the first half of the 1960s, private investment actually picked up very fast, but with cuts in public investment, the brunt was very much felt on infrastructure and therefore the rate of increase in private investment experienced during the early 1960s could not be maintained, implying a positive relationship between core infrastructure investment and private investment, which is clearly evident in Figure 2.

This observed relationship between public and private investment cast some doubts on the the complementary effect of public investment in general, on private investment and hence needs an empirical testification. Because, as we have argued in previous chapters, what matters for growth is the sign and magnitude of public policy multiplier, in this case the degree of crowding-out.

II. Empirical Results

For estimation, we rewrite here the reduced from equation as derived from the model eq (3), in the the previous chapter as -

$IP_t = \alpha_0 \Delta GDP_t + \alpha_1 IG_t + \alpha_2 HI_t + \alpha_3 FBC_t + \alpha_4 FDI_t + (1-b_0) IP_{t-1}$ .....(*)

With expected signs $\alpha_0 > 0$, $\alpha_1 >$ or < 0, $\alpha_2 > 0$, $\alpha_3 > 0$, $\alpha_4 < 0$ or > 0

where IP_t = private investment i.e. gross fixed capital formation in the private sector.

$\Delta GDP_t = [1-(1-\delta)L] Y^*_t$

where δ is the rate of depreciation

L - one period lag operator

Y^*_t - expected output, which is defined as the average of current real GDP and past four years GDP at market prices. Thus, GDP_t shows the acceleration effect of output on private investment.

IG_t = public investment, i.e. gross fixed capital formation (GFCF) in the public sector.

HI_t = households financial savings net of their currency holdings and deposits with banks.

$FBC_t = (1-\Gamma).BD$ where Γ = statutory liquidity ratio (SLR)

BD = total scheduled commercial bank deposits.

So FBC_t is nothing but the flow of bank credit to the private sector.

FDI_t = fiscal deficit net of exogenous foreign Borrowing $(\overline{FB})$

IP_{t-1} = lagged private investment.

Methodology

We will use ordinary least square (OLS) regression for estimation.

Sample: The sample period is from 1960-61 to 1990-91 (in Indian fiscal year)

Data: For the whole sample period, we use secondary data for all variables, published through various sources.

Data for India on GDP, household net financial savings and investment both public GFCF and private GFCF are from various issues of National Accounts Statistics (New series), published by the Government of India, Central Statistical Organisation (CSO). Data on bank credit has been taken from various issues of RBI's Report on Currency and Finance. Data on fiscal deficit[3] and Foreign borrowings is derived from various issues of Economic Survey, published by the Government of India, Ministry of Finance. For estimation, all the data are taken at 1980-81 prices. GDP data and investment data are readily available at 1980-81 prices, but institution wise on sectoral break-up data on investment are not readily available for the whole period at 1980-81 prices, but are available at current prices. But aggregate investment data are readily available both at current and at 1980-81 prices, from which we have obtained the investment deflator. Using this deflator then, public investment and privte investment at 1980-81 prices are compiled from their respective figures at current prices.

Similarly, for the other variables the GDP deflator (at market prices) has been used to construct the data at 1980-81 prices.

Model Adaptations:

To estimate the model with the above defined variables, we have used two dummies to take into account the effect of exogenous shocks on private investment.

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[3] He define the total public sector's resurce gap, as defined in the Economic Survey, as fiscal deficit

One dummy (DUM1) is used for exogenous oil shocks which occured thrice in the sample period 1973-74, 1979-80, and 1990-91 which is expected to have negative effect on private investment. Because, since oil used as an intermediate input in private production, negative such oil shocks (oil price rise) raises the cost of production and thereby depress investment.

The other Dummy (DUM2) is used to capture the effects of droughts on private investment. Droughts have been recurrent in nature in India, mostly duringthe 1960s and 1970s - 1965-66, 1966-67, 1972-73, 1974-75, 1979-80 and 1987-88 and has greatly affected agricultural output, which is basically depended on monsoon. So in this light, if there is strong interlinkages between agriculture and industry, then formally one can say that any decline in agricultural output will impose a demand constraint for private investment, in its own right. Secondly, droughts may also restrict the food availability in the economy and thereby cause inflation. If not properly managed by the government. So while studying the relationship between public and private investment, to judge the effect of droughts on private investment i.e. whether it affects negatively or positively depends on how the government fight with such shocks. For example, to fight drought induced inflation, how effectively the government manages its Buffer stocks and food imports in the event of such crisis matters for growth. Because investment planning is based on long term decisions and if such inflationary spirals caused due to droughts are temporary (i.e. if it does not leads to uncertainty interms of inflationary expectations about the future) then it is unlikely that droughts will have negative effect on private investment. Again, if supply constraint is more binding in nature, such drought induced inflation (being temporary in nature), may contribute positively to investment, if nominal rate of interest is not fully indexed to inflation (by lowering the real cost of funds), though it is likely that in response the

composition of investment may alter in favour of inventory accumulation. Again such inflationary expectations is also depended on how close the economy is to its productive capacity. Thus, a priori, we cannot say what sort of effect droughts will have on private investment. In this light, since supply bottlenecks were considered as more binding in nature and effects of droughts have been temporary in nature over the sample period, one may guess that while oil shocks contribute negatively, droughts might have contributed positively for private investment.

So with these adaptations, we can write the above private investment function as

$IP_t = \alpha_0 \Delta GDP_t + \alpha_1 IG_t + \alpha_2 HI_t + \alpha_3 FBC_t + \alpha_4 FDI_t + \alpha_5 DUM1 + \alpha_6 DUM_2 + (1-b_0) IP_{t-1}$ ---------- (1)

with signs $\alpha 0>0$, $\alpha 1>$ or < 0, $\alpha 2>0$, $\alpha 3>0$, $\alpha 4<0$ or >0 $\alpha 5< 0$, and $\alpha 6>0$.

Therefore, estimating this equation, according to our first objective we can know whether public investment crowds-out or complements private investment.

Our second objective is to test the differential effect of different types of public investment on private investment. Therefore, we break-up public investment into two parts and judge the differential effect of each type. So in our formulation, we define the following components of gross public capital formation by industry of use as public infrastructure -

i) transport, storage and communication

ii) electricity, gas and water supply, and

iii) construction.

Since there is no proper boundary in its definition and no such break up data on GFCF are available. we have considered the above three core categories as public infrastructure. And deducting this component from the total GDCF in the public sector by industry of use, we get the non-infrastructure - component of public investment.

Accordingly, we write IG = INFRA + NINFRA ----------(**)

where IG = public investment

INFRA = public infrastructure investment.

NINFRA= public non-infrastructure investment.

and substituting into eq. (1), we get

$$IP_t = \alpha_0 \Delta GDP_t + \alpha'_1 INFRA + \alpha^{*}_1 NINFRA + \alpha_2 H1_t + \alpha_3 FBC_t + \alpha_4 FD1_t + \alpha_5 DUM_1 + \alpha_6 DUM_2 + (1-b_0) IP_{t-1} \ldots (2)$$

with expected signs, $\alpha_{0>0}$ $\alpha'_{1>0}$, $\alpha_1^{*}<0$, $\alpha_{2>0}$, $\alpha_{3>0}$, $\alpha_{4>0 \text{ or } <0}$, $\alpha_{5<0 \text{ and }} \alpha_{6>0}$

(i) Because, as we have argued in the model, the infrastructure coefficient to be positive ($\alpha'_{1>0}$) in the sense that, the crowding-in effect of infrastructure is stronger than the crowding out effect, and hence we can fairly say that public infrastructure doe snot crowd-out private investment.

(ii) On the other hand, we expect the non-infrastructure coefficient to be negative (α_1^{*} $_{<0}$), implying a stronger crowding out effect than its complementary effects on private investment. With other coefficients having usual signs as discussed in the model.

Results: We have estimate these two equations for the period 1960-61 to 1990-91, using ordinary least squares (OLS)regression and given the estimated equations in Table 5.

Table - 5

INIDIA : ESTIMATED EQUATIONS (Period of fit 1960-90)

Private Incvestment

(1). $IP_t = 1114.931 + 0.45 \ \Delta GDPt - 0.28 \ IGt + 0.81 \ H1_t + 0.44 FBC_t - 0.25 FD1_t + 0.87 \ Ip_{t-1} - 1250.69 DUM1 + 731.62 DUM2 \ AR(1)$

(0.93) (2.44)** (-1.89)*** 4.33)* (2.73)* (-2.30)** (10.14)* (-2.07)** (1.82)***

ADJ.R^2 = 0.98, Durbin h = -1.16

(2). $IP_t = 153.2682 + 0.3516 \ \Delta GDP_t + 0.1423 \ INFRA - 0.357 \ NINFRA + 0.7622 \ H1_t$
(0.14) (2.04)** (0.44) (-387)* (4.49)*

$+ 0.4154 \ FBC_t + - 0.3679 \ FD1_t + 0.9923 \ Ip_{t-1} - 1060.883 \ DUM_1 + 614.3147 \ DUM_2 \quad AR(1)$
(1-88)** ((-3.0)* (13.39)* (-2.12)** (1-88)***

ADJ.R^2 = 0.98 Durbin h = - 0. 87

DUM_1 = 1 for Oil shocks years
= 0 otherwise
DUM_2 = 1 for Droughts years
= 0 otherwise

Figures in Parentheses are t - ratios and the number of asteristks denotes significance as follows:
* at the 1 percent level,
** at the 5 percent level,
*** at the 10 percent level.

The flexible accelerator framework, as modified for the private investment function to take care the financing constraints with public investment as an argument clearly provides a good fit for the sample period 1960-61 to 1990-91. The coefficient of determination of the estimated equations are high. When we initially estimated the equations, we got the evidence of autocorrelation. This was tested by checking the Durbin-h value (because in a autoregressive model, i.e. a model with lagged dependent varaible as one of the explanatory variable, the Durbin-d statistics does not hold good) calculated as,

$$\text{Durbin h} = (1 - 1/2\, d) \sqrt{\frac{n}{1 - n\,[\text{var}(\hat{A})]}}$$

where, d is the usual D-W d value from the OLS regression

n is the number of observations, and

$\hat{A}$ is the coefficient of the lagged dependent variable lagged by one period in the equation.

which is used to check the presence of autocorrelation in autoregressive models. As Durbin has suggested for large n, the h statistic follows the standardized normal distribution [h ~ AN (0,1)] and therefore the statistical significance of an observed h is determined from the standarized normal distribution table.

Therefore to check against autocorrelation, we fitted AR(1) process to both the equations and finally reported these values as in table 5. We have reported the coefficient of determination value (R^2) and the h -value which are very satisfactory.

Equation - 1: For equation (1), we have got the accelerator coefficient to be positive ($\alpha_0 > 0$) as expected. Which implies that the demand factor has also a role to play in explaining private investment its coefficient is also large (0.45) and is statistically significant at 5 percent level of significance.

The coefficient of public investment is negtive ($\alpha_1 = -0.28$) and is significant at 10 percentlevel of significance, implying the evidence of crowding-out. This implies that, as in our formulation, though both complementary and crowding-out effect may present, the crowding-out effect of public investment on private investment outweighs the complementarity effect. Which supports the concept of partial crowding out and in our formulation, it can be fairly thought of as due to financial strignency imposed by the specific pattern of financing public investment. This point again can be forcefully justified from the fact that both the coefficients of the financing variables on private investment - the household credit (HI_t) and flow of Bank Credit (FBC_t) are positive and highly significant. The household credit explains around more than 80 percent point and bank credit around more than 40 percent point in the change in private investment. Thus with such high explanatory power, if financing of increae in public investment is done through domestic market borrowings under a not so well developed financial market, may restrict credit to the private sector thereby crowding-out private investment. The coefficient of the fiscal variable FDI_t ($\alpha_4 = 0.25$) is negative, implying that high fiscal deficit net of foreign borrowing depress private investment. This reflects the government's lack of control over its unproductive expenditure and

deficiency in resource mobilisation front, as we have seen in the previous section that public savings has actually fallen over these years, but public investment has increased.

The dummy variables are significant and have the expected signs, implying that oil shocks, by raising the cost of production depress private investment, which is seen from the coefficient of $DUM_1(\alpha_{5<0})$. But the drought dummy (DUM_2) has contributed positively to private invetment, ($\alpha_{6>0}$) implying that the effects of droughts was temparary in nature and was dealt with carefully in the presence of supply bottlenecks.

The lagged private investment has a positive coefficient and is very high, thus giving a low value of the adjustment coefficient (bo), for equation (1), $1-b_o = 0.87 \Rightarrow b_o = 0.13$. This throws some light on the adjustment of actual investment towards its desired level within one period, which is very low, implying that private investor face different constraints during planning their investment, which is a typical feature of developing economies - like resource constraints, financial constraints etc.

Thus, it shows that our model very well fits into the case of the Indian economy characterised by structural and institutional constraints. And the implication of the fit is that the immediate crowding-out effect of public investment is stronger than its complementary effects.

Equations-2:

For the second equation also the regression fit is very good and the coefficients have usual signs and are significant, except for the case of infrastructure. This needs an interpretation. While we disaggregate the public investment into infrastructure and

non-infrastructure, we experience differential effects on private investment, as expected. According to our formulation, both the infrastructure and non-infrastructure should have negative coefficients, since we have simply disaggregated public investment into its two components. But contrary to this, we have got a positive sign for the infrastructure coefficient ($\alpha'_1 = 0.14$) though insignificant. This implies that infrastructure investment does not crowd-out private investment and positive coefficient is an indication of the fact that the crowding-in effect is much stronger which outweights the immediate crowding-out (if any) through financing channel. And the whole burden of crowding-out is caused by the non-infrastructure component. This implies that the involvement of public sector in direct commercial activities and poor financial performance might have caused crowding-out of private investment. Therefore in an attempt to maintain a high growth rate public infrastructure investment has to be maintained against a stabilization prescription of public expenditure cut.

Thus, on an average our model fits very well into the case of India.

The next chapter gives a summary of our discussion.

CHAPTER - 5
CONCLUSION

CONCLUSION

This dissertation has attempted to sketch the story of the relationship between public and private investment, under a flexible accelerator model of private investment with property modifying it to take care the institutional and structural characteristics specific to the Indian economy. Since the main question that has been asked, hovered around the possibility of crowding-out of private investment by public investment, an attempt has been made to clarify the meaning and nature of crowding-out, the transmission mechanism that cause crowding-out and the dimension of the crowding-out debate overtime. In this context, the main policy debate between the keynesians and the monetarist which dominated the decade of 1970s has been introduced, The main focus of which was on the question of relative efficacy of fiscal and monetary in the shorter and longer run. On the modelling front, question regarding a proper specification of the private investment function under various constraints, specific to developing economies has been raised to emphasize on the relevance of neoclassical investment model to these economies.

The question of crowding out has a long history, since the days of classical economics. In the traditions aposition it was argued that, every increase in public spending and more so if it was deficit spending, cause an equal reduction in private spending without affecting either income or employment. Their argument was that public borrowings implied a reduction in the availability of fund of private savings for private investment. Thus, in their view there was full crowding-out. But keynesians discredited this by arguing that under conditions of widespread unemployment neither additional investment nor additional public sector deficit spending takes away available savings, rather they generate savings. Therefore to them complete crowding out was essentially a full employment phenomenon. The case which was later on taken up by the Monetarists, who with their basic presumption about near fullemployment in the economy fostered arguments interms

of full crowding out. Thus the argument was mainly interms of demand based management.

But what is interesting today is that, it is possible to have inflation and crowding-out even in the presence of large scale unemployment. It is possibly the coexistence of these phenomena-crowding-out, investment and unemployment that has appeared to contradicts the earlier writings on this subject. And from this fact, it seems, the debate has shifted to the possibility of crowding out of private investment by public investment, which is of prime importance for most countries in their economic planning. Thus from the general expansion in public expenditure as a prescription, in recent time, more and more stresse has been given to the composition of it, as a measure of public support to the process of growth.

The relevant theory and empirical studies on the question of crowding out has emphasized more on the different forms of crowding-out that occurred through the rate of interest and categorised as indirect crowding-out. So the interest rate being the transmission mechanism, economists employed mostly the IS-LM framework to judge on the extent of crowding-out. As a real world phenomena there was increasing consensus on partial crowding out, which implies potency fiscal policy in the short and long run. And in the new economic environment, methods and means of monetary management increasingly used to reduce the amplitude of the business cycle fluctuations. The increase in public expenditure and the consequent increase in deficits has integrated the monetary policy with the fiscal policy for long run growth.

We have seen that in live with the macroeconomic thinking, Indian planners were also emphasized more and more on monetary management in the economy. Because with positive fiscal impulse and the consequent increase in the size of the deficit, money supply cannot be properly checked, because monetary base is partly determined by the government's fiscal operation. On the other hand, both money supply as well as bank credit being related to the same monetary base, are subject to the same controls and movements. Consequently any effort to restrict money supply will also restrict credit availability in the economy and vice versa. Thus, this

increasing integration between the monetary and fiscal policy cast doubts on the relevance of the conventional discussions on crowding-out which was the result of financing of deficits under unaccomodative monetary policy. This also makes ground for the possibility of partial crowding-out. Therefore what matters for growth is the sign and magnitude of the public policy multiplier, consequent on a positive fiscal impulse.

This being the real issue in most of the developing countries, including India, public investment was given an important rule in planned policy formulation. Therefore the way public sector has grown over time and its performance has implications for growth in private investment and hence long run growth. Because the performance of the public sector determines the size of the deficit (fiscal gap) and then the way government finance the deficit i.e., through deficit financing or market borrowings has implications for private investment. We have argued, in the context of the Indian economy, how such poor performance of the public sector on the resource mobilisation front might have caused crowding out which is essentially a financial phenomena in the event of underutilised resources. Therefore, we have argued that under not so well developed financial market, the financing of public investment by different modes may exert differential impact on private economic activity. Thus discarding the possibility of Ricardian Equivalence or ultrarationality in a developing country like India.

Again we have shown, how interest rate mechanism may be deficient in explaining the extent of crowding-out in an underdeveloped financial market subject to different controls both price and non-price rationing. Therefore in the Indian case with an administered interest rate regime, we discarded the role of interest rate as the equilibrating mechanism, rather it is the rationing of credit which may have corrected any disequilibrium in the lonable funds market. Therefore taking into account the possibility of such rationing, we developed our model on private investment under various means of financing public investment which has performed well over the sample period. Therefore in our framework, we proceeded without specifying the demand for credit functions by the private sector.

The estimated results indicate that, in addition to other relevant variables, public investment had an overall negative and significant effect on gross private investment over the period 1960-61 to 1990-91. The result also suggested that it is the non-infrastructure public investment which crowds-out private investment, not the infrastructure component in which case the positive spillover effects outweighs the immediate negative effect, thus rendering the coefficient to be positive. In light of these estimates, policy makers should pay attention not just on the level of government expenditure but also to its composition-infrastructure and non-infrastructure, and in so far as the former is concerned, a concerted effort should be made to maintain adequate levels of investment in core infrastructure, which has long run effects on private investment.

Thus, on the policy front, in this context, the stabilisation prescription which calls for public expenditure cuts across the board, needs to be very carefully handled by policy makers, ensuring that the brunt of such action does not fall on public infrastructure investment, which has a high positive spillover effect on private investment. Otherwise, it will constrain the long run rate of growth of the economy, under general supply bottlenecks.

Secondly, the model defining the various modes of financing of public investment hinted at the possible financial crowding-out in the Indian economy. It has been shown that in a country like India with large unutilised resources, it is essentially a financial phenomenon. Therefore it calls for effective monetary planning which should facilitate the fiscal policy action to achieve and sustain an increasing rate of long term growth in investment and output. Thus, recognisng that both demand forces and supply bottlenecks are at work in the growth process of a developing country like India, monetary policy be assigned the dual task of maintaining price ability and adequate supply of credit to the productive sectors of the economy.

Therefore, it may be in order, to emphasize here the links between fiscal policy, investment and growth which are, of course, highly complex. Changes in the overall fiscal balance as well as in the structure of expenditure and taxation have

important implications for investment and growth. Large fiscal deficits make it difficult to combine the objectives of high growth and low inflation and therefore has to be dealt with properly, with a redefinition of the role of public investment to make effective inroads against poverty. This in turn calls for a proper coordination between monetary and fiscal policy for effective planning and development of the Indian economy.

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Study of Morphometry Under Varying Lithological Conditions in the Selected Basins of Indravati

Dissertation submitted to the Jawaharlal Nehru University
in partial fulfilment of the requirements for
the award of the Degree of
MASTER OF PHILOSOPHY

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Certified that the dissertation entitled 'STUDY OF MORPHOMETRY UNDER VARYING LITHOLOGICAL CONDITIONS IN SELECTED BASINS OF INDRAVATI RIVER' *submitted by Miss ARCHANA SRIVASTAVA is for the degree of Master of Philosophy is a bonafide work to best of my knowledge and may be placed before the examiners for their consideration.*

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DEDICATED TO MY PARENTS

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CSRD/JNU (ARCHANA SRIVASTAVA)

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C H A P T E R I

INTRODUCTION

C H A P T E R I

INTRODUCTION

Geography, is the science of the surface of the earth and its inhabitants. Of its many branches we are now, concerned with geomorphology, which deals with the surface of the lithosphere, explaining its origin and'interpreting' its history. Thus, geomorphology is the science of study of landscape. It developed rapidly from early 40's. After the introduction of quantative analysis of drainage basis as a fundamental and appared. A lot of emphasis has been laid on the intensive study of a basin and its evaluation. The term Geomorphology is used in different branches of science to analyse the shape, form and structure. This term is primarily, applied to the quantitative measurement of land forms known as geomorphology.This is further divided into two-General geomorphology, an extensive and general study and Specific geomorphology, intensive study. Early 40's was the revolutionary period, when geomorphology included in quantification of drainage basins and thereafter several research work have been carried out. Geomorphology, in the begining was limited in United States and U.K.. Later, it rapidly spread to other contries. Indian scholars accepted it after the end of 60's.

1.1 REVIEW OF LITERATURE:

" Morphometry ", which means measurement and mathematical analysis of the earth's surface and of the shape and dimensions of its land forms. The basic points for the investigation of the earth landforms, was the area, altitude, volume, slope and texture. Dury (1952),[1] Twidale, Jenning and Christan(1957)[2] applied various methods for the analysis of the land forms and classified in different ways. They presented in the form of graph, maps and statistical indices. Some methods of morphometry was devised but analysis was based on description. Recently, morphometry is being applied for intensive analysis of small morphologicaunits, i. e. river terrain. In 1945 Horton[3] provided a new approach in geomorphology, pioneered the quantitative approach to drainage basin description realising that the hydrological characteristics of a drainage system are organically linked to their morphologic characteristics. After his paper in 1945 he lead the structure and direction for the geomorphological research, since then numerous works have been done in this field. Horton was the first person who, realised that dynamicity of drainage basin and its hydrological characteristics are closely related to their morphology. He analysed the inter

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relation ship of the function of drainage basin to the numerical values. After him Strahler (1952)[1], Schumm (1956)[2], Melton(1958)[3], Kesseli (1946)[4], Miller (1953)[5], Russel (1949)[6], Smith (1958)[7], Morisawa (1962)[8], Scheidegger (1965)[9], Shreve (1967)[10] and various others have

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9. Scheidegger, A.E. (1965), " The Algebra of Streams, Order Number ", U.S. Geol. Sur. Prof. Paper, 525 -8, pp.187 - 189.

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continuously stressed on morphometry.

Gardiner (1982)[1], studied drainage basin morphometry under following headings "Network, Delimitaton Sampling, Variable definition and analysis."Generally the the delimitations of drainage net and data related to morphometry are derived either from topographic maps or remote sensing sources and these sources have certain limitations, such as surveyors, convectios for field mapping process of plotting of streams on the map, scale of the map and data of the survey because time plays a vital role in development and extension of drainage net (Gregory and Gardiner, 1975)[2]. Suggestions of some scholars was that function of the identoty of drainage basin should be based on field survey, is irrelevant in larger areas. Morisawa (1957)[3] suggested the use of contour crenulations to identify the small streams which exists in the field not in map, was highly criticised by Gregory (1966)[4] because

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1. Gardiner, V. (1981), " Drainage basin morphometry: Quantitative analysis of Drainage basin form", Perspective in Geomorphology, Ed. H.S. Sharma, Concept publishing Co. New Delhi, p. 107.

2. Gregory K.G., and Gardiner, V.(1975), " Drainage Density and Climate ", Zeitschrift Fur Geomorphologie, 19, pp 287-88.

3. Morisawa M.E. (1957), " Accuracy of determination of stream lengths from topographic maps ", Trans. Amer. Geog. Union, 38, pp.86-88.

4. Gregory, K.J.(1966), " Dry valleys and the composition of the Drainage networks ", Journal of Hydrology, 4, pp. 327 - 340.

it may include fossils of palaeohydrologocal eleme nts. On Shreve (1974)[1] suggestion of " A value of channel slope should determine to define the source of channel ", was applied by Smart (1978)[2]. Hydrologiwal and morphological methods were introduced by Shreve. Shreve's third method of exterior links in which he analyded that " all exteror links, either from stream lines on the map or contour crenulations are extended head ward to water shed to delimit the basin and drainage network" was not famous and rarely used in U.S.A.by the mesh - length extension network.

The revolutionary introduction in the field of drainage morphometry of the idea of stream order was given by Horton. According to Bowden and Wallis (1964)[3], the stream order concept is " The touch stone by which drainage drainage net characteristics could be related to each other and to hydrology and erosional processes".

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Ordering described by Horton and modified by Strahler in 1952 as, " All finger tips designated as the first order, two first-order produces a second order segments, two second orders provided a third order and so on. Melton (1959)[1], accepted this idea because of this advantage of this simple method,i.e. it can be derived mathematically from concepts of elementary combinational analysis, But this method was highly critised- firstly, the order of trunk stream is not changed by the addition of tributary stream of lower order and secondly, the addition of a single first order stream could raise the order of the trunk stream.

Scheidegger (1965)[2], stated "An algebra of segment which is associated and cumulative. Gardiner (1977)[3] first used grid squares of mapping Drainage density and also introduced the relation ship of topological characteristics of drainage network in selected quadrants.

Horton's supplementary law is summarised by Gardiner(1981)[4]in which relation ship of morphometric parameters was tested by him, using huge data.

After two decades, Horton's method was used to examine and determine the basin morphometry in different climatic and lithologic conditions.

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1. Melton, (1959), "Aderivation of Strahlers' channel ordering system ", Journal of geology 67, pp. 345-346.

2. Scheidegger, (1965), " The algebra of stream order, numbers " U.S. Geol. Surv. Prof. Paper. 525 B, pp. 187-189

3. Gardiner, V. (1977), " Estimated Drainage density and Physical Regions in S.W. England, National Geographer Vol, 12 pp. 115- 188.

4. Gardiner, (1981), op. cit. Ref. page no. 4

Ghose, et.al. (1963)[1], Ghose and Pandey (1963)[2], Singh and Ghose (1973)[3], worked on the arid region applying morphometric parameters to the drainage basin.

Comparison betweem the lithological conditions usting same method was done by Gardiner (1971)[4], Brunden (1969)[5], Tondon (1964)[6], Padmaja (1975)[7], Mithal et,al.(1974)[8], Gregory(1976)[9], Gregory and Gardiner(1975)[10],

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1. Ghose,B. Pandey, S. ,Lal,G (1967) " Quantitative Geomorphology of the Drainage Basins in the Central Luni basin in W. Rajasthan ", Zeitschrift fur geomorphologie, I, pp. 146-160.

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3. Singh S. and Ghose B (1973), " Interrelation ship between quqntitative geomorphic characteristics of drainage basins sub-humid to humid environment of Rajasthan" Annals of Arid Zone 12, pp. 82-89.

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5. Brunsden, (1969), "Dartmoor ", Geog. Assoc.

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6. Tondon S.K. (1974), " Litho-control of some Geomorphologic properties, Zeitshcrift fur Geomorphologie, 18, pp. 460-71.

8. Mithal R.S., Prakash B. and Bajpai I.P., (1974) 2 Drainage basin network morphometric study of a part of the Garhwal Himalayas", Himalayan Geology, Vol. 4, pp. 195-215

9. Gregory (1976), "drainage network and climate of Derby-Shire " Ed. Geomorphology And Climate, Wiley.

10. Gregory and Gardiner(1975), "Drainage Density and Climate" Zeitschrift fur Geomorphologie, 19 pp. 287- 98

worked on postulating the variations in the basin due to climate conditions and their effect. Morgan (1971)[1], William(1972)[2], Bassett and Ruhe(1973)[3], studied about the drainage network under Karst region.

In India, the adaptation of Hortonian method is recent and several scholars have tested and analysed them working on different basins, Singh (1960),[4] produced the study on Rajmahal Hills. Morphometric evaluation was studied by Asthana(1967)[5], in Alwar district. He considered three aspects of terrain i.e. geology, configuration and drainage. Singhs' (1969)[6], was based on Topa and Shilpi rivers of Ranchi, giving inter-relation ship between length and drainage area. He postulated that " As order increases, area of each basin

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1. Morgan R.P.C(1971), " A morphometric study of some valleys systems on the English Chalklands, Trans. Instt. Brtish Geog. Vol. 54 pp. 33-44.

2. William(1972), " The analysis of spatial characteristics of Karst terrain ", ed. R.J.Chorley, Spatial Analysis in geomorphology.

3. Bassett, J.L. Ruhe R.V. (1973), " Fluvial geomorphology in Karst Terrain, ed. Morisawa, Fluvial geomorphology Binghamton New York University.

4. Singh (1960) "Geomorphological Evolution of the Highlands of Rajmahal " National Geographical Journal of India , Vol. VI part 1, PP. 1-13.

5. Asthana V.K.(1967),"Morphometric evaluation of Land form in Almora & its environs" Nat. Geog. Jour. Ind. Vol. XIII, Pt. 1, PP. 37-54.

6. Singh R.P. & Kumar A.(1969),"Geomorphological evolution of stream orders of Topa & Shilpi Basins, Ranchi Nat. Geog. Jour. In. Vol. VIII,p. 119-29.

Decreases in a region of high precipitation. Singh (1970)[1] study of Hoshiarpur(Kangra) was based on relation between different parameters and basin circularity ratio is controlled by relief, slope, area, underlying, topography and ruggedness. Kharakwal(1970)[2], attempted his work and gave the idea that basin height, ground slope of basin, channel gradient and drainage density have negative correlation with hypsometric integral in accordance with Strahler.

Satpathy (1972-73)[3], analysed the landforms of Deo river basin(Singhbhum)with the help of Morphological information. Pal, S.K.(1973)[4] attempted quantitative geomorphology of the drainage basins in Himalayan region. Kumar (1973)[5], has tried to distinguish

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1. Singh (1970), " Basin circularity ratio as a terrain type element: A case study of Hoshiarpur , Kangra tract, Deccan Geographer , Vol. VIII, PP.119-28

2. Kharakwal S.C.(1970), " Morphometric study of a Himalayan basin - A sample study " Nat. Geo. Jour. In. Vol. 16, part 1, pp. 47-60

3. Satpathy P.P., Dedidutt(1972-73), " Quantitative analysis of landforms- A case study in the Deo river of Bihar" Geographical Out look , Vol. IX pp. 57-66.

4. Pal S.K.(1973)," Quantitative Geomorphology of Drainage basins in the Himalaya ", Geographical Review Of India, Vol. 35, pp. 81-101.

5. Kumar A. (1973-75), " Pair wise Relation ship of Basin area and stream length- A case study of the upper Burha Basin " Geographical OutLook, Vol.X, p.49-58.

the relationship between variables of drainage basin morphometryand applied pair wise correlation in upper Burha basin. Singh, Gupta and Kaith(1976)[1], presented relation ship among morphometry attributes. They gave conclusion that bifurcation ratio dominates and influences the discharge and distribution of surface runoff but ratio of bifurcation is not an independent variable.

Padmaja (1976)[2], using Horton'S and Strahler's method worked on Mej river basin under different geological formations. Singh and Srivastava(1977)[3] studied Belan river basin and demarcated different slope zones. Sharma and Padmaja(1977)[4], correlated various geomorphic variables in varying lithologies of Morel basin and concluded that the Ratio of bifurcation varies from basin to basin, according to different lithology.

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1. Singh, Gupta & Kaith, (1976), " Multiple relation ship between ratio of bifurcation and some morphometric variables of drainage basin in Banas Catchment", Deccan Geographers Vol.XIV No. 2, pp. 151-156

2. PadmajaG.(1976)," Geomorphology of the Mej river basin Rajasthan " Unpub. Ph.D. thesis University of Rajasthan Jaipur.

3. Singh S. and Srivastava(1977) " A stastical analysing of the average slopes of the Belan Basin" Deccan Geographers, Vol. XV pp. 307-316.

4. Sharma H.S. & Padmaja(1977) " Quantitative Geomorphic characteristics of streams of Moreal Basin Rajasthan" Geographical Review of India, Vol.39 pp. 353- 366.

Verma and Bhattacharya(1978)[1] gave the relation ship of some theoretical measusement by analysis of 101 third orderbasins. Singh (1979)[2], produced the drainage density of 23 basins of 5 different physiography conditions of Ranchi and cocluded that geological structyre rainfall a nd slope contols drainage density.

Pofali (1979)[3], studied an account of linear , areal and relief characteristics of drainage network of Vidarbha region. Singh and Upadhyay (1981)[4] proved that Horton's and Strahler's model is related to drainage may not be applied in totality. Padmaja and Soudervallie (1981)[5] discussed the variations of bifurcation ratio in Godavari and Krishna basin.

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1. Verma V.K. & Bhattacharya G. (1978)," Graph theoretic concepts and drainage nets " Nat. Geog.Jour. Ind. Vol. 24, pp. 62 - 65.

2. Singh S. (1979) " A geomorphological study of drainage density of small drainage basins of the Ranchi plateau India " Nat. Geog. Jour. Ind. , Vol. 35 pp. 215-230.

3. Pofali R.M. (1979) " Linear characteristics of the drainage net work of Vidarbha Region " Deccan Geographers Vol. XVII pp. 631-643.

4. Singh S. and Upadhyay D.P. (1981) " Topological and Geometrical study of Drainage network, Perspectives in Geomorphology , Ed. H.S.Sharma, Vol.2, pp.191-233.

5. Padmaja & Soudervallie (1981), " The behavioral pattern of bifurcation ratios in Godavari and Krishna basin, A.P. Perspectives in Geomorphology Vol. 2, p.235-45.

Vats (1985)[1], studied morphometric variables in the Mithri river basin and correlated these variables. Others, like Joshi and Rawat (1985)[2], studied a quantitative analysis in Upper Ramganga Catchment. Pofali (1985)[3], studied on Hiran catchment and related to the land resources & management with the help of aerial photograph Rawat (1985)[4], studied about the hydrometric implications of morphometry and geology with reference to lower Ram Ganga catchment . Bhamare (1985)[5] correlated morphometry with hydrology and studed about the Panzara river basin taken under homogenous litho- climatic conditions.

Latest work was done by Dohrenwend (1987)[6]

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1. Vats P.C. (1985), " Quantitative geomorphic characteristics of Mithri river basin." Nat. Geog. Jour. Ind. Vol. 31, pp. 18-22.

2. Joshi S.C. And Rawat (1985), " The upper Ram Ganga catchment: A quantitative geomorphic analysis. " Geog. Rev. of Ind., Vol. 47, No.1, pp.18-24

3. Pofali R.M. Singh S.R., Batta R.K. (1985) : "Quant. -tative analysis of the Hiran Catchment for land resources Development and Management " Nat. Geog. Jour. Ind. Vol. 31, part 1 pp. 10-17.

4. Rawat J.S.(1985), " Hydrmetric implication of morphmetry and geology: A case study of lower Ram ganga catchment" Journ. Geol. Soc. Ind. Vol. 26, PP.734.

5. Bhamare S.M. (1985), " Morpho- Hydrological Analysis of Panzara basin " N.G.J.I. Vol. 31 pp. 23 - 27-

6. Dohrewend J.C. Athol, D. Abrahams and Brent D.T.(1987), " Drainage Development On Basaltic Lawa Flow : California and Nevada ". Geol. Soc. Amer. Bull. Vol.99 Sept. 3, pp. 405 - 413.

where the study was based on drainage development in Basaltic lava flow in California and Nevada and stated that After accumulation of an eolian mantle, master drainage extends to all parts of flow. During this period of elongation drainage density and link frequency incresed rapidly where as the value of Shreve's kappa(k) declined.

A few authors studied the theoretical aspect. Though there was great contribution of the scholars in morphometric field, still we need correlation of these variables in the development of the land resources, then only it willbe significant as pofali et.al.[1] attempted.

1.2 SIGNIFICANCE OF THE STUDY

According to above facts, an attempt has been made to draw the correlation of the morphometric variables and its variations under different lithological conditions, especially in hard and soft rocks. This aspect may be applied to the land use planning as is evident from the work done by K.N. Prudhviraju (1988)[2]. This aspect may also be taken into consideration for construction of dams, where, minimum sediments, and maximum discharge of water is found.

The behaviour of streams under different lithological conditions, its adjustments to surrounding areas, reflect its lithological and climatic conditions

and by the morphometric analysis it gives stress to the study.

Morphometry can be used to analyse land use pattern(a recent Study), land slides (study of slopes as a morphometric parameters), flood control etc. Branching of streams reflect geologic structure, lithological characteristics, general relief, plant cover, pedological characteristica, slopes and rain fall intensity, With the above variables in mind an attempt has been made to evaluate the lithological conditions of two basins of Bhaskel and Gudra in Indravati river basin.

1.3 SELECTION OF THE STUDY AREA :

Indravati river basin (Gudra and Bhaskel) has been selected as a basic unit because of its limited convienient and usually clearly defined topography units, available in a nested hierarchy of sizesoon the basis of stream ordering. Secondly,,it is comprising of totally different geological formations and structural conditions which will give a remarkable comparison for the study.

The selection of these river basins due to its location in Bastar region (Sedimentary and metamorphic rocks) and Koraput region (metamorphic). Its geology is the point of interest to the geologist and mineralogists from several years. No geologist had earlier, set foot in this area since the days of the great explorer

P.N. Bose who on the basis of regbonal travesses under taken during 1897-1900, described the rock types of the area as that of Dharwar facies.

A comparative study of the processes of drfferent drainage basins is possible. On the other hand, this virgin land, where this type of work has not been carried out so far, has two lithological formations i.e., sedimentary and metamorphic. The comparative study of land forms developed by these different processes over different conditions will be of great interest.

1.4 LOCATION OF THE STUDY AREA:

Indravati river basin stretches from 80° to 83° eastlonitude and 18°25'N to 21°North, latitudes. It rises at an elevation of 915 meters, in Kalahandi district of Orissa on the western slope of eastern Ghats. It drains an area of 41,665 kms.^{2} lying in a relatively high rainfall zone with about 1524 mm. of rain fall annually. Politically, it is surrounded by Rayagada, of Orissa in the east, Junagarh ,Raigarh and Armori of Madhya Pradesh in North, Sironcha in west, and Dantewara, Kotpad of Orissa Venkatpuram of Andhra Pradesh in south.

Gudra and Bhaskel, both the rivers ate an important north bank tributaries of Indravati river in Bastar and Koraput region respectivly. Geographically the Gudra extends from 81°E to 81°27' E of longitudes.

LOCATION MAP
GUDRA AND BHASKEL

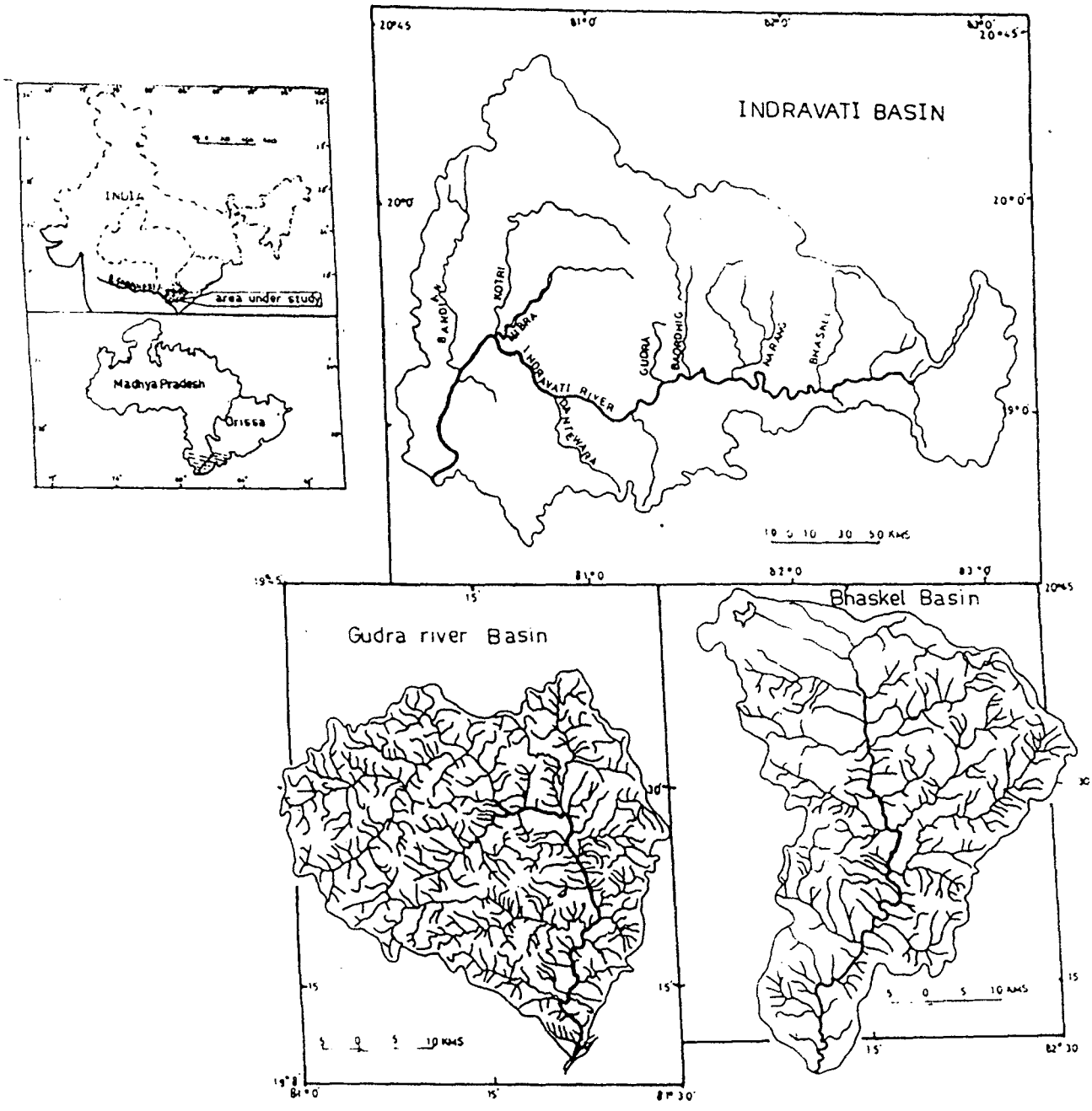

FIG. 1.1

Bhaskel extends from 82° 30'E of longitudes and 19° 13' N to 20° 25' N of lattitutes. Politically, these two basins covers an area of Bastar district of Madhya Pradesh (Gudra) and Korapatdistrict of Orisa (Bhaskel).

Geologically, Gudra river basin is composed of metamorphic rocks where gnesses and quartzites are in abundance, whereas Bhaskel river is composed of Metamorphic rocks in North and sedimentary in southern parts having lime stone in the east central parts.

1.5 PLAN OF THE WORK:

The present study is based on secondary data available literature.The work is divided into five chapters dealing with morphometric analysis of the study area.

Chapter I is an intriductory chapter which gives an idea about the subject, review of literature, selection of the study, location, data base and maps. Methodology and hypothesis of the worh.

Chapter II consists of general information of geology, climate , vegitation and soils by the help of geological map and climatic data.

Chapter III deals with different linear, areal, relief aspects of the drainage basin which gives the calculation of different morphometric variables and their distribution of the selected basin.

Chapter IV deals with the comparative analysis of the behaviour of the morphometric parameters of two different (Geologically) tributaries of Indravati river basin selected for the study.

Last chapter V deals with the conclusion and summary.

1.6 HYPOTHESIS:

1. Area of a drainage basin is determined by various morphometric parameters viz stream frequency, drainage density, dissection index, ruggedness number, constant of channel maintenance, length of over land flow, relative relief, mean channel length , total channel length and number of stream segments.
2. Stream length is controlled by area.
3. Slope is directly related to the relief..
4. Drainage density and drainage texture are the function of relief,dissection index, ruggedness number and stream frequency.
5. All the morphometric parameters are dependent on each other directly or indirectly, giving a particular shape to the basin.

1.7 METHODOLOGY:

Drainage basin are selected according to the lithologically variations, where the formation of rocks is different. The major classification is hard rocks of Gudra (metamorphic) and soft rocks of Bhaskel(Sedimentary). It is attempted to find out how,

different morphometric parameters behaves in different lithogies and to support these results some correlation is calculated between these parameters.

Some of the parameters are chosen for this study to assess the drainage basin of Gudra and Bhaskel, their areal, linear, relief characteristics. These parameters are linear i.e.stream orders, numbers, patterns, bifercation ratio ; areal, shape, area, length and relief,relative relief, dissction index, ruggedness number, stream frequency. They have been represented in tables and maps.

The following morphometric parameters have been taken for the evaluation of the nature of lithology:-

TABLE 1.1

Sl. No.	VARIABLES	FORMULAE	UNIT	DERIVATION
1.	Number of stream orders	Nu	Enumerative	Strahler
2.	Total number of streams with basin order.	$\Sigma Nu=N1+N2 + ..$	"	Strahler
3.	Bifercation ratio	Rb=Nu/Nu+1	-	Horton
4.	Total length of stream of order u	Lu	Kms	Horton
5.	Mean length of stream of order u	$\bar{L}u = Lu/Nu$	--	Horton
6.	Area of the basin	Au	Sq. Kms.	Strahler
7.	Basin Circularity(Rc)	$Ax4\pi/P^2$	-----	Miller

Sl. No.	VARIABLES	FORMULAE	UNIT	DERIVATION
8.	Basin Elongation(Re)	$2/\sqrt{\pi} \times \sqrt{A/L^2}$	--	Schumm
9.	Drainage Density (D)	$\Sigma Lu/Au$	Km/Km^2	Horton
10.	Texture Ratio (Tr)	$\Sigma Nu/\Sigma Pu$	No/Km	Horton
11.	Constant of channel(C) maintenance.	1/D	Sq. Km/Km	Schumm
12.	Stream frequency	$\Sigma N/A$	No/Sq.Km	Horton
13.	Absolute relief	H	Mtrs	Schumm
14.	Relative relief	Max-Min Absolute Relief	Mtrs	Schumm
15.	Ruggedness number	DxH/1000	----	Schumm
16.	Dissection index	Relative relief / Absolite relief	-	Schumm
17.	Basin slope	$\theta = \frac{CIxNo.\ of\ contours}{3361}$	-	Wentworth

8. DATA AND MAP BASE:-

The present study is totally based on the secondary data.The toposheets have been used on 1:50,000 scale published by servey of India.Toposheets of 65A/10,11, 13,14,15 and 65E/2,3,6,7 and 8 are used for Gudra river and 65I/2, 3, 4,6,7,8,11,12 and 14 are used for Bhaskel basin . For map work 65A, 65E and 65I on the scale 1:250,000.

Geological map of Indravati Bhaskel and Gudra are taken from the'Indravati project!'Geological Servey of Indiaand from a unpublished project work from CSRD/ J N U .

CHAPTER - II

GENERAL CHARACTERISTICS OF THE STUDY AREA

CHAPTER - II

GENERAL CHARACTERISTICS OF THE STUDY AREA

The Godavari basin extends over an area of 312,812 Square Kilometer which is nearly 10% of the total geographical area of the country. The basin lies between East longitudes 73°26' and 83°7' and north latitudes 16°16' and 22°36'. The basin lies in Deccan plateau and covers large areas in the state of Andhra Pradesh, Madhya Pradesh and Maharashtra in addition to smaller area in Mysore and Orissa. It is bounded on the North by Satmala hills and Ajanta Range and the Mahadeo hills on the South and East by Eastern Ghats and on the West by the Western Ghats. It is roughly traingular in shape & the main river itself runs practically along the base of the traingle. The entire basin of the river comprises rolling & undulating country a series of ridges and valley interspersed with low hill ranges.

The river Godavari rises in the North district of Maharashtra about 80 Kms. from the Arabian Sea at an elevation of 1067 Mtrs. After flowing for about 1465 Kms. in a generally South-East direction, through the Maharashtra and Andhra Pradesh it falls into the Bay of Bengal.

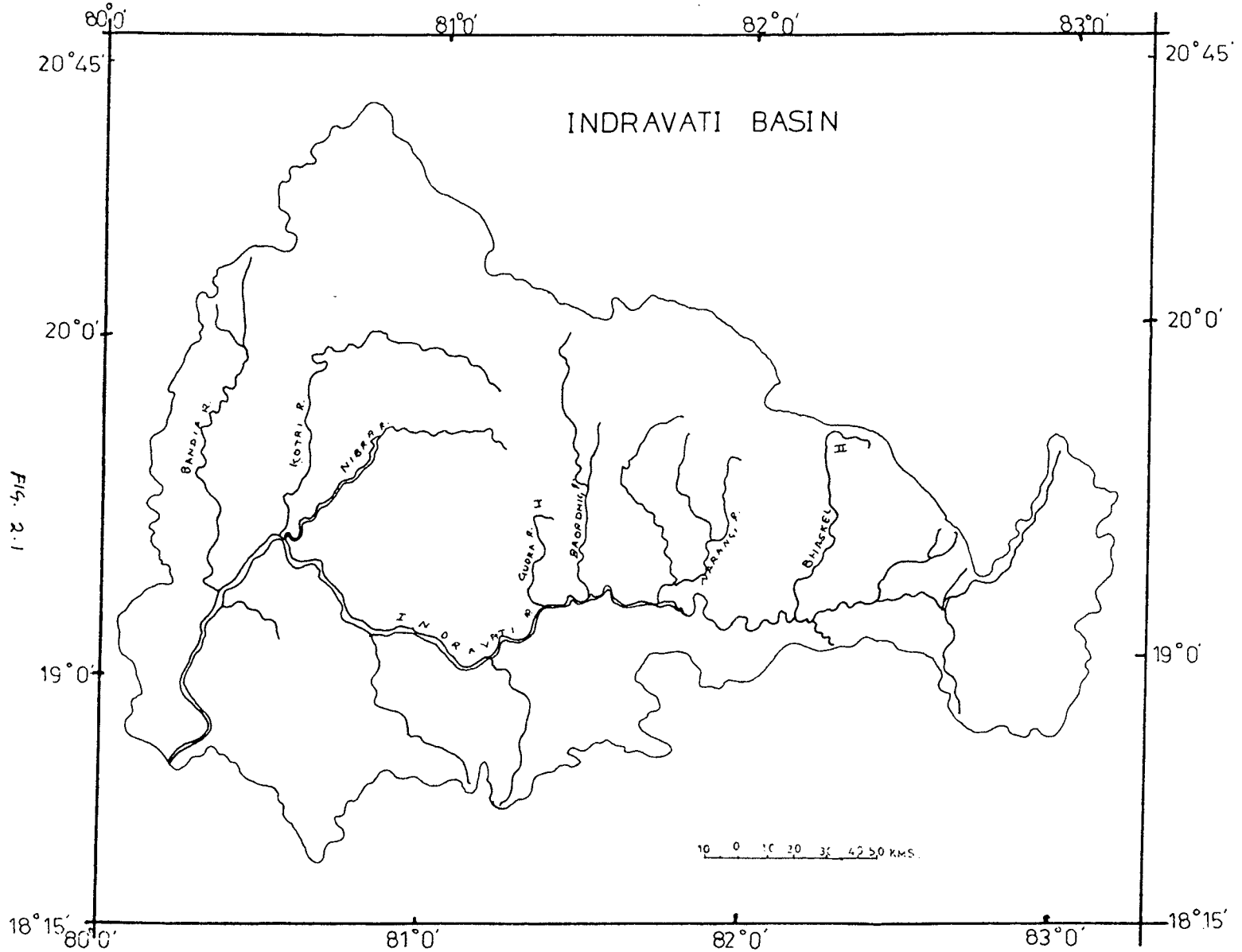
INDRAVATI BASIN
80°0'
81°0'
82°0'
83°0'
20°45'
20°0'
19°0'
18°15'
BANDIAR.
KOTRI R.
NIBRA R.
GUDRA R.
BAGDHIS
MARANGI R.
BHASKEL
INDRAVATI R.
10 0 10 20 30 40 50 KMS.

FIG. 2.1

About 64 Kms. from its source the Godavari receives the water of the Darua, on its right bank and a short distance lower down the Kadwa joins it from the left.

Indravati rises at an altitude of 914 Mtrs. in the Kalahandi district of Orissa on the Western Sloper of the Eastern Ghats. It flows West ward through the Korapur district of Orissa & the Bastar district of Madhya Pradesh, turns to South at about 531 Kms. from its source and joins the Godavari at an elevation of about 82 Mts. The largest and the longest river in South India is the Godavari of which the source is traceable to the Western Ghats. In its course through Maharashtra and Andhra Pradesh it is joined by then tributaries on the left and by eleven on its right. Among its important and major tributaries Indravati is one on which present study is based.

The Indravati, a major tributary of Godavari covers about 41,665 Square Km. of Catchment area of Madhya Pradesh and Orissa, rises at an altitude of 915 Mts. in the Kalahandi district on the Western Slopes of Eastern Ghats. It flows Westward through Korapur and Bastar districts, turns south and joins the Godavari about 530 Kms. from its source at an elevation of 82 Mtrs.

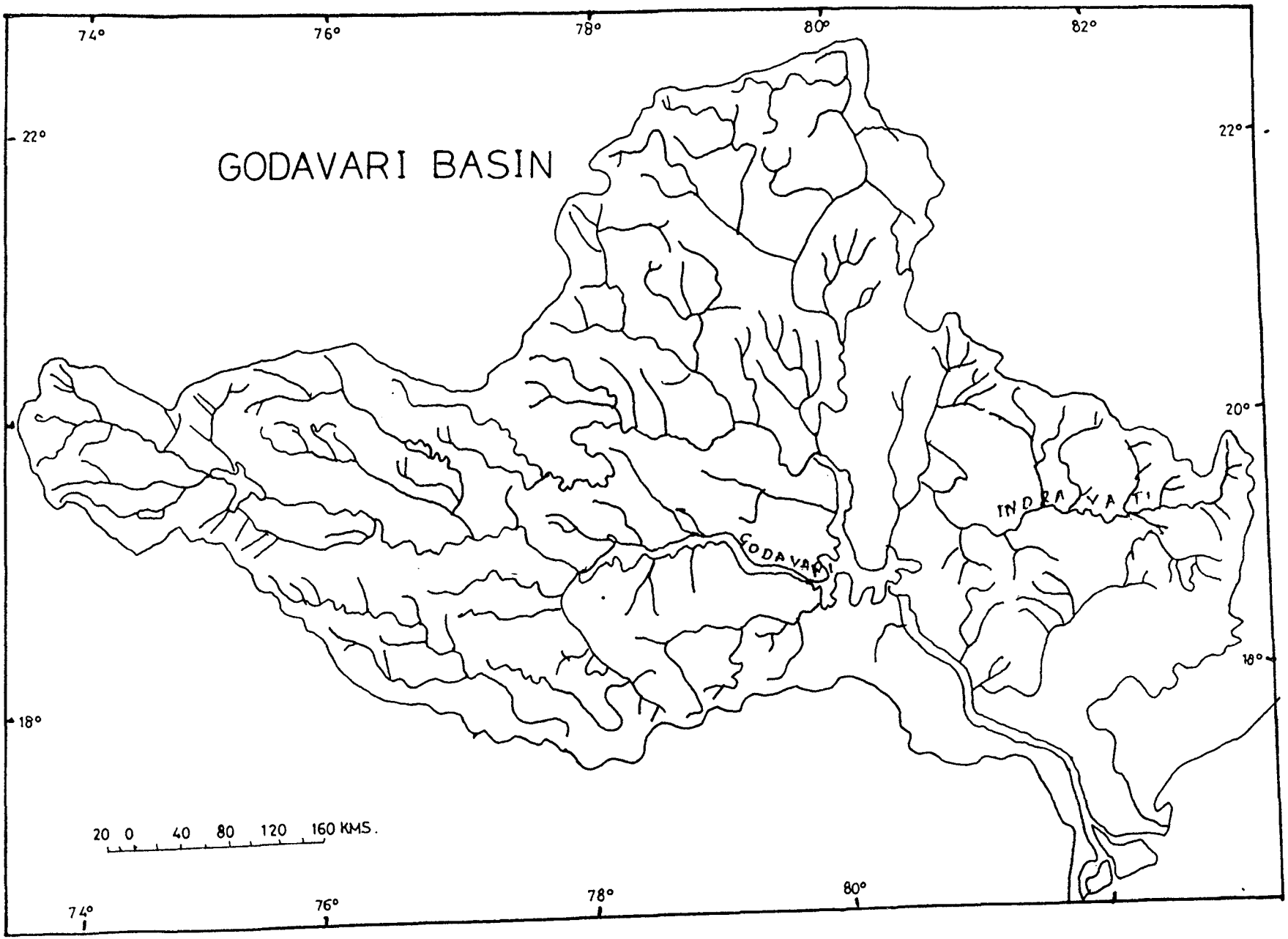
GODAVARI BASIN
74°
76°
78°
80°
82°
22°
20°
18°
GODAVARI
INDRAVATI
20 0 40 80 120 160 KMS.

FIG. 2.2

Bhopal pathanam. At chitrakot about 40 Kms west of Jagdalpurthe Indravati, while descending from the quartzitic sandstone, to the Archaean granite and gneisses makes 30 meter water fall.Also it makes a few rapidstowards further west from Chitrakot.

The majour tributaries of the Indravati river basin are Narangi, Baordhig, Kotri, Bandia,Nibra, Bhaskel flowing from its right Nandiraj as well as Dantewara from the left.The Abujhmar hills, lying between Indravati the Gudra and Nitra exhibit radial drainage pattern.

Bhaskel and Gudra are the two different tributaries of Indravati which have been taken for the present study as geologically they are of different origin.

GUDRA:

It is bounded with Kondagaon and Narayanpurin the North. Bijapur in south west, Dantewar in south. It stretches from 19^0 10' Nto 17° 35' Nand 82°20' Eto 82° 30'E of longitude. It rises at an altitude of 853 meters. Its major tributaries are Madin Nadi , Orcha Nadi.Madin Nadi meets to Gudra at an altitude of 500 meters in south. After covering 17.25 Kms of the way another tributary Orchha nadi from left bank joins Gudra. Crossing varioue dense forest of Sal it joins

Indravati river 22 kms. aheadnnear Barsur village.The flow of Gudra is north to south.

BHASKEL :

It covers the districts of Kotpad, Nowrangpur and Umarkot of the Koraput (Orissa). It stretches from 82°10' to 82° 21' longitudes and 19°6' to 19°50' of latitudes It is bounded with Jeypore and Koraput district in the south Kashipur and Kalahandi in the east and Bastar district of Madhya Pradesh in the north, west. Its direction of flow is from north to south.Amar nadi joins on the right bank, and also Agua nadi, Chitrangi nadi, Kharakjori nadi, Belari nadi and Angi nadi . Singari nadi jpins in the left bank of the Bhaskel river basin. It covers an area of sq. km. It joins Indravati in south near Nagarnar village.

2.1: GEOLOGICAL SETTING:

The whole Indravati river basin, geologically, is found very heterogenous. Lithologically it can be divided into followings:

(i)- Indravati sedimentary sequence.

(ii) Pakhal sedimentary sequence.

(iii) Abujhmar volcano- sedimentary sequence.

(iv)- Dangargarh Granite complex.

(v)- Nandgaon volcanic complex.

(vi) Bailadila iron- ore group.

(vii) Bengpal gneissic complex.

(viii)Granulite charnockite complex.

(ix) Eastern Ghats complex.

A wider range of whole Indravati river basin consists of Bengpal Gneissic complex and Abujhmar volcano

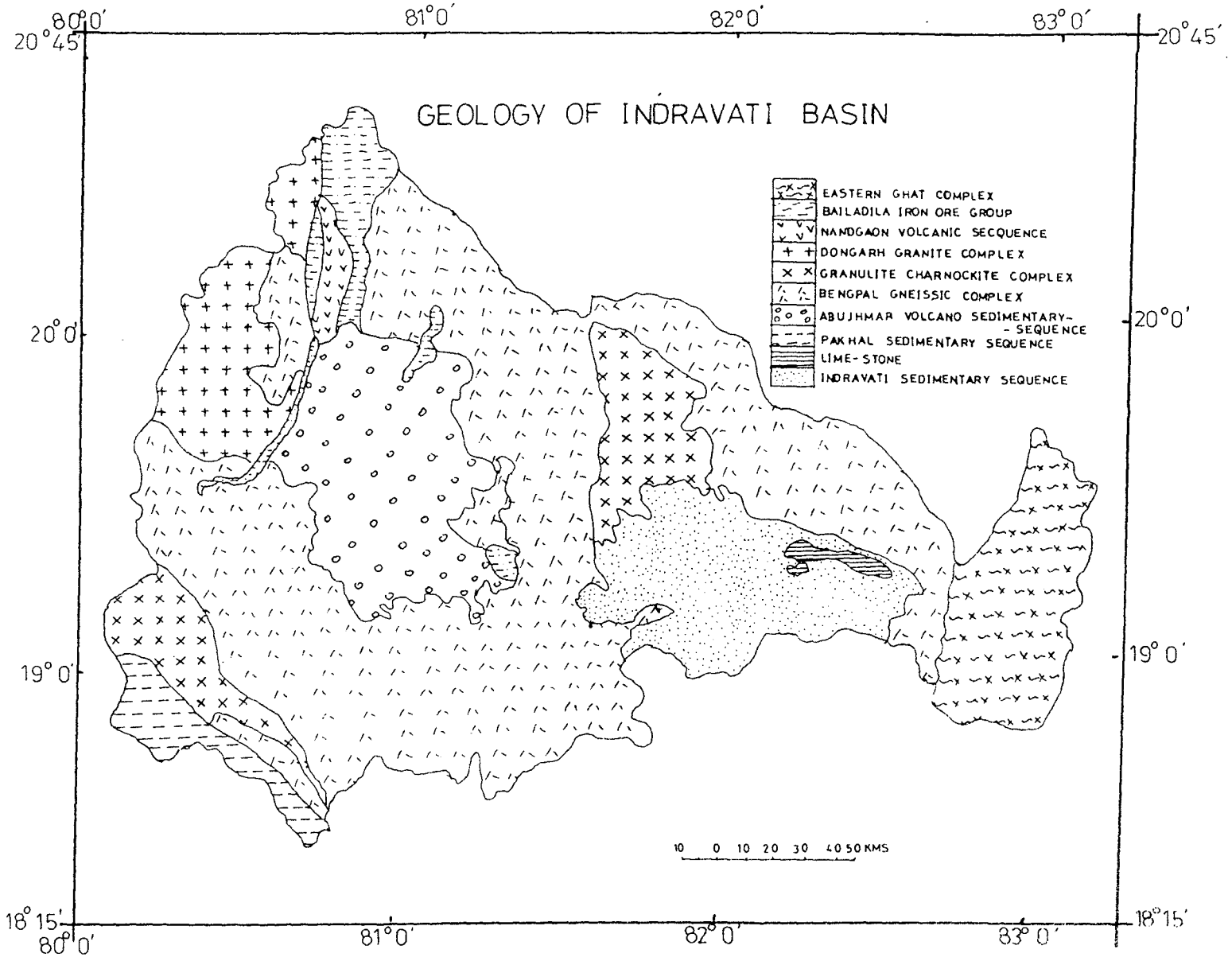
GEOLOGY OF INDRAVATI BASIN
80°0'
81°0'
82°0'
83°0'
20°45'
20°0'
19°0'
18°15'
EASTERN GHAT COMPLEX
BAILADILA IRON ORE GROUP
NANDGAON VOLCANIC SECQUENCE
DONGARH GRANITE COMPLEX
GRANULITE CHARNOCKITE COMPLEX
BENGPAL GNEISSIC COMPLEX
ABUJHMAR VOLCANO SEDIMENTARY- - SEQUENCE
PAKHAL SEDIMENTARY SEQUENCE
LIME-STONE
INDRAVATI SEDIMENTARY SEQUENCE
10 0 10 20 30 40 50 KMS

FIG. 2.3

2.1(a) GUDRA RIVER BASIN :

The main geological formations of the area belons to the Bengpal, the Bailadila, the Nandgaon and the Abujhmar groups and sub recent to recent deposits. The sequence of Rock type in this area is as follows:

TABLE 2.1

Purana		Arkose and Quartzites
Archaean		Quartz vein
		Diorite, dolerite and amphibolite
		Biotite Granite
		Biotite Granite Gneisses.
		Bailadila series: Banded hematite Quartzites; Ferruginous shale
		Bengpal series: Quartzites, quart schist, phyllite, horn blende schist.
	BASIC	LAVA

BENPAL GROUP : This group comprises of metasediments including pyroxene, quartzites, quartz schist, banded magnetite, mica schist and hornblende schist occuring as enclaves with the granite gneisses, migmatite and granite. The discontinuous exposures of these metasediments show a variation in strike from

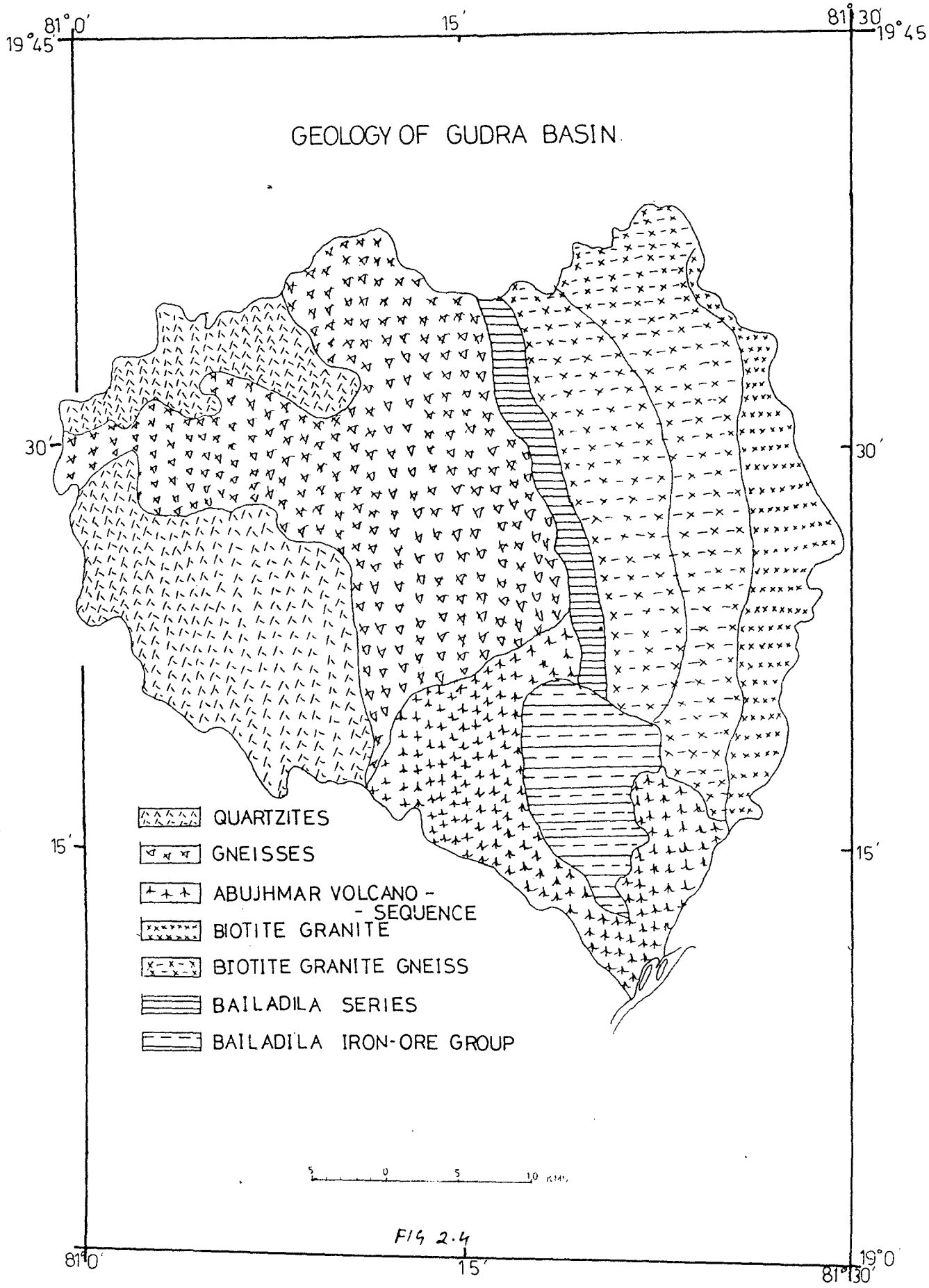
81°0'
15'
81°30'
19°45'
19°45'
GEOLOGY OF GUDRA BASIN
30'
30'
15'
15'
QUARTZITES
GNEISSES
ABUJHMAR VOLCANO - - SEQUENCE
BIOTITE GRANITE
BIOTITE GRANITE GNEISS
BAILADILA SERIES
BAILADILA IRON-ORE GROUP
5 0 5 10 KMS
81°0'
15'
19°0'
81°30'

FIG 2.4

North-east- south west to north west t- south west with dips varying from 30°-80° in either direction, at places becoming vertical. Granite gneiss, migmatite and granite are the product of the granitisation and anatexis of the above metasediments and predominantl ly occur in the north eastern part of the area. Meta-basic dykes and quartz veins (at places sheared) and mylon itised intrude these rocks.

THE BAILADILA GROUP: This group of rocks forms a small in lier, occuring in the northern part and comprise banded magnetide and ferrugeous phyllites.

THE NANDGAON GROUP : The Nandgaon group of rocks include ferrugenous sand stone and shale ryolites and granophytes occuring in the north western finger of the area, forming a large in lier with in the younger Gundul sand stone-conglomerate. Their relation ship with the rocks of other groups and granite is observed by the overlying sediments of the Abujhmar group. Rhyolite and Granophyre occur in the north western part of the area around Mahla and east Pratappur. The intrusive relation of these rocks with ferrugenous sand stone and shale is seen at a few places. Pebbles of rhyolite occur in the Gundul conglomerate, indicating that the rhyolite is older than Gundul sand-stone conglomerate. The acid volcanic rocks in contribution with rhyolite in the north have been grouped as "Greenstone" by Chatterjee(1951).

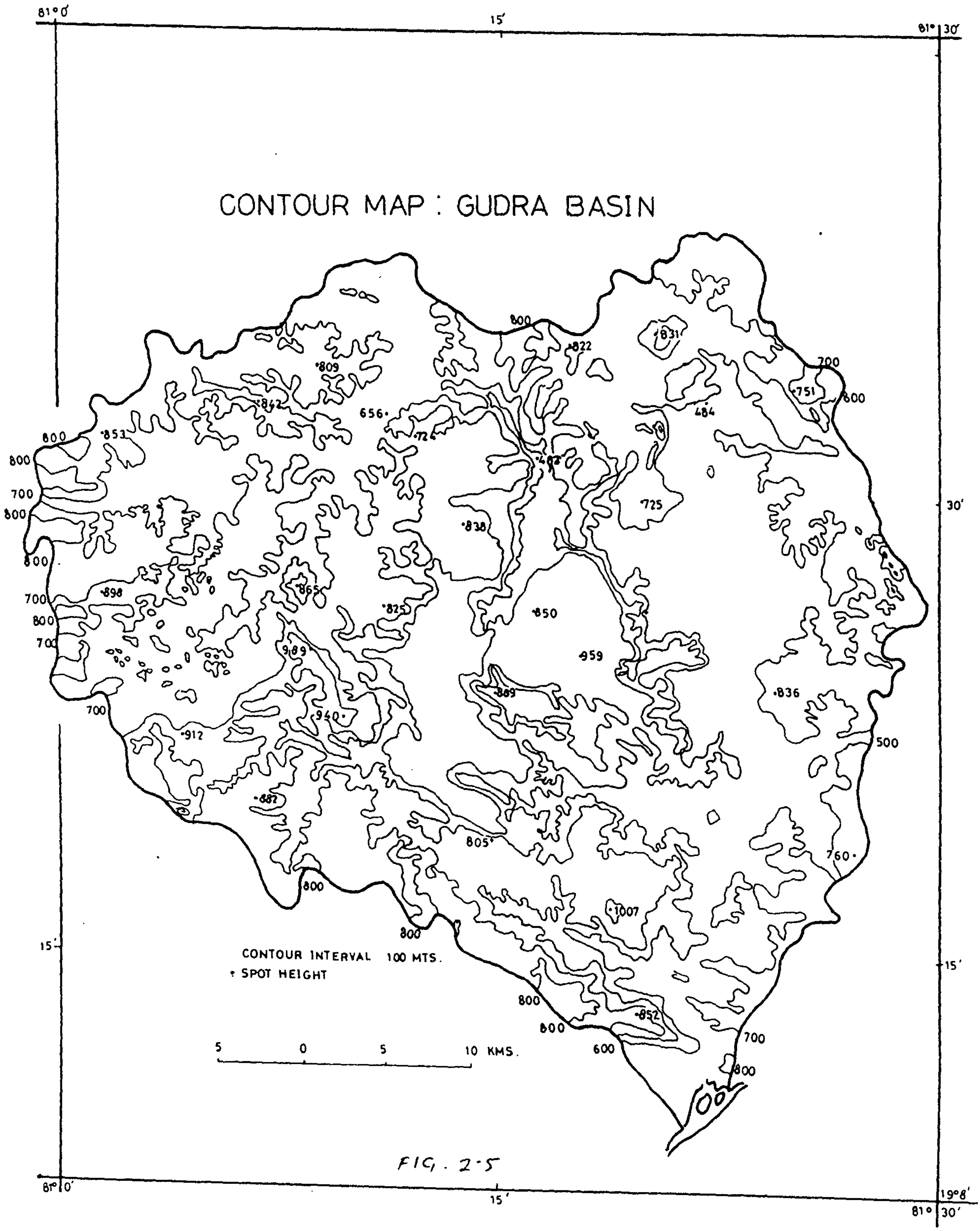
CONTOUR MAP : GUDRA BASIN
81°0'
15'
81° 30'
30'
15'
19°8'
CONTOUR INTERVAL 100 MTS.
• SPOT HEIGHT
5 0 5 10 KMS.
800
700
600
500
809
842
853
656
726
822
831
751
484
725
838
898
865
825
850
959
889
836
940
912
887
805
760
1007
852

FIG. 2·5

NARAINPUR GROUP : The Narain pur group is also known as "Abujhmar Group", it include the lower Gundul formation of sand-stone, shale, conglomerate, unconformably overlain by the upper formation, Maspur trap (basalt) and intrusives.

FERRUGENOUS SAND STONEAAND SHALE : These form linear ridges trending NNE-SSW occuring to the east of Pratappur. Shale occurs as interscalation with in sand stone is laterised. Rhyolite and Granophyre exhibit intrusive relation with sed-mentaries and occur on all sides of the ridge. The bedding trend NW-SE to NNE-SSW, dipping 15°-30° towards east.Sand stone is greyish white to dark brown in color, medium grained in persistently banded and fragile to compact. Shale is purple colored well laminated and indurated in nature with small pockets of iron ore at places.

RHYOLITE AND GRANOPHYRES: These acid volcanics occur in the north western part. These are overlain directly by Gundul sand stones.Acid volcanic rocks at places exhibit prophyritic texture though generally crypto-crystalline and glassy. Rhyolite is light brown and pinkish to dark grey in color and breaks with equigranular texture.

GUNDUL FORMATIONS : Comprises an inter bedded sequence of sand stone is the most dominant of three and conglomerate occurs as large bands in it. Where as shale forms smaller pockets.

Sand stone is well bedded and form cliffs and high hills It shows variable composition being arkose at many places. The thickness and composition of the sand stone are variable as also thegrain size from grit to fine sill sizes. The sandstone is greyish white or pinkish to dirty white in color, well bedded and compact.Shale occurs as intercalation with in the sand stone and is noticed in differeht localities, but good exposures are present along the Dokrighat road section. Shale is purplish to greyish white in color, well laminated and at places slaty in places due to induration and compactness.

SUB RECENT DEPOSITS : Laterite capping developed over theMaspur trap forms the extensive plateau in the area. There are few pockets of bauxite with in the laterite. At other places the laterite is cavernes to pistolitic and ferrugeous to brown color.

2.1 (b) BHASKEL RIVER BASIN:

The cheif groups of the region are Archaeans, Cuddapah, Tertiary and recent formations like laterite and alluvium.

ARCHAEAN : The archaean of the region may be divided into two main rocks groups:

(i) Sedimentary rock and their metamorphic variants with which are associated basic igneous rocks

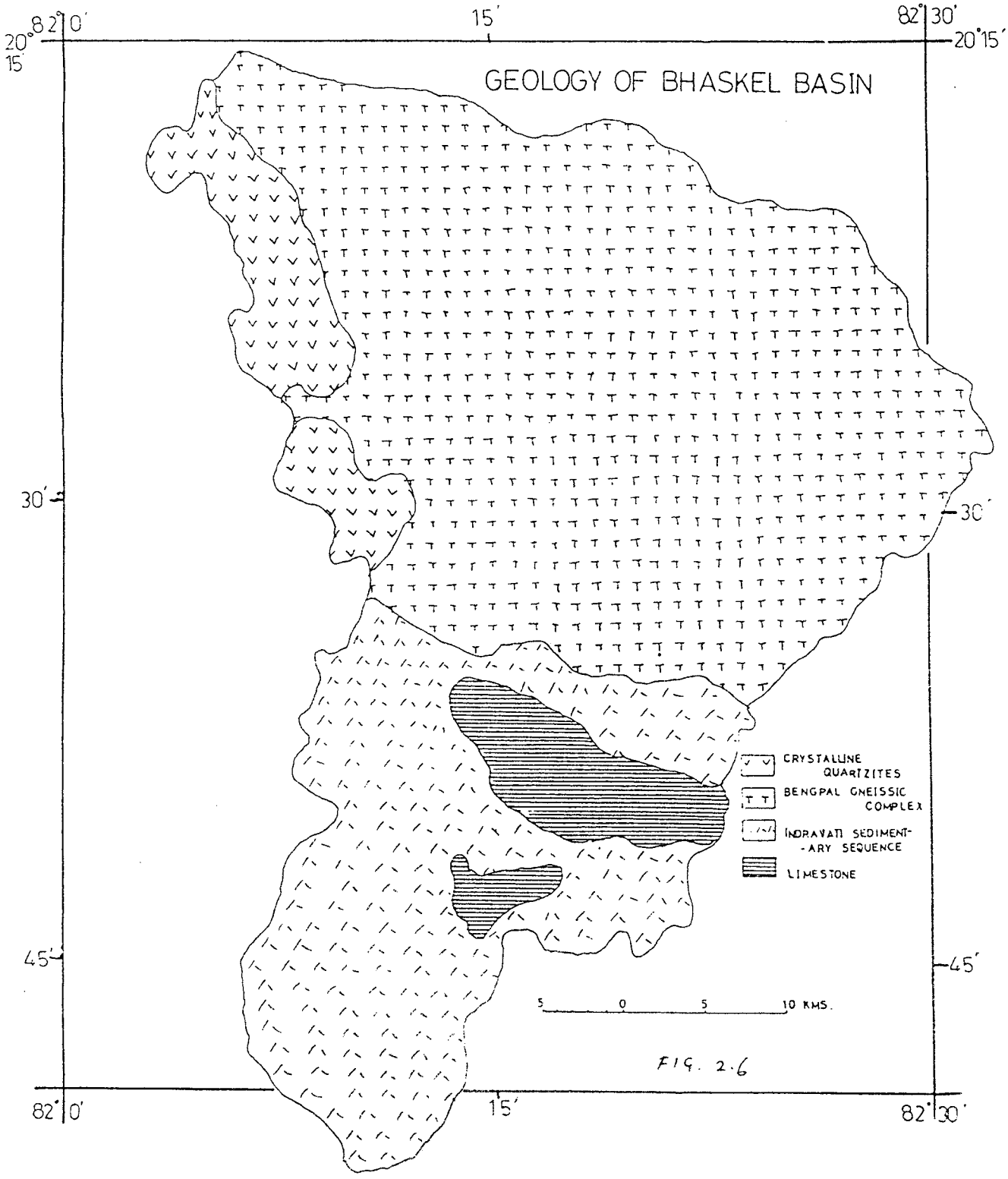
GEOLOGY OF BHASKEL BASIN
82° 0'
15'
82° 30'
20° 15'
20° 15'
30'
30'
45'
45'
82° 0'
15'
82° 30'
CRYSTALLINE QUARTZITES
BENGPAL GNEISSIC COMPLEX
INDRAVATI SEDIMENTARY SEQUENCE
LIMESTONE
5 0 5 10 KMS.

FIG. 2.6

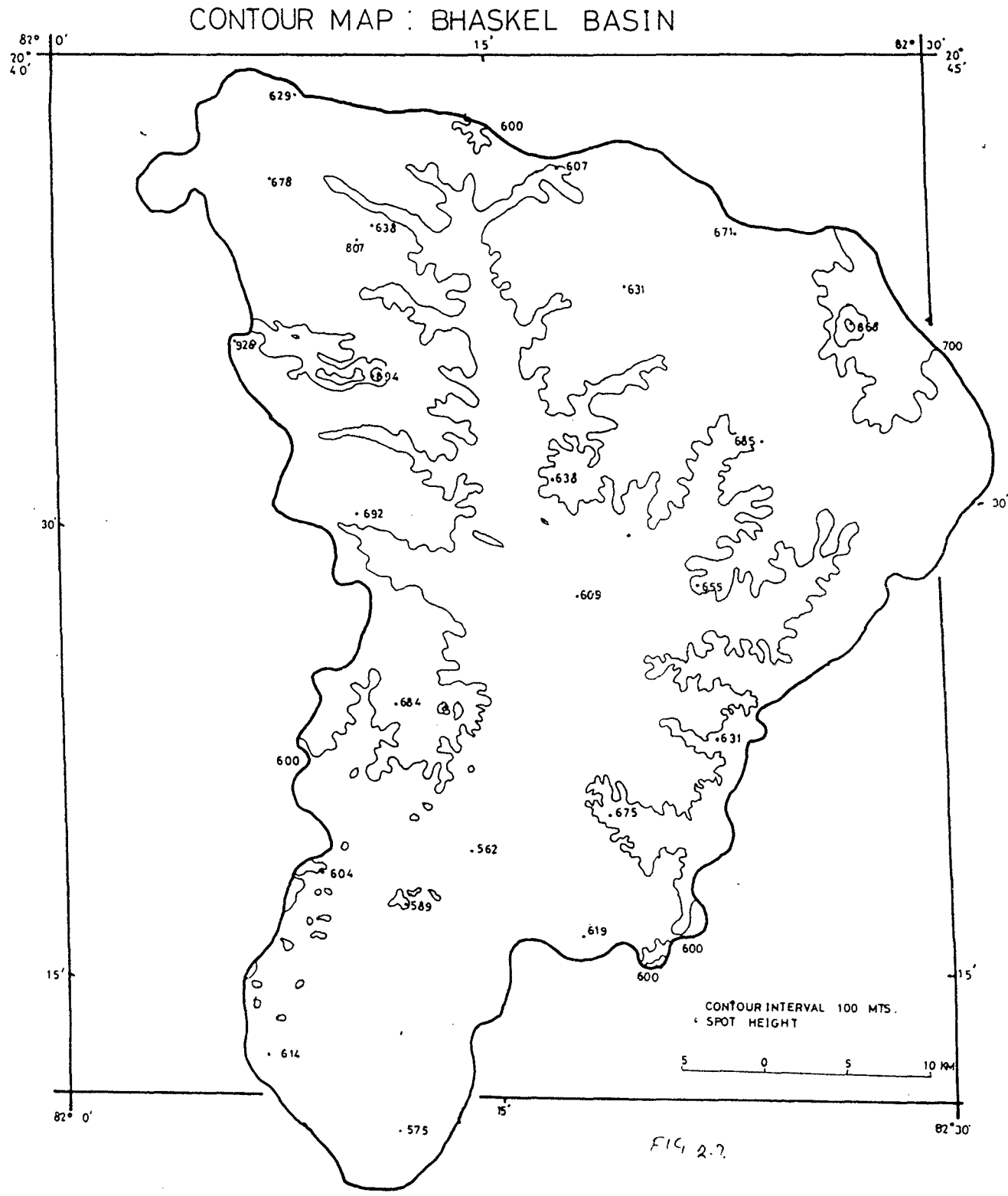
CONTOUR MAP : BHASKEL BASIN
82° 10'
15'
82° 30'
20° 40'
20° 45'
629
600
607
678
638
807
671
631
868
926
894
700
685
638
692
30'
609
655
684
631
600
675
562
604
589
619
600
600
15'
CONTOUR INTERVAL 100 MTS.
SPOT HEIGHT
5 0 5 10 KM
614
82° 0'
15'
575
82° 30'

FIG 2.2

(ii) Widespread intrusions of granite and charnokites .

The sedimentary Archaean rocks ofthe region are highly metamorphosed, The cheif rock types consists of quartz garnet and sillimonitewith some feldspar and graphite and very often maganese, iron minerals(khondalites). In a few localities calc gneeisses, quartz veins ,limestone are associated withtypical khondalite rock forms a psrt of the Koraput plateau which passes south wards into the Vishakh--apattnam district of Andra Pradesh.

METAMORPHOSED ARCHAEAN : Archaean sediments is a different type which have not suffered such intense metamorphism as the Khondalites, occupy large areas of the western and southern parts of the Jeypore plateau and extends into the lower tracts of Makkangiri. These rocks are known as the Bengal series, extend westward into Bastar where they are better developed, included with in the Bengpal of the Koraput plateau region are Andalusite bearing grits and schist, biotite schist and crystalline quattzites,associated with them are haematite quartzites binded magnetide and grun esite quartzites.

The above Archeeam sediments are associated with basic lavas and minor intrusions which are also present in gneisses. The basic rocks have been subjected to varying degrees of metamorphism and in all probabilty belong to more than one period. They consists of epidocites amphibolite

non blendes diopside-chloride and talc-schist. The green stone intrusions in the Tulsi and Lokkhi hills assumes enormous proportions of rocks of this type.

The complex group of granitegneisses and metamorphic rock have been so much altered by regional metamorphism and different cycles of igneous activity, that the nature of the parent rock can't always be determined. Some of them may represent the crystalline product of true melts where as others appear to be hybrids or remnants of older rocks which have absorbed liquid or have been altered by liquid and gaseous emanations. Other types of gneisses found in the region are porphyritic granite gneiss,charnockites. They vary from coarse grained banded gneisses and typicak injection gneisses to entirely massive granite and carry bands and patches of basic hypersthene and other dark colored rocks, Basic charnockite occurs in the form of minor patches or bands, associated with the granite gneisses.

2.2 CLIMATE:

The entire Indravati basin lies with in the tropics, is characterised by the hot and humid climate. The temperature varies from 19° in the coldest month,December to 31° in May, the hottest month showing a considerable annual range of 12°C. The rain fall in the region charac teristically occurs between June and September, ranging from

125 cm. and 150 cm. The periods between December - February remains generally dry. The region, however, suffers from uneven distribution, un reliabily and uncertainty of rainfall. The rainfall, fairly heavy though irregular and unevenly ditributed, mostly caused by the south west monsoon.

This variability of rainfall from normal is relatively high but since the annual precipitation is fairly high, floods are bigger menace than drought.

2.2(a) CLIMATE OF GUDRA:

Rainfall: Mean annual rainfall ranges from 13.75 Cm to 150 CM. It increses from west to east . Generally rainfall ocurs in the month of June to October, maximum reaches upto 30 to 40 Centimeters in the month of July to August.

Temperature: Annual meam temperature through out the year remaims between 24°C to 26°C . December and January are the coldest months in the year. Thereafter the temperature goes on rising almost steadily till it attains Maximum temperature which takes place in the month of May. May is the hottest month of the year. After May the temperature starts decreasing till August. The drop being some what conspicious from June to July. In August the temperature is checked by heavy down pour. July and September are more or less equally warm. October is the month of transition from rainy to cold season and presents an interesting contrast of hot days and cool nights. From November

again the mercury atarts declining constantly till it touches the minimum in the month of January.

2.2 (b) CLIMATE OF BHASKEL :

Rainfall : The climate of the region is more like that ofDeccan but milder than main Deccan plateau. The average annual rainfall is 152.2 CM. The spatial distribution of rainfall is largely influenced by the eastern Ghats which run roughly from south west to north east. Eastern side of Eastern Ghats get lesser rain fall that those on the West. 79% of the rainfall falls during the monsoon season. July and August are the rainiest months in the year.

Temperature: December is the coldest month of the year with the mean daily temperaure at 11.2°C (52.2°F). Both day and night temperatures progressively increases after January till May which is the hottest month.

2.3 NATURAL VEGITATION:

Although the implementation of agriculture extension programmes recently in many parts of this Indravati River basin has resulted in deforestation and decreasing of original forests with a view to increasing cultivable land. The region appears to be exceptionally rich in the forest wealth mostly confined on the upland hills and the Eastern Ghats.

The typical cover is of the mosist tropical deciduous forests of "SAL" being the most dominant species.About 57.8% of the area is under forests cover.

At present a high proportion of the forest in the region is either reserved or protected.Main trees are Teak, Sal, Sirsa, Bijasal, Kusum, Palas, Mahua, Tendu, Harsa, Salai and char etc

2,3 (a) NATURAL VEGETATION OF GUDRA:

Sal and Teak are the most common vegetation found here with. Sal forests aredeciduous forests. The Sal forest are found in the North North western parts of the region. Broader area consists of Teak forest which are found in the Northern, Central, Eastern tropical dry mixed deciduous forests and the tropical dry deciduous forsets. The dues region proceeds gradually towards North- western region and the proportion ofTeak also falls down in the same direction. The soil on the plateau and escapments are fit for dry deciduous forest with species like Hurra, Karra, Mahua, Sahaja, Palsa, Tendu Khair etc.

2.3 (b) NATURAL VEGETATION OF BHASKEL:

The vegetation is of considerable interest as although typically northern in character it has also affinities with the florad southern part.

The greater part of plateau was covered with 'SAL' of a moist peninsulas type and this forest still survives where it is under protection. The commonest trees are ShoreaRuusta (Sal), Asana, Dhama, Simili, Bagali, Atund etc. Bahoos are very rare. Scattered patches of teak occur as far west as 82°36' longitudes. Kusum is common in open cultivated tracts.

U Umarkot, Nowrangpur, Kotpad and part of Ramagin range are all situated on a plateau which is typically Sal of a moist peninsulas type. A few patches of teak occur locally. The whole crop was at one time under slufting cultivation and the forest now comprises pole crops in various stages of growth.

2.4 SOIL: Adequate and systematic record about the characteristics of soils of the region of Indravati river basin is hardly available. The soil types however vary widely depending on the configuration of surfaces while the peaks on the region have bare rocks almost devoid ofvegetative cover , the plateau and hill slopes contain rocky soil with thin veneer of loam and the plains and valleys are characterised usually by fertile alluvium. Majot part of arable land in Eastern Ghats contain mixed red and black soil deficient in humus nitrogen phosphoric acid potash and lime.

Extremely poious and generally sedentary type of soils are formed through the weathering of metamorphic rocks e.g. schists and gneisses and generally deficient in plant nutrients with low PH value (5.5 to 6.5). They are generally red with patches of grey color being too shallow with very fertile clay content. Being less moisture retentivity they are unableto sustain Ravi crops except under favourable conditions.

However the parent rocks slope and other factors produces greate variety of soils in different parts. The upland contain red soils rich in iron content and formed mostly due to the fact that soils are shallow ,exessively drained and non -calcareous, developed on 15 to 25% slope. The soilpedon exhibits brown sandy clay. A horizon grading to Ac horizon of dark brown color with gravelly clay underlain by weathered granite.

In the hilly tract of Abujhman are found that the soils are containing high concentration of iron oxides. Soils of Bodeli series are found to occur in this region . The soils are deep, well drained and non - calcareous developed on 1 to 3% slope, The soil pedon exhibits dark brown sandy clay. A horizon grading to Bt horizon dark brown to dark red in color having clay loam with thick patchy clay skin on ped faces underlain by massive unconsolidated lateritic materials in C horizon.

Being a hilly terrain with un dulating topography , flood plains occur in areas along this river at an elevation of 250 meters above Mean Sea Level. Soils of Khande series are found to occur in this unit. These soils have yellowish brown silty clay A horizon grading to B horizon of brown to olive grey clay with pressure faces and yellowish brown mottles underclain by clayey olive grey alluvium of 'C' Horizon.

2.4 (b) BHASKEL SOILS:

No systematic soil servey has been made yet the following soil classification is based on

physical characteristics only.

COARSE TEXTURE SANDY SOIL:

Composed of a large percentage of coarse textured sand and a small amount of organic molten. Fine silty alluvial soil available on both sides of south Bhaskel river in Nowrangpur and Borigumns areas ,it is very rich in organic matter and contains silt and fine sand deposits of the river Indravati and Bhaskel.

RED LATERITE SOIL:

It is partly in this area.It is red in color and very clayey in nature, poor in organic matter contents and its fertility is low.

BLACK COTTON SOIL:

It occurs in Umarkot tehsil in North west part of Bhaskel river. It is slightly alkaline in nature. The soil stiffens and cracks when dry and grows sticky with a shower or two. Though black in color its humus contents is poor. The sub-soil is light yellow, impervious and forms a hard pan below the cultivated soil.

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C H A P T E R III

AN ACCOUNT OF MORPHOMETRY OF GUDRA AND BHASKEL

C H A P T E R I I I

AN ACCOUNT OF MORPHOMETRY OF GUDRA AND BHASKEL

The term morphometry is used in several disciplines to mean the measurement and analysis of form, characteristics, in geomorphology, it is applied to numerical examination of land forms. It provides, tool for analysis of surface configuration of a land scape. It evaluates the topological, geometrical areal, relief characteristics of the basin.

The present study is based on an evaluation of morphometric parameters. Bearing different lithologies Gudra and Bhaskel basins of, Bastar and Koraput districts, respectively, has been studied for geomorphological analysis based on Strahler's and Horton's method.

3.1 DELIMITATION AND SAMPLING OF THE BASIN :

Streams of various orders, following Strahlers' technique is marked and delimited the entire Indravati and sample basins. The geology of both, Gudra and Bhaskel have been superimposed on the drainage map and fourth order basins have been grouped according to different geological formations of the basins. These IV order basins have also examine according to Chorley's criteria as " Basins must be connected with the main stream network, must be ' permanent,' form a part of a distinctly bifurcating channel pattern and must conduct laterally concentrated surface runoff from a well defined drainage area.

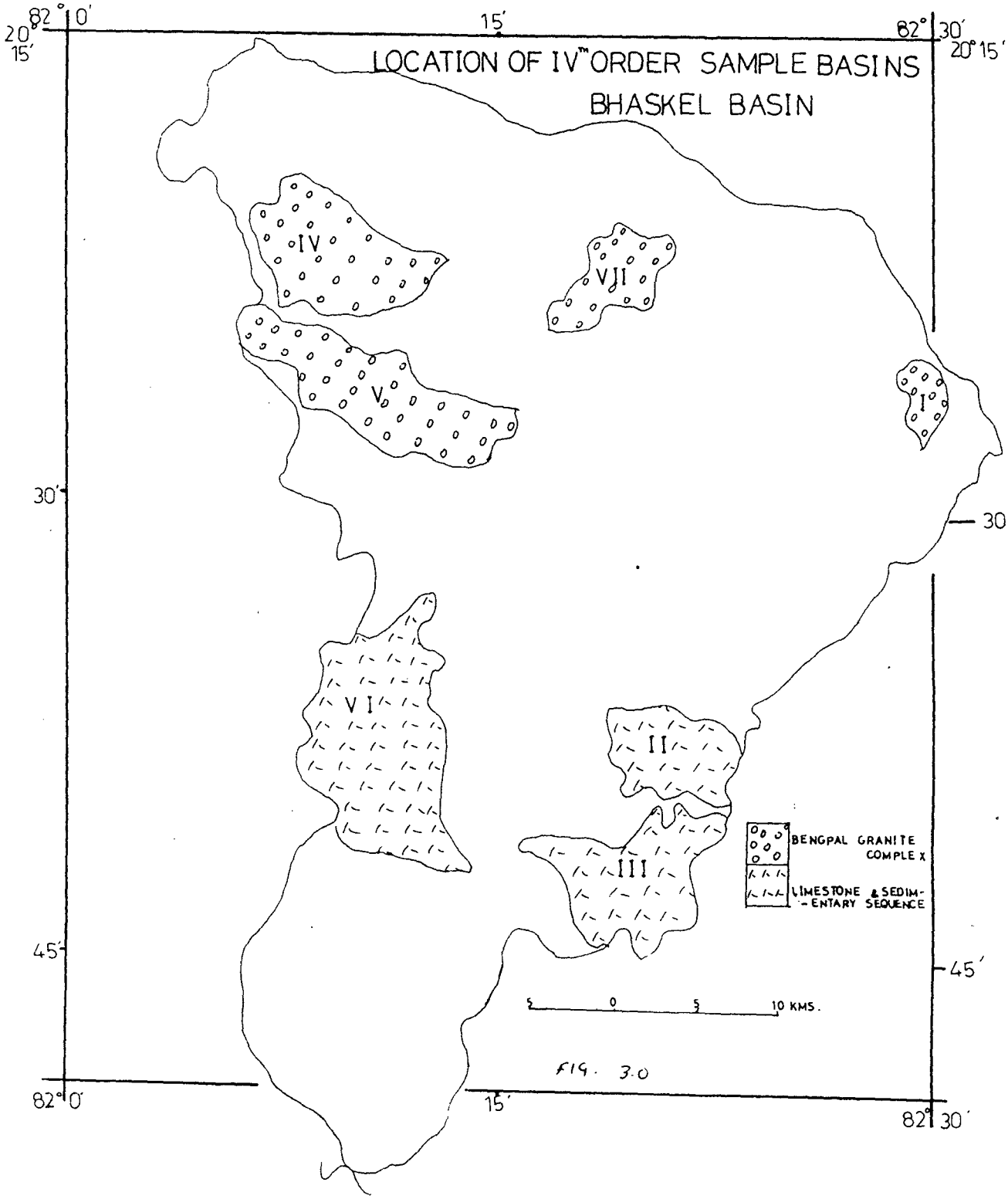

LOCATION OF IV^m ORDER SAMPLE BASINS
BHASKEL BASIN
82° 0'
15'
82° 30'
20° 15'
20° 15'
30'
30'
45'
45'
82° 0'
15'
82° 30'
IV
VJI
V
I
VI
II
III
BENGPAL GRANITE COMPLEX
LIMESTONE & SEDIM-ENTARY SEQUENCE
0
5
10 KMS.

FIG. 3.0

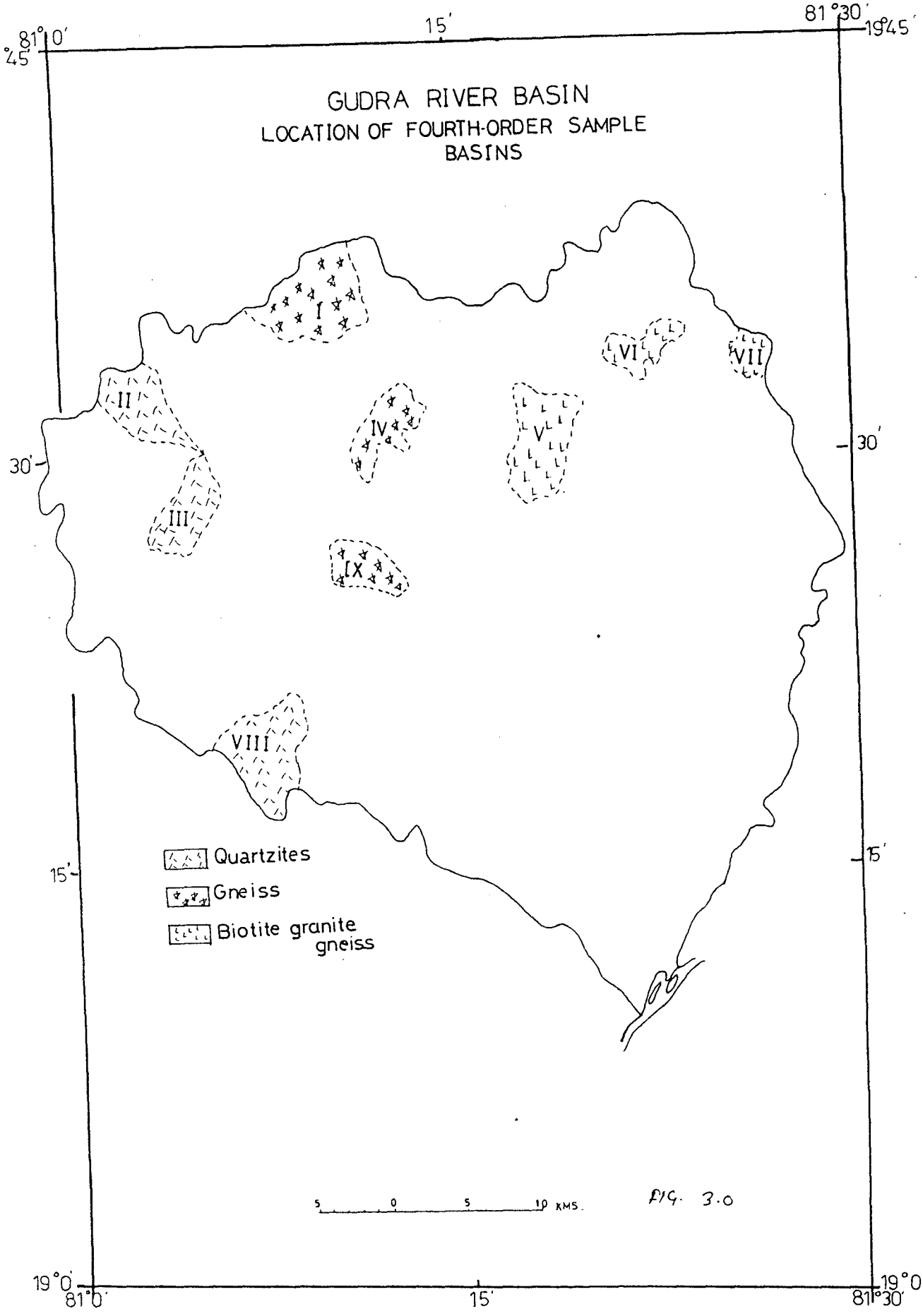

GUDRA RIVER BASIN
LOCATION OF FOURTH-ORDER SAMPLE BASINS
81°0'
81°30'
19°45'
19°0'
15'
30'
I
II
III
IV
V
VI
VII
VIII
IX
Quartzites
Gneiss
Biotite granite gneiss
5 0 5 10 KMS.

FIG. 3.0

These fourth order sample basins have been randomly selected. There are 16 fourth order basins selected from the different geological formations of the three tributaries of Indravati, broadly classified as hard rocks and soft rocks.

SELECTION OF THE BASIN :

TABLE 3.0

ROCK TYPE	GELOGICAL FORMATIONS.	MAIN DRAINAGE BASIN.	NO. OF IV ORDER STREAM
HARD ROCKS	Gneisses	Gudra	3
	Biotite Granite gneisses	Gudra	2
	Quartzites	Gudra	3
	Bengpal Gneissic complex	Bhaskel	4
SOFT ROCKS	Lime stone	Bhaskel	1
	Indravati Sedimentary sequence.	Bhaskel	3

In the present chapter some measurement of linear, areal, relief characteristics of Baskel and Gudra have been assessed. The first 2 categories of measurement i.e. linear and areal are planimetric, where as, the relief aspect have been treated vertically in equalities of the drainage basin form.

3.2 LINEAR ASPECTS OF DRAINAGE BASIN :

Linear characteristics of channels are defined in terms of, number, length and arrangement of the stream segments and can be assessed from 2 main view points:

(a) The topological, which considers the inter connectios of the system and include stream ordering.

(b) Geometrical, which considers the length, shape and orientation of the constituent parts of the network.

3.1 (i) STREAM ORDERS :

The initial step in drainage basin analysis is designation of stream orders. Streams are ordered after Strahlers' (1952, p. 1120)[1] adaptation of the Hortons' [2] scheme of classification. Melton (p.340 - 345)[3] has suggested the mathematical concept for ordering of the strem. Assuming a channel which includes all intermittent flow lines with well defined valleys gives the smallest finger tips designated as order 1. When 2 first order streams meet, forms a second order stream and so on. The trunk stream in which all discharge of water and sediments passes are therefore, the segment of higher order.

Stream order is useful in determination of the size of a strem channel as well as, hydrological potential. Intensity of erosion and sedimentation could also evaluated by the same technique. In a basin, streams are ordered to ascertain the dimension of the basin and to measure the amount of water and sediments which discharge through the tributaries with respect to trunk stream.

3.1 (ii) STREAM NUMBERS :

Horton developed a model of stream ordering and suggested that " The number of streams of each form an inverse geometric series with the order" Infers, as order

1. Strahler (1952), op. cit., ref. chapter I
2. Horton (1945), op. cit., ref. chapter I
3. Melton (p.340), op, cit. ref. chapter I

STREAM ORDERS : GUDRA BASIN

IV ORDER SAMPLE BASINS

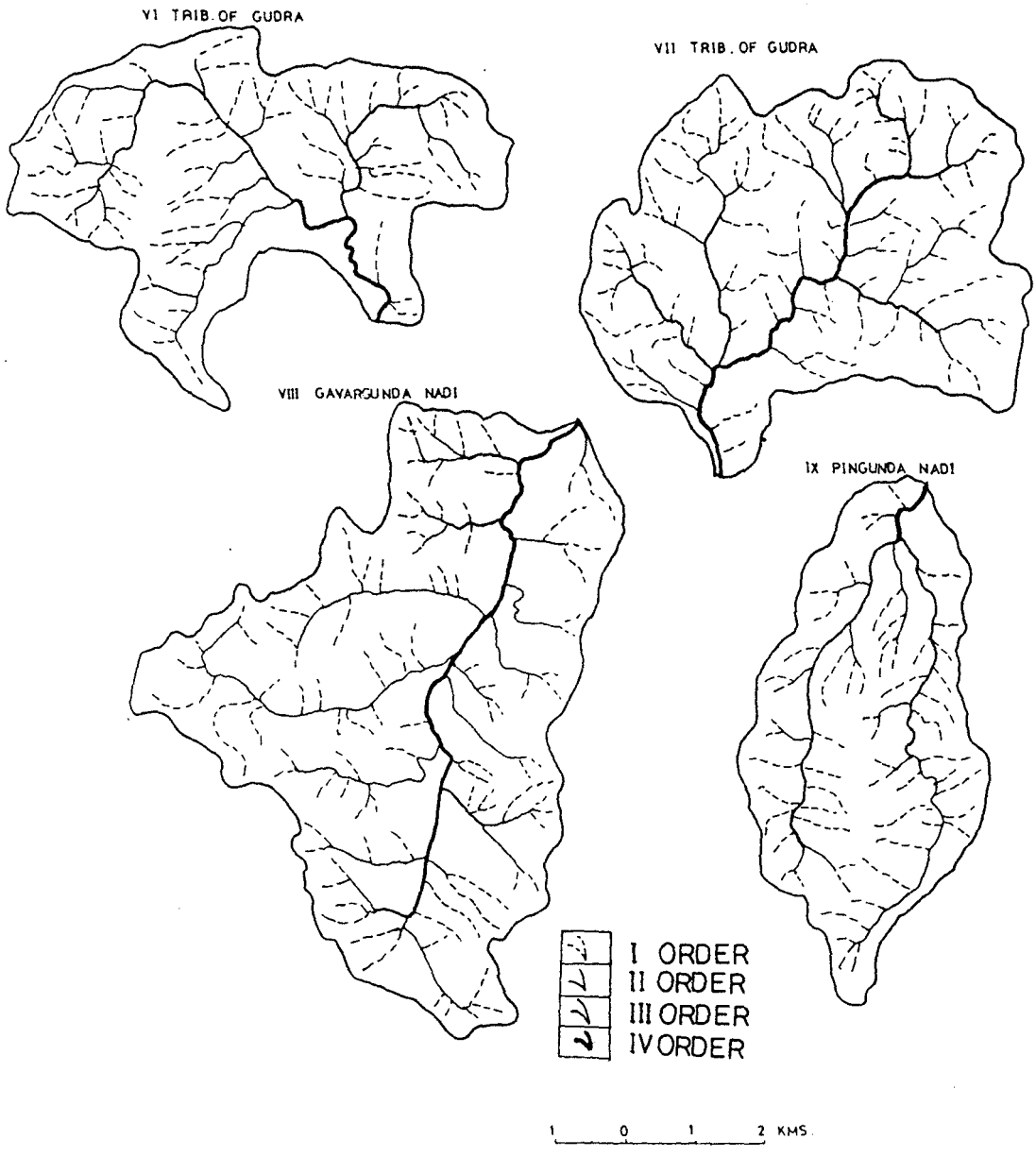


FIG. 3.1

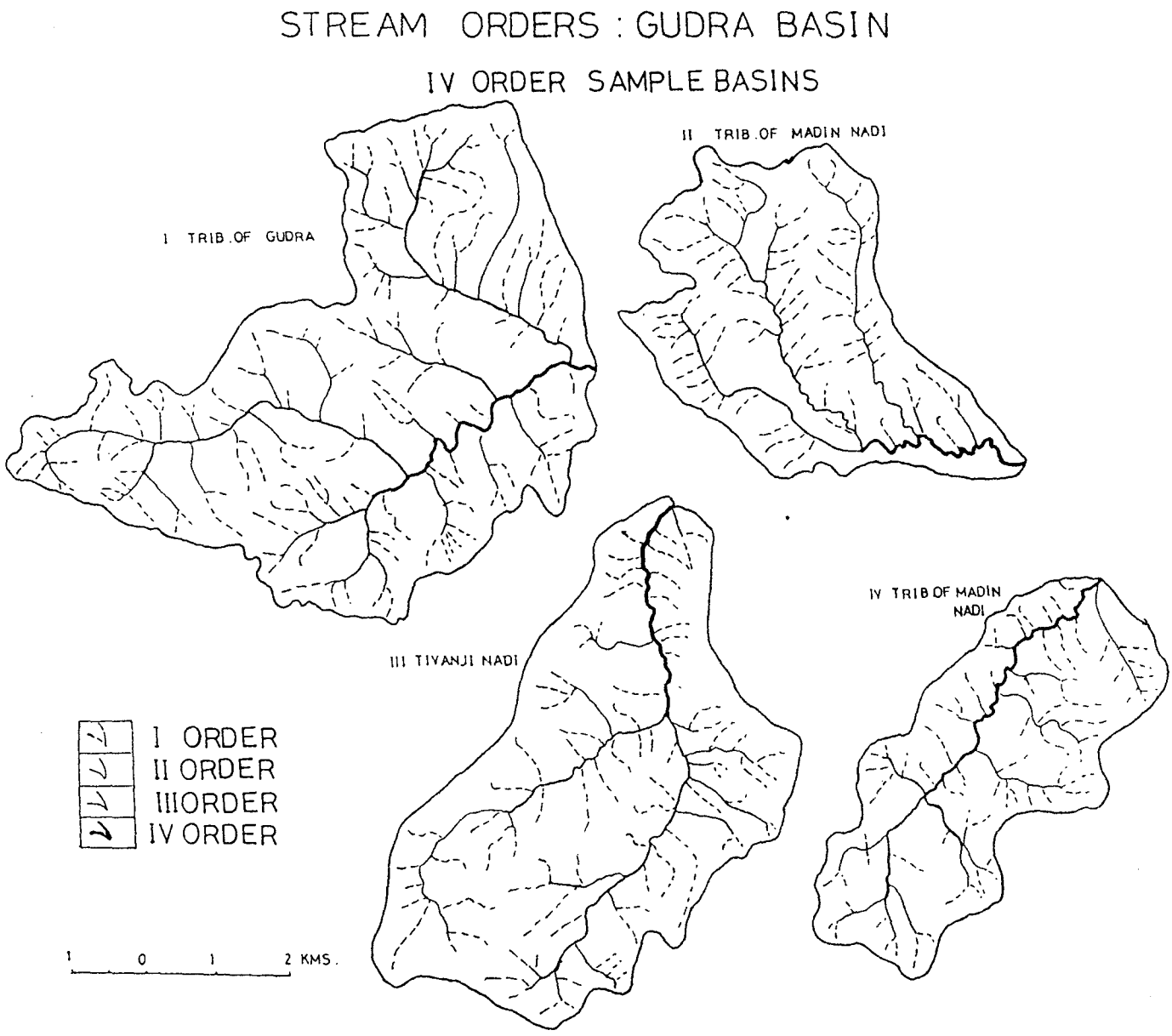

STREAM ORDERS : GUDRA BASIN
IV ORDER SAMPLE BASINS
I TRIB. OF GUDRA
II TRIB. OF MADIN NADI
III TIVANJI NADI
IV TRIB OF MADIN NADI
I ORDER
II ORDER
IIIORDER
IV ORDER
1 0 1 2 KMS.

FIG. 3.1

increases the number of streams of each order decreases. It is calculated as the number of finger - tips in a drainage basin, number of second order in a basin and so on. This has been termed as first law of drainage morphometry and has widely heen tested.

STREAM ORDER AND NUMBER IN GUDRA BASIN :

TABLE 2.1

S.No.	Basin Name	Number of streams of individual orders				Total no. streams
		Nu_1	Nu_2	Nu_3	Nu_4	
I	Tributary of Gudra	190	30	5	1	226
II	Tributary of Madin nadi	64	10	2	1	77
III	Tivanji nadi	85	16	2	1	104
IV	Tributary of Madin nadi	70	14	3	1	88
VI	Tributary of Gudra	64	19	3	1	87
VII	Tributary of Gudra	85	20	4	1	110
VIII	Gavargunda nadi	99	24	6	1	130
IX	Pingunda nadi	59	12	2	1	74

Gudra river is a seventh order stream. Number of streams of first order is higher in gneisses area (Basin I), 190, leading Quartzites (Basin VIII), 99, and Basin III, i.e. Tivanji nadi, 85. The first order streams is comparatively lower in Basin II of Quartzites, 64, Basin IV, 70 and Basin IX Pingunda nadi having gneisses as under - ground lithology.

The calculated mean value of first order streams give higher values in Quartzites i.e.82.67 and gneisses

areas 83.00 than in Biotite granite gneisses regions 74.5. The number of second order is higher in the Basin I under gneissic lithology i.e. 30 than in Basin VIII of Quartzites and Basin VI and VII of Biotite granite gneisseic group i.e. 20 and 19, respectively.

The average stream number is calculated as in Biotite granite gneisses is 19.5 streams and gneisses 18.67, Quartzites as 16.67. In Basin I, VII, and VIII, the third order streams is more 5, 4, and 6, respectively, which is due to the hilly terrain and humid climate.Average value in Quartzites, Gneisses and Biotite granite gneisses is varying from 3.33 and 3.50. The total number of streams is highest in Basin I under Quartzites which is a hilly region and well dissected by streams.

STREAM ORDER AND NUMBER IN BHASKEL BASIN:

TABLE 3.2

S.NO	BASIN NAME	NO. OF STREAMS OF INDIVIDUAL ORDERS Nu_1	Nu_2	Nu_3	Nu_4	TOTAL NO. OF STREAM ORDERS
I	Angi nadi	28	8	2	1	39
II	Baliajori nadi	59	14	5	1	79
III	Tributary of Bhas--kel	133	32	5	1	171
IV	Nangi river	136	37	8	1	182
V	Singari nadi	139	35	11	1	186
VI	Tributary of Bhas--kel	75	17	5	1	98
VII	Agua nadi	32	9	2	1	44
VIII	Tributary of Indravati	37	6	3	1	47

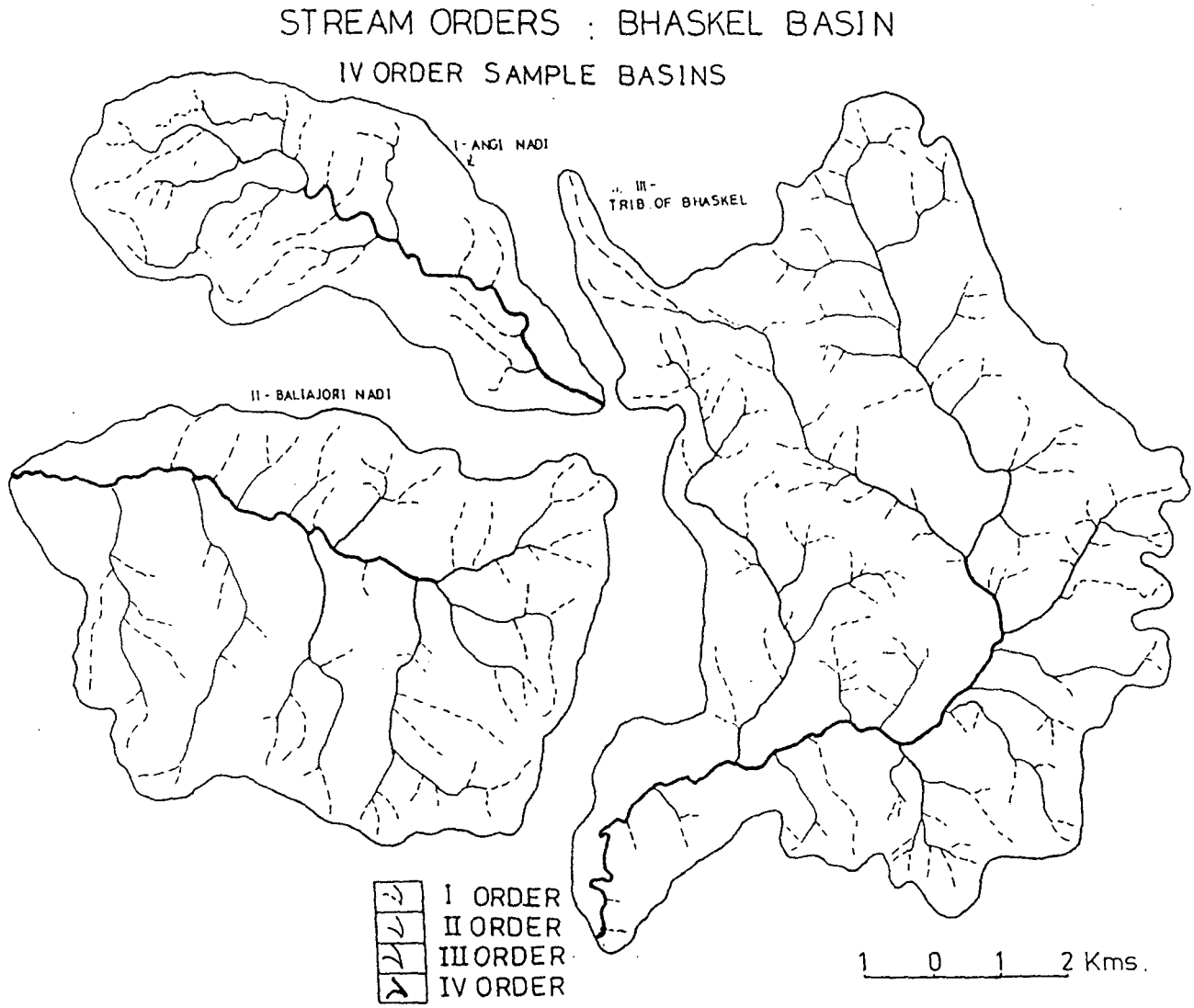

STREAM ORDERS : BHASKEL BASIN
IV ORDER SAMPLE BASINS
I - ANGI NADI
III - TRIB. OF BHASKEL
II - BALIAJORI NADI
I ORDER
II ORDER
III ORDER
IV ORDER
1 0 1 2 Kms.

FIG. 3.2

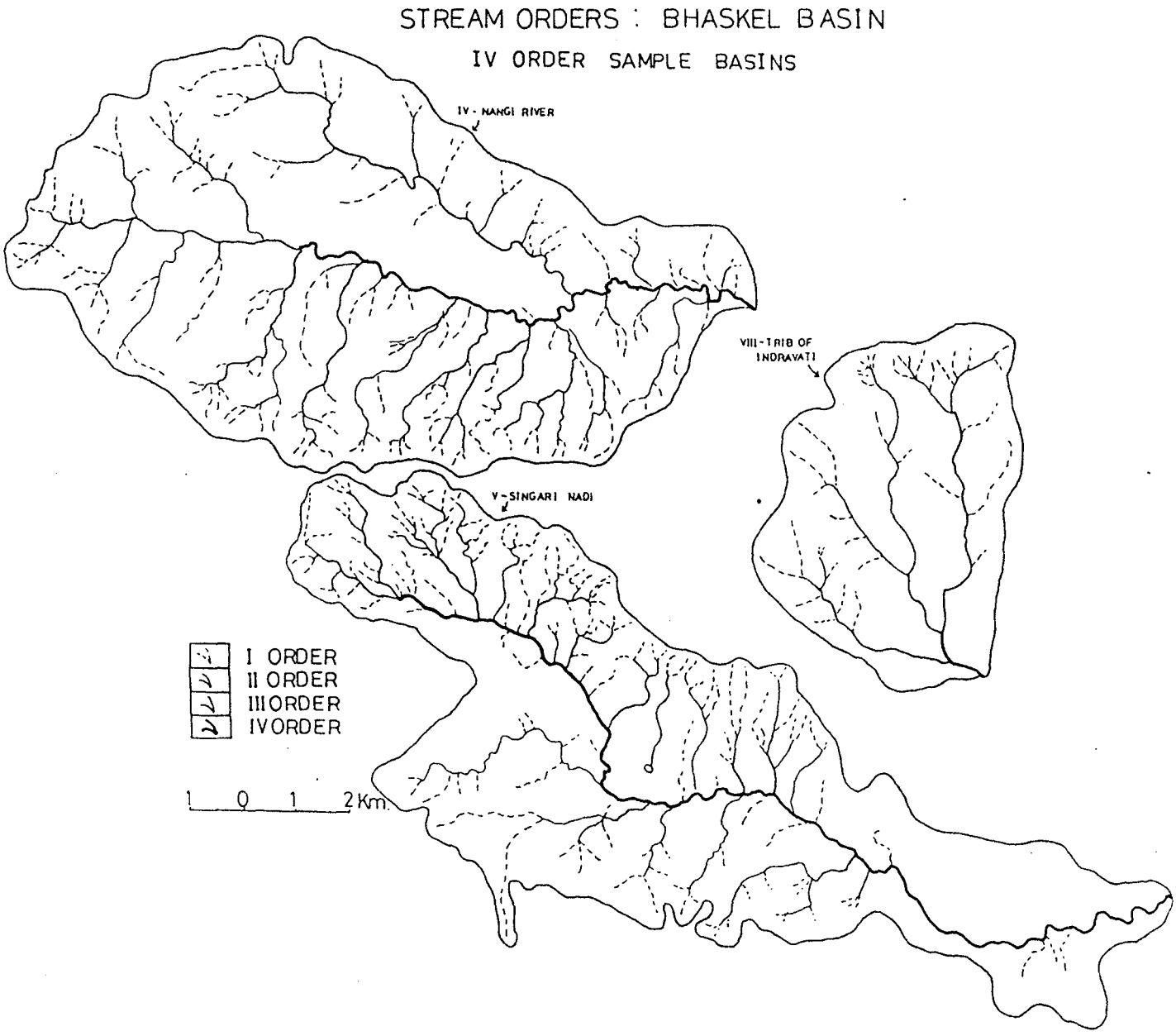

STREAM ORDERS : BHASKEL BASIN
IV ORDER SAMPLE BASINS
IV - NANGI RIVER
VIII - TRIB OF INDRAVATI
V - SINGARI NADI
I ORDER
II ORDER
III ORDER
IV ORDER
1 0 1 2 Km.

FIG. 3.2

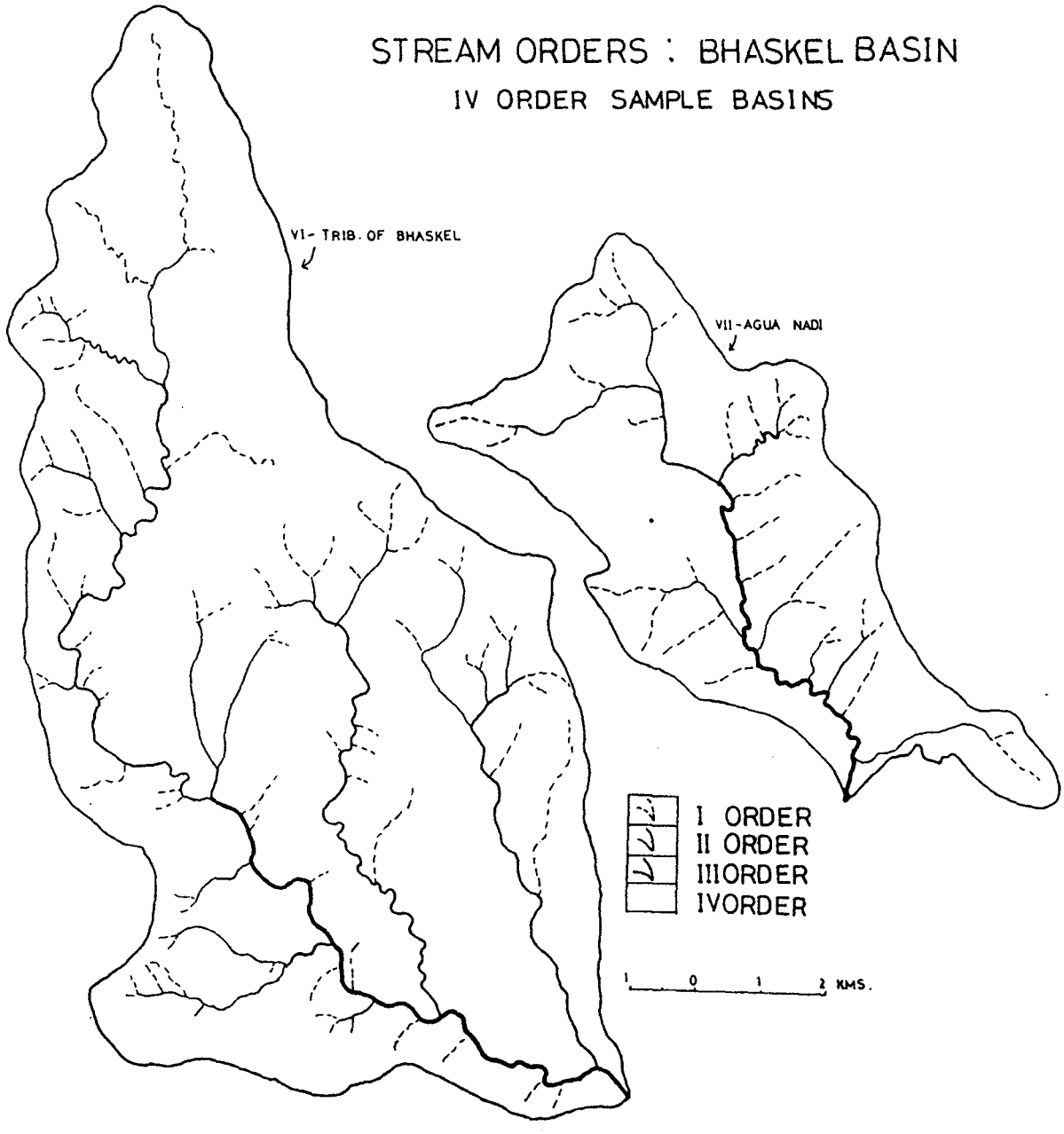

STREAM ORDERS : BHASKEL BASIN
IV ORDER SAMPLE BASINS
VI- TRIB. OF BHASKEL
VII-AGUA NADI
I ORDER
II ORDER
IIIORDER
IVORDER
0 1 2 KMS.

Fig. 3.2

The basin, selected for Bhaskel river comprises of sedimentary and limestone area and Bengpal Gneisses Complex. First order varies from 139 Of Singari nadi which comes under Bengpal gneissic complex to Angi nadi, 28, Of the same geology, where as, Basin III of sedimentary is also giving higher values for first order i.e., 133. The mean average value of first order in Bengpal group is higher i.e. 85.75 than that of sedimentary and limestone group, 76.

Streams order II in Bhaskel is higher in Bengpal group i.e. 37, leading 35 of the geological formation(Basin IV and V,respectively). Less numbers are found in basin I, Angi nadi, Basin VII;Agua nadi, and basin VIII; Tributary of Indravati, giving the values of 8, 9, and 6, respectively. The mean average for Bengpal is 22.25 numbers and for sedimentary is 17.25.

We can see exceptional cases in Bengpal group as the third order basins is concerned. It is having highest value of 11 in Basin V leading 8 in Basin VI. Even basin II, III,and VI is also giving higher values of 5. All these three basins are of sedimentary and limestone region.

3.3 (iii) BIFURCATION RATIO:

Horton considered the bifurcation ratio as an index of relief and dissection.It is designated as Rb. Due to the different lithological formations the value of bifurcation ratio varies. Generally many streams networks evolved out of the region of uniform climate, rock type

and stage of development. Confirm to the principal of exhibiting relatively constant Rb. from one order to next value ranging from 3 to 5 in a natural stream system. Wats (1958)[1] observed that " The minimum possible value of 2.0 is rarely approached under natural conditions because the bifurcation ratio is a dimension less property and because drainage systems in homogenous materials tends to display geometrical similarity it is not surprising that the ratio shows only a small variation from region to region". High bifurcation ratio might be expected in region of steeply, differing rocks strata where narrow strike valleys are confined between hogback ridges.

BIFURCATION RATIO IN GUDRA BASIN :

TABLE 3.3

S.NO.	BIFURCATION RATIO Rb_1	Rb_2	Rb_3	MEAN Rb
I	4.125	4.00	6.00	4.71
II	4 .92	6.00	2.00	4.31
III	5.00	4.67	3.00	4.22
IV	5.31	8.00	2.00	5.10
VI	6.40	5.00	2.00	4.47
VII	6.33	6.00	5.00	5.78
VIII	3.36	6.33	3.00	4.23
IX	4.25	5.00	4.00	4.42

The value of Rb_1 is ranging from 3 - 6.33 having net much variation in the topography. High value of 5.31, 6.40 and 6.33 is in the Basin IV, Basin V and Basin VI of Quartzite Gneisses And Biotite gneissic group, resoectively.

Rb_2 is ranging from 4 - 8 where the highest values of 8 is in IV basin of Quartzites. Basin II, Basin VI, and Basin VII are varying in 6 - 6.33 seems to be in rugged topography of Abujhmar plateau.

Rb_3 is also giving the highest value of 6 in Basin I of the Quartzites. Mean value of Rb. is ranging from 4 - 6 having not much variations in the underlying topography over all.

BIFURCATION RATIO IN BHASKEL BASIN:

TABLE 3.4

S.NO.	BIFURCATION RATIO			MEAN Rb
	Rb_1	Rb_2	Rb_3	
I	3.95	4.75	2.00	3.56
II	4.21	2.80	5.00	4.00
III.	4.16	6.40	5.00	5.19
IV	3.56	4.62	8.00	5.43
V	3.94	3.18	11.00	6.05
VI	4.41	3.50	5.00	4.30
VII	3.56	4.50	2.00	3.35
VIII	6.16	2.00	3.00	3.72

The value ranges from 3 - 6 in Rb_1. Basin VIII (6.16)is having highest value under sedimentary sequence of Indravati river.In Rb_2 the highest value of 6.40 is exhibiting in Basin III of sedimentary areas. It infers that sedimentary group of Bhaskel river is having highest value in Rb_1 and Rb_2. The topography is somewhat homogenous and undulating. Rb_3 values are extreme in the case of Bengpal Gneissic group. It is a hard rock type and highly dissected, having hetero - geneity in the basin. Mean Rb value is ranging 3 - 6 where 6.05 is in the Basin Vcalled Singari Nadi.

3.3(iv) STREAM LENGTH:

Length of a stream channel segment is a dimensional property. The length of first order segments increases because the number of segments of finger tips is always higher than the number of segments of increasing orders. It is the second law of Horton(1945;p.291) as " The average length of streams of each order in a drainage basin tend closely to approximate a direct geometric series in which the first term is average length of streams of first orders."

STREAM LENGTH IN GUDRA BASIN:

TABLE 3.5

S.NO.	STREAMS LENGTH OF INDIVIDUAL ORDERS IN KMS.				TOTAL STREAM LENGTH
	Lu_1	Lu_2	Lu_3	Lu_4	
I	59.00	24.00	12.00	5.00	100.00
II	31.00	12.25	8.00	2.25	54.00

(contd.)

(contd.)

III	47.00	38.00	8.75	4.50	72.25
IV	30.00	10.25	3.35	5.00	48.55
VI	37.50	11.25	9.50	7.50	61.50
VII	48.20	16.00	10.00	6.50	80.50
VIII	44.25	20.00	4.25	8.00	76.50
IX	30.00	8.50	9.50	1.15	49.15

The total length of all order is highest in basin Iof Gneisses area (100 kms.), others are 72.75kms. in basin III, 80.50 kms. in basin VIIunder Biotite granite group. The lowest value is in Basin IV under gneisses group i.e., 48.55 kms.

The higher value of 59.00 kms. in Basin V of gneisses region shows that there are more finger tips in this area. It is true , having 190 initial tributaries, is the highest. This area is a high land which develop finger tips.

Average length of streams is higher in Quartzites, 19.35 kms. and,comparatively,lower in gneisses area, 16.48 kms.

STREAM LENGTH IN BHASKEL BASIN :

TABLE 3.6

1 S.NO.	2 LENGTH OF INDIVIDUAL STREAM ORDERS IN KMS.				3 TOTAL STREAM ORDERS
	LU_1	LU2	LU_3	LU_4	
I	21.62	10.50	1.50	4.88	38.50

(contd.)

(contd.)

1	2				3
II	34.85	21.65	15.25	11.25	83.00
III	58.75	34.65	17.25	13.35	117.25
IV	69.50	36.75	17.30	21.50	145.00
V	59.75	33.50	27.52	10.75	112.30
VI	41.00	20.50	22.62	10.35	94.00
VII	22.50	9.75	4.50	6.75	43.00
VIII	18.75	9.50	8.00	2.38	37.00

The total length of all order is highest in Basin IV of Bengpal granite gneisses area, 145 kms. others are basin V, 123 kms.;Basin III, of sedimentary,117.5 kms. The lowest length is of the basin VIII in sedimentary sequence of Indravati basin,i.e.,37.00 kms.

Average length of stream is almost same in sedimentaries as well as, Bengpal region.

3.4 AREAL ASPECTS OF DRAINAGE BASIN :

The shape and area of the drainage basin is considered as an areal characteristics of a basin. In this study, area of the basin, elongation ratio, circularity ratio, drainage density, drainage texture, constant of channel maintainence and stream frequency has been taken into consideration. The systematic interpretation is as follows :

3.4 (i) BASIN AREA :

Drainage basin area is an independent variable. It is most sensitive and controls texture, shape

and direction of the basin. Drainage basin area is defined as the total area projected upon a horizontal plane, contributing flow to channel segment of a given order and including all tributaries of lower order. Horton inferred that " mean drainage basin areas of progressively higher orders should increase in a geometric sequence as do stream length ". Schumm (p. 606)[1] expressed this relationship in a law of stream areas as " the mean basin area of stream of each order tend closely to approximate a direct geometric sequence in which the first term is the mean area of the first order basin."

AREA OF GUDRA RIVER BASIN :

TABLE 3.7

S.NO.	TOTAL AREA IN KM^2.
BASIN I	53.84
BASIN II	19.63
BASIN III	43.29
BASIN IV	29.59
BASIN VI	33.78
BASIN VII	44.81
BASIN VIII	47.20
BASIN IX	22.40

The large area is covered by basin I of Quartzites, leading basin VIII and basin VII

Quartzites and Biotite granite group. In all Quartzites are covering average area of 36.71 sq. kms. and Biotite granite is covering 39.29 sq. kms. The lowest area is covered by Gneissic group i.e. 22.87 sq. kms.

AREA OF BHASKEL RIVER BASIN :

TABLE 3.8

S.NO.	TOTAL AREA IN SQ. KMS.
BASIN I	20.75
BASIN II	62.25
BASIN III	65.81
BASIN IV	73.65
BASIN V	81.18
BASIN VI	95.25
BASIN VII	33.75
BASIN VIII	27.00

The higher value of sedimentary region is 95.25 sq. kms. leading Bengpal group as 81.18 sq. kms. of the basin V and 73.65 sq. kms. of basin IV. The lowest area is covered by Bengpal gneissic complex i.e. Basin I. The average area is higher in recent alluvial sedimentary region of Bhaskel than in Bengpal geisses of metamorphic type(52.33sq. kms.).

3.4 (ii) BASIN SHAPE :

The shape is also considered as an out line

form of a drainage basin and is projected upon the horizontal datum plane of a map. It is a dimension less property and controlled by stream discharge characteristics and under lying lithology. Horton described " the out line of normal drainage basin as pear - shaped ovoid " as a proof thatdrainage basins are foremed largely by sheet erosion process acting uponan initially inclined plane, or / and surface. These dimensionless properties can be termed as shape parameters. In the presemt study two shape parameters - elongation and circularity ratio- have been taken to assess the shape of Gudra and Bhaskel. El ngation ratio is defined as " The ratio of a diameter of a circle of the same area as the basin to the maximum basin length " and designated as Re'.Circularity ratio designated as Rc, can be defined as " the ratio of the basin area divided by area of a circle with two same basin perimeters."

Value of unity shows thatbasin is perfectly circular/ elongated and any change indicates distortion of basin shape.

BASIN SHAPE OF GUDRA RIVER :

TABLE 3.9

S.NO.	ELONGATION RATIO	CIRCULARITY RATIO
BASIN I	0.92	0 .70

(contd.)

(contd.)

BASIN II	0.75	0.59
BASIN III	0.90	0.94
BASIN IV	0.78	1.00
BASIN VI	0.97	0.65
BASIN VII	1.08	0.90
BASIN VIII	0.69	0.95
BASIN IX	0.73	0.97

Basin elongation and circularity ratio ranges from 0 - 1. Here Basin Vii of Biotite granite group shows a basin to be perfect elongated.The higher values of elongation ratio is shown in Gneisses, Basin I (0.92) Quartzites, basin II (0.90), Basin VI,Biotite granite (0.97).

Higher values of circularitycan be seen in the Basin IV of gneisses, where it is giving perfect circular shape, but, elongation ratio is also higher which distorts the cicularity of the basin. Basin III, of Quartzites, Basin VII of Biotitegranite, basin VIII of Quartzites and basin IX of gneisses are also giving high value in Rc as well as, in Re. The Rc of these above basins are 0.94, 0.90, 0.95, and 0.97, respectively.

The mean value in Quartzites is showing 0.78 (Re), and 0.83(Rc); in gneisses 0.81(Re), 0.89(Rc) and in biotite gneisses as 1.02(Re), and 0.78(Re).It can't be derived perfectly whether the basins are of circular

shape or elongated. May be it is distorted by the nature of undulating topography in this region.

BASIN SHAPE IN BHASKEL RIVER :

TABLE 3.10

S.NO.	ELONGATION RATIO	CIRCULARITY RATIO
BASIN I	0.53	0.62
BASIN II	0.85	0.93
BASIN III	0.65	0.39
BASIN IV	0.66	0.68
BASIN V	0.50	0.36
BASIN VI	0.52	0.66
BASINVII	0.62	0.56
BASIN VIII	0.78	0.77

The higher value of elongation ratio is shown in basin II of limestone region (0.85), and basin VIII of sedimentary region of Indravati(0.78). The lower values of 0.50, basin V of bengpal gneisses region; and 0.53, Basin I, of same geology can be seen, showing somewhat elongated shape. No sample basin is having high value of elongation.

The higher value of circularity ratio can be seen in the limestone region (0.93) of basinII and the lower value can be seen in Bengpal group- Basin V (0.36)

The average value of elongation and circularity

in Bengpal gneisses complex is 0.58 and 0.56; sedimentary and limestone region is 0.70 and 0.69, respectively.

3.4 (iii) DRAINAGE DENSITY :

Introduced by Horton as "The ratio of total channek segments lengths cumulated for all orders with in a basin to the basin area (projected to the horizontal).It is the length per square unit area. It is highly influenced by the structure of rocks, distribution of rainfall and density of vegetation over.

3.4 (iv) CONSTANT OF CHANNEL MAINTAINENCE:

Schumm used the inverse of Drainage density as a property termed as constant of channel maintainence This constant, in units of square/kilometers, has the dimension of length.

GUDRA RIVER BASIN :

TABLE 3.11

S.NO.	DRAINAGE DENSITY PER SQ. KM.		CONSTANT OF CHANNEL MAINTAINENCE
BASIN I	1.86	Moderate	0.54
BASIN II	2.75	High	0.36
BASIN III	1.68	Moderate	0.59
BASIN IV	1.82	Moderate	0.55
BASIN VI	1.82	Moderate	0.55
BASIN VII	1.80	Moderate	0.56
BASIN VIII	1.62	Moderate	0.62
BASIN IX	2.17	High	0.46

Drainage density is ranging from 1.62 - 2.75 km./km.^{2} This means that the lower value shows in Basins VIII of quartzites which having 1.62 km ./kms^2 of channel maintainence and higher value is in Basin II having same geology 2.75 kms. of channek for every sq. kms.The average drainage density in quartzites are 2.02 km./kms^2., gneisses is having 1.96 km. /kms^2. and Biotite granite as 1.81 km. /kms^2.

Constant of channel maintainence shows higher values in Basin VIII of quartzites is 0.62. This means that 0.62 sq. kms. of surface is needed to support one km. of channel. The lower value is of Basin II in quartzites is 0.36 km./kms^2,

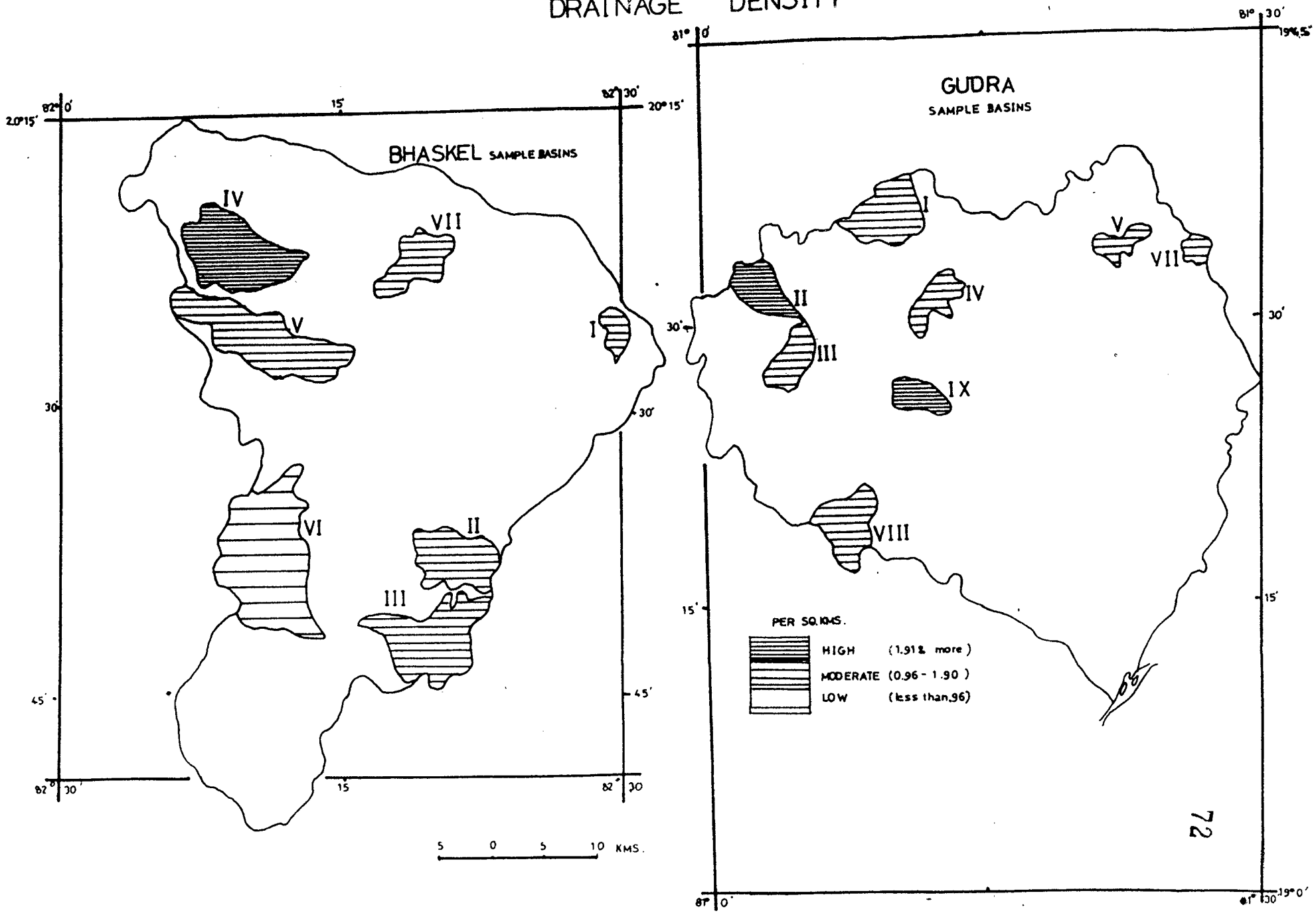
The average value in quartzites is 0.52 km^2/km, in gneisses 0.52 km^2/km. and Biotite granite gneisses area is 0.55km^2/km.

BHASKEL RIVER BASIN :

TABLE 3.12

S.NO.	DRAINAGE DENSITY KM. PER SQ. KM.		CONSTANT OF CHANNEL MAINTAINENCE SQ.KM./KM.
BASIN I	1.86	Moderate	0.54
BASIN II	1.14	Moderate	0.88
BASIN III	1.89	Moderate	0.53
BASIN IV	1.97	High	o.51
BASIN V	1.52	Moderate	0.66
BASIN VI	0.92	Low	1.01
BASIN VII	1.27	Moderate	0.79
Basin VIII	1.39	Moderate	0.72

DRAINAGE DENSITY



In Bhaskel river basin (sample) drainage density varies from 0.92 - 1.97 km./ km^2 from Basin VI of sedimentaryarea to Basin IV of Bengpal group. This means that in sedimentary part 0.92 km. of channel is needed for a unit area of 1 sq. km. to 1.97 km./ km^2 in metamophic.

The average drainage density in sedimentary is 1.35 km/sq. km. and in Bengpal gneisses group is 1.66 km/sq.km. Higher value of constant of channel maintainence can be seen in sedimentary region of basin VI having 1.01 sq. km./ km. TH The lower value is of Basin IV in Bengpal group i.e., 0.51 sq. km. / km.

Average value in sedimentary sequence is 0.79 sq. km./km. and in Bengpal gneissic complex is 0.62 sq.km./km. The drainage density is the basin ranges from 0.92 - 2.75 The total range of drainage density has been divided into 3 categories with an interval of 0.95 sq.km./km.

3.4(v) DRAINAGE DENSITY :

Texture ratio of a drainage basin gives an idea about the individual element of the underlying topography in a basin. As drainage density increases, texture ratio also increasesfrom coarse to ultrafine.

TEXTURE RATIO IN GUDRA BASIN :

TABLE 3.13

SNO.	TEXTURE RATIO	
BASIN I	7.29	Fine

TEXTURE RATIO IN SAMPLE BASINS

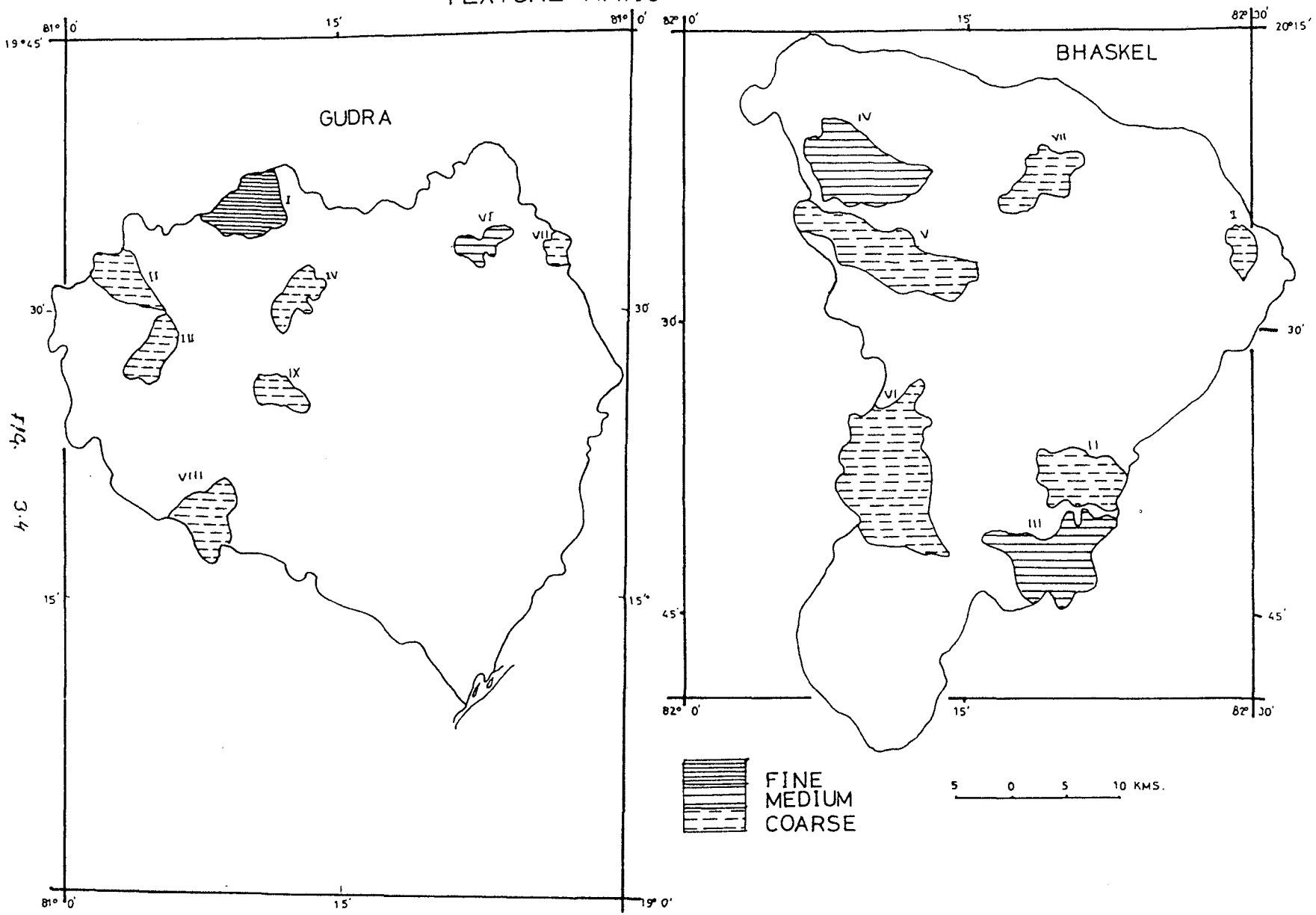


Fig. 3.4

(contd.)

BASIN II	3.76	Medium
BASIN III	4.33	Medium
BASIN IV	4.82	Medium
BASIN V I	3.41	Coarse
BASIN VII	4.40	Medium
BASIN VIII	5.20	Medium
BASIN IX	4.35	Medium

Texture ratio in gneisses of basin first is higher than other basins. Here, texture is comparatively finer in contrast to the Biotite granite gneisses area, it is having lower value of ratio i.e. 3.41 which gives coarser texture to the basin. These all regions comes under metamorphic rocks. The average texture is 5.49 in quartzites, 4.43 in gneisses and 4.80 Biotite group.

TEXTURE RATIO IN BHASKEL :

TABLE 3. 14

S.NO.	TEXTURE RATIO	
BASIN I	1.90	Coarse
BASIN II	2.72	Coarse
BASIN III	3.76	Medium
BASIN I V	4.95	Medium
BASIN V	3.48	Coarse
BASIN VI	2.30	Coarse
BASIN VII	0.93	Coarse
BASIN VII	2.24	Coarse

From the above table we can find that comparatively higher ratio is in basin IV of Bengpal granite i.e. 4.95 can be termed texture. The lowest value of Bengpal granite is 0.93 basin VII having same texture. In the same geology we can see the variations.

Average texture ratio is 2.76 in sedimentary and 2.82 in Bengpal gneissic complex. On an average this area is having coarser texture.

3.4 (vi) STREAM FREQUENCY :

Horton 1945, (p. 285) introduced stream frequency or channel frequency as the number of streams segments per unit area.

STREAM FREQUENCY : GUDRA BASIN :

TABLE 3.25

S. NO.	STREAM FREQUENCY No./Km^2
BASIN I	4.21
BASIN II	3.92
BASIN III	2.40
BASIN IV	3.31
BASIN V	2.57
BASIN VI	2.45
BASIN VII	2.75
BASIN VIII	3.30

The highest stream frequency is shown in Basin I, and basin II, i.e., 4.20/sq.km. and 3.92/sq.km. both of gneisses and quartzites areas, respectively. In other words we can say that 4.20 streams are draining these two basins per square kilometer. The lowest is in basin III of quartzites having 2.40 / sq, km.Mean stream frequency are 3.02 / sq. km. in quartzites, 3.06 / sq. km. in gneisses and 2.5 / sq. km. in biotite granite gneisses regions.

STREAM FREQUENCY IN BHASKEL BASIN :

TABLE 3.16

S.NO.	STREAM FREQUENCY NO./SQ.KM.
BASIN I	1.88
BASIN II	1.27
BASIN III	2.59
BASIN IV	2.47
BASIN V	2.29
BASIN VI	1.03
BASIN VII	1.02
BASIN VIII	1.25

The highest value is showing in basin III of recent alluvial and Basin IV, V in Bengpal gneissic complex having 2.59/sq. km., 2.47/sq. km. and 2.29/km.^{2} frequency, respectively. The lowest is exhibiting in

Bengpal Gneissic complex having the value of 1.0 /km^2 (BASIN VIII).Average stream frequency in bengpal group is 1.99/sq. km. and in Indravati sedimentary sequence is 1.54/sq.km.

3.5 RELIEF ASPECTS :

Relief is a continuous function of processes working under different climatic conditions over different lithologies. Several agents are continuously shaping the relief characteristics of a region such as geology, stratigraphy, climatic weatheribg, mass wastbng, runoff, etc. From the study we will see the climate is same is same in Gudra and Bhaskel but different relief features are developed, this gives the reflection of the underlying rock. Different rock types plays an important role in the development of land forms.

Different aspects of relief for Gudra and Bhaskel is studied under sub-heads as follows :

3.5 (i) ABSOLUTE RELIEF :

Absolute relief is the maximum height taken, base , as a mean sea level. Absolute relief is more stable in nature as it changes with time. It determines the climate and natural vegetation. The absolute relief may be defined as "the vertical elevation of a point or surface above the datum plane." Here, spot

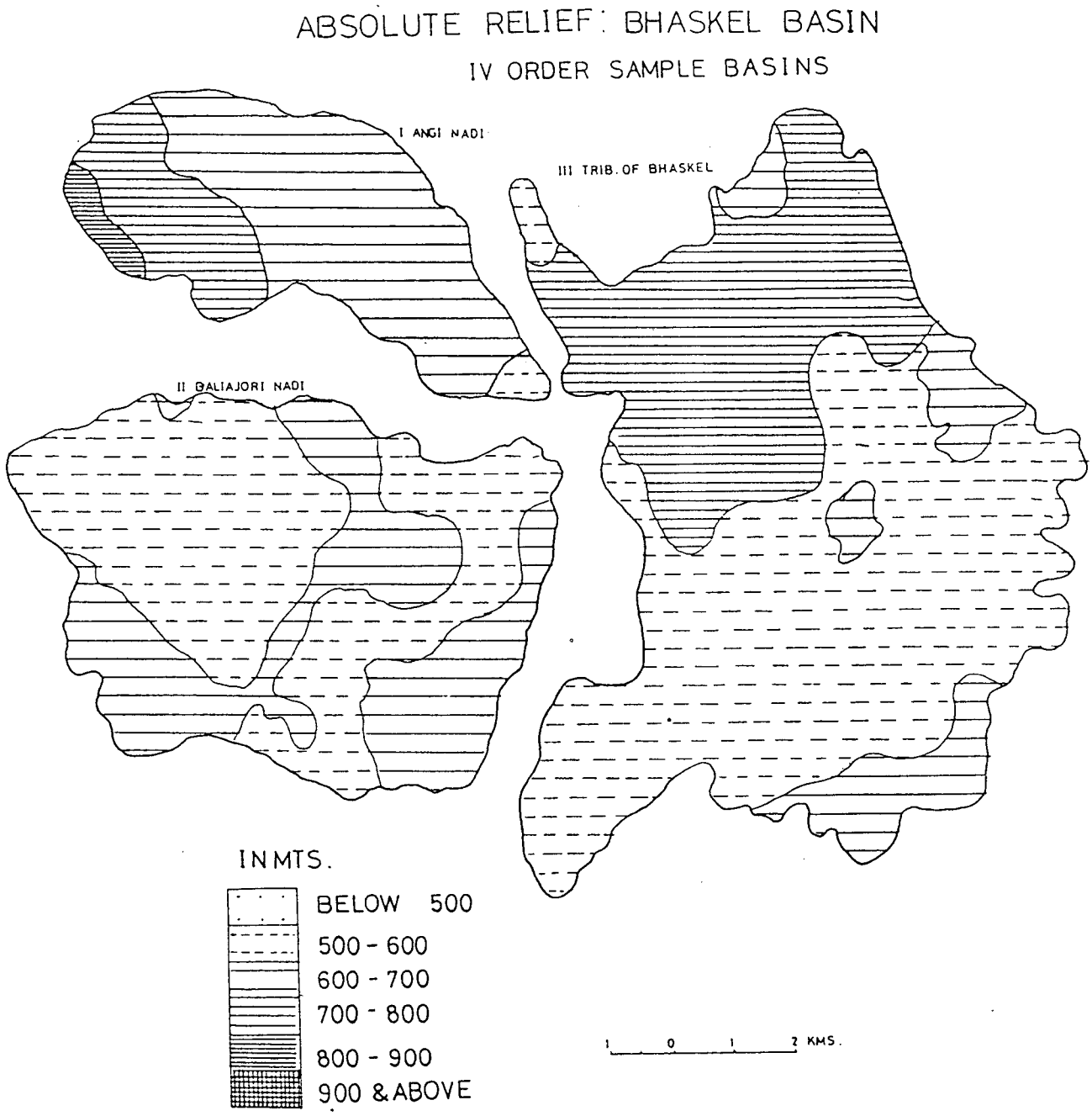

ABSOLUTE RELIEF: BHASKEL BASIN
IV ORDER SAMPLE BASINS
I ANGI NADI
II BALIAJORI NADI
III TRIB. OF BHASKEL
IN MTS.
BELOW 500
500 - 600
600 - 700
700 - 800
800 - 900
900 & ABOVE
1 0 1 2 KMS.

FIG. 3-4

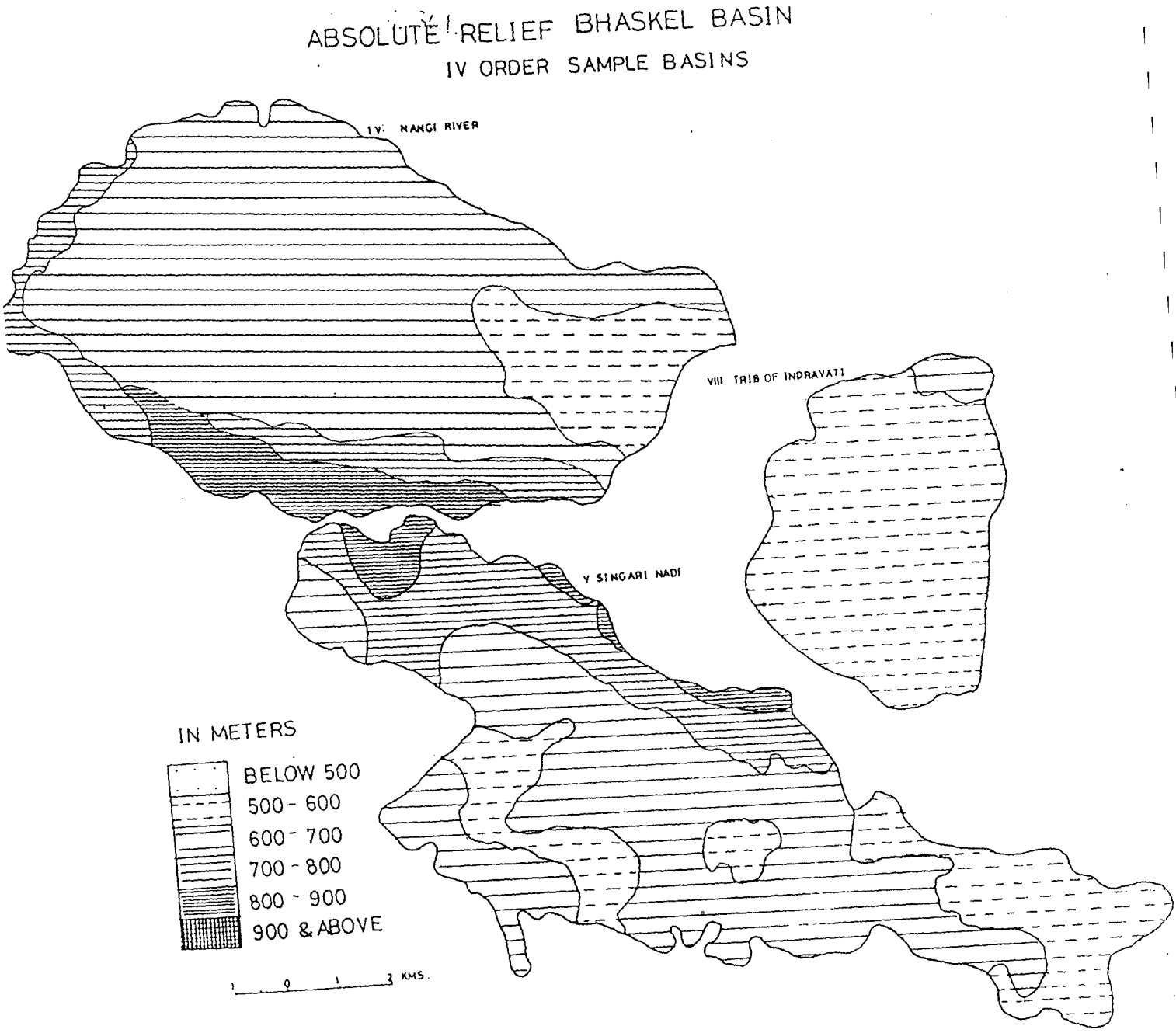

ABSOLUTE RELIEF BHASKEL BASIN
IV ORDER SAMPLE BASINS
IV NANGI RIVER
VIII TRIB OF INDRAVATI
V SINGARI NADI
IN METERS
BELOW 500
500 - 600
600 - 700
700 - 800
800 - 900
900 & ABOVE
0 1 3 KMS.

FIG. 3.4

ABSOLUTE RELIEF : BHASKEL

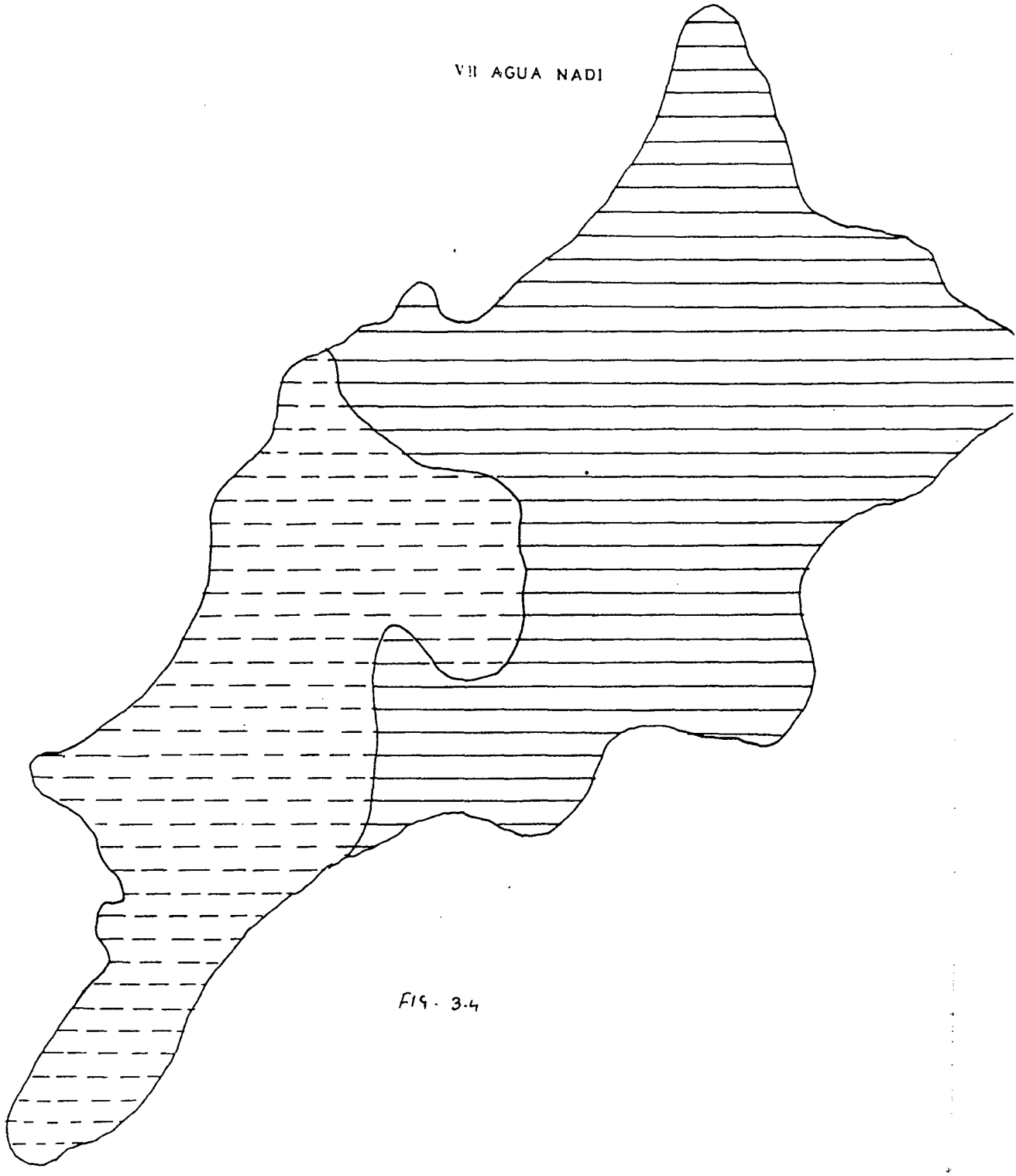


FIG. 3.4

ABSOLUTE RELIEF: GUDRA

IV ORDER SAMPLE BASINS

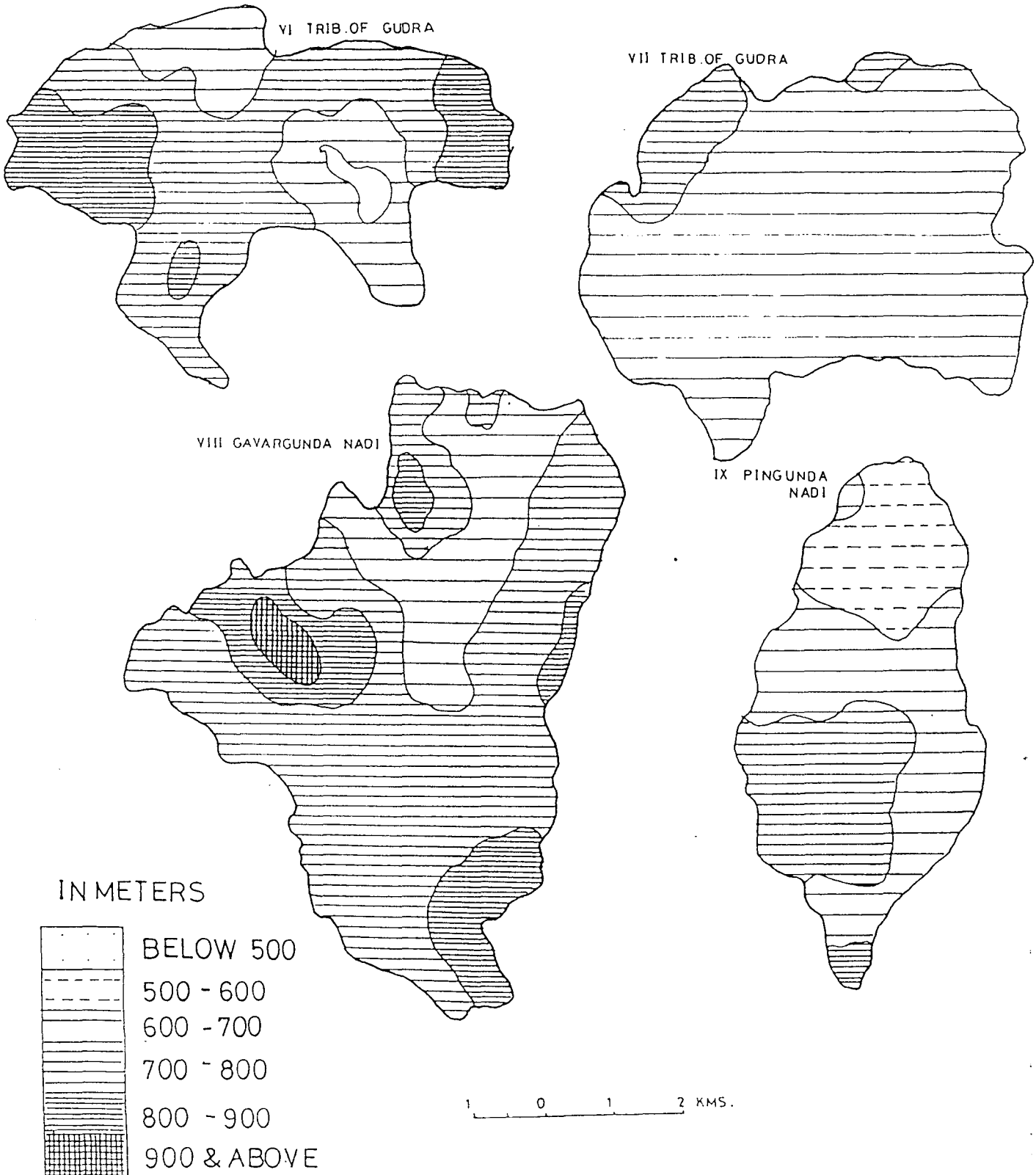


FIG. 3.5

height has been taken into consideration as an absolute relief, but, where spot height is not available it has been measured by contours.

3.5 (ii) RELATIVE RELIEF :

Relative relief is a basic morphometric property. It is defined as the difference of elevation between the highest and the lowest points of any region. It gives an idea of gradient of a terrain. In the present study relative relief is measured on an average by calculating maximum and minimum absolute values.

RELIEF : GUDRA BASIN :

TABLE 3. 17

S.NO.	ABSOLUTE RELIEF IN MTS.	RELATIVE RELIEF IN MTS.
BASIN I	840	180
BASIN II	853	193
BASIN III	897	257
BASIN IV	787	207
BASIN VI	837	257
BASIN VII	715	175
BASIN VIII	882	282
BASIN IX	848	328

Absolute relief is highest in Basin III , which is under quartzites. This quartzites area is situated in the North-Western part of the basin and is higher than other regionin the Gudra Basin*. The lowest value is found in basin VII of Biotite granite gneisses which lies in the North - Western part of the Gudra basin.

Absolute relief varies from 553 mts. in biotite group to 1007 mts. in quartzites. Relative relief is higher in basin VIII of quartzites and basin IX of gneisses i.e., 282 mts. and 328 mts. respectively. The lowest value is found in the basin ofbiotite group,VII 175 mts. Average height is 832.38 mts. and mean relative height is 234.88 mts

RELIEF : BHASKEL BASIN

TABLE 3.18

S.NO.	ABSOLUTE RELIEF IN MTS.	RELATIVE RELIEF IN MTS.
BASIN I	825	225
BASIN II	654	94
BASIN III	654	93
BASIN IV	927	327
BASIN V	920	320
BASIN VI	684	122
BASIN VII	660	80
BASIN VIII	614	74

*In the selected basins of Gudra.

The absolute relief is higher in Basin IV of Bengpal gneissic complex i.e.,927 mts. leading under same geology in basin V i.e., 920 mts.The lower relief is found in basin VIII, a tributary of Indravati and totally comes under sedimentary sequences accumulated by the river.

Relative relief also ranges from 74 mts. to 327 mts., in basins VIII and IV respectively, of Bengpal group. Average absolute relief for the basin is 745.25 meters and mean relative relief is 166.88 meters.

3.6 (iii) RUGGEDNESS NUMBER :

Ruggedness number is a function of drainage density and relative relief of the area. It is a unit less measurement which gives the degree of roughness of underlying rocks. It is the ratio of the product of drainage density and relative rekief and divided by the constant.

RUGGEDNESS NUMBER OF GUDRA BASIN :

TABLE 3. 19

S.NO.	RUGGEDNESS NUMBER	
BASIN I	0.33	Low
BASIN II	0.53	Medium
BASIN III	0.43	Low
BASIN I V	0.37	Low

(CONTD.)

(CONTD.)

BASIN VI	0.47	Medium
BASIN VII	0.32	Low
BASIN VIII	0.47	Medium
BASIN IX	0.72	High

Ruggedness number is ranging from 0.32 - 0.72 Basin I, III, IV and VII are having lower values and hence ruggedness number is comparatively low. It is ranging from 0.52 - 0. 43. Basin II of quartzites, VI of Biotite granite gneisses and VIII of quartzites are having medium ruggedness number ranging from 0.46 - 0.53 Basin IX of gneisses is having comparatively higher value of 0.72. Average ruggedness number in quartzites is high 0.47 and also in gneisses 0.47, and lower in Biotite granite gneisses, 0.39.

RUGGEDNESS NUMBER IN BHASKEL :

TABLE 3. 20

S.NO.	RUGGEDNESS NUMBER	
BASIN I	0.42	Low
BASIN II	0.11	Low
BASIN III	0.18	Low
BASIN IV	0.64	High
BASIN V	0.49	Medium

(CONTD.)

(CONTD.)

BASIN VI	0.12	Low
BASIN VII	0.10	Low
BASIN VIII	0. 10	Low

Ruggedness number is varying from 0.10 - 0.64 Basin I, II ,III, VI, VII, and VIII are showing lower values having low ruggedness number. Basin V is having medium ruggedity and Basin IV is having high ruggedity. On an average sedimentary and limestone areas are showing low ruggedity 0.13 than in Bengpal gneissic complex, 0.41.

3.5 (iv) DISSECTION INDEX :

It is another morphometric parameter to illustrate the relief properties of the region. It is the measurement of dissected topography in mathematical terms.

DISSECTION INDEX IN GUDRA :

TABLE 3.21

S.NO.	DISSECTION INDEX	
BASIN I	0.21	LOW
BASIN II	0.23	MEDIUM
BASIN III	0.28	HIGH
BASIN IV	0.26	MEDIUM

(CONTD.)

(CONTD.)

BASIN VI	0.31	HIGH
BASIN VII	0.21	MEDIUM
BASIN VIII	0.32	HIGH
BASIN IX	0.39	HIGH

Basin IIIof quartzites , Basin VI of biotite granite gneisses, Basin VIII of quartzites are comparatively highly dissected than other basins.Basin I of gneisses is having low dissected underlying topography. In an average quartzites and biotite granite gneisses group are highly dissected, values ranges from 0.276 - 0.28.

DISSECTION INDEX IN BHASKEL :

TABLE 3.22

S.NO.	DISSECTION INDEX	
BASIN I	0.29	MEDIUM
BASIN II	0.14	LOW
BASIN III	0.14	LOW
BASIN IV	0.35	HIGH
BASIN V	0.34	HIGH
BASIN VI	0.18	LOW
BASIN VII	0.121	LOW
BASIN VIII	0.120	LOW

DIssection Index value is varying from 0.12 - 0.35 basin VIII is having lowest value and Basin IV of Bengpal group is having the highest values. Both basins, IV and V are highly dissected than Basin I which is medium, others are low dissected. Mean value of dissection index is high in Bengpal gneissic complex 0.27 and low in sedimentary and limestone areas.

C H A P T E R IV

A COMPARATIVELY ANALYSIS OF THE MORPHOMETRIC VARIABLES IN GUDRA AND BHASKEL RIVER BASINS.

C H A P T E R IV

A COMPARATIVE ANALYSIS OF THE MORPHOMETRIC VARIABLES IN GUDRA AND BHASKEL RIVER BASINS.

For the study of the behaviour of morphometric parameters in hard rock and soft rocks; Gudra and Bhaskel have been selected due to different lithological conditions.

In Gudra, basin II,III and VIII are from quartzites and IX are from gneisses area has been selected for the study purpose. These come under metamorphic rocks and in Bhaskel Basin II, VI, III, and VIII are taken for study. First basin comes under limestone region and rest comes under recent alluvial deposits of Indravati and Bhaskel- soft rocks. The comparison is done for both the basin :

4.1. DRAINAGE PATTERN :

The pattern which stream forms are determined by inequalities of surface slope and inequalities of rock resistence. Firstly, pattern produced by the stream is dependent on the slope of the initial surface. At a glance, we can vaquely determine the under lying lithology of the basin, by the help of its pattern.

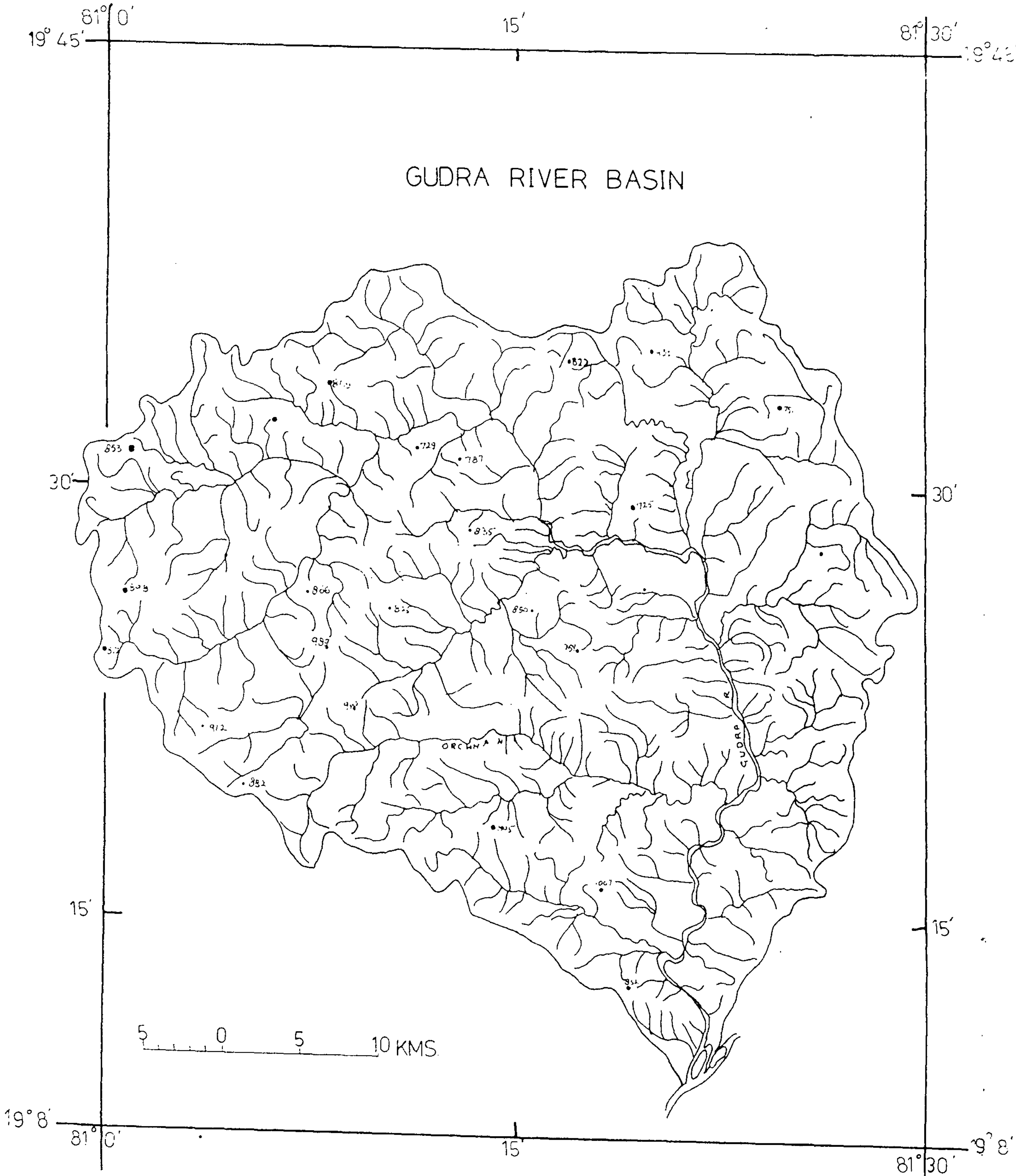

GUDRA RIVER BASIN
81° 0'
19° 45'
15'
81° 30'
30'
19° 8'
5 0 5 10 KMS
ORCHHA N
GUDRA R
853
729
787
822
835
725
809
806
850
912
882
1007

FIG 4.1

1.1- DRAINAGE PATTERN IN GUDRA BASIN :

Gudra is showing dendritic as well as sub - parallel pa ttern in its basin. " Dendritic pattern is characterised by irregular branching in all directions with the tributaries joining the main stream at all angles. The streams are insequent in origin ".* Gudra basin shows this type of pattern in its southern part in the tributaries of Orchha river, which joins from West. Here, true dendritic pattern is not developed may be because of zones of weakness and is determined by valley growth by subsequent streams. Some of the tributaries are by chance parallel in its source mainnly, Orchha. Rocks are offering uniform pattern of Abujhmar volcanic sequence. This area is a flat lying beds of plateaus and crystalline rocks. The north eastern part of Gudra i.e. gneisses has under gone intense metamorphism and hence developed dendritic pattern. The appropriate dendritic pattern can be seen as " Pinnate " type. The more or less parallel and rythmical arrangement of the small tributaries is found here due to the uniformity of slopes on the sides of Gudra valleys and it is having almost homogenous type of resistence of rocks i.e. metamorphics.

1.2- DRAINAGE PATTERN IN BHASKEL :

The drainage pattern which can be seen by the map is of sub - parallel type. Radial pattern

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* Zernitz E.R.(1932), Drainage patterns and their significance. Journal Of Geology Vol. 40, PP.498-521

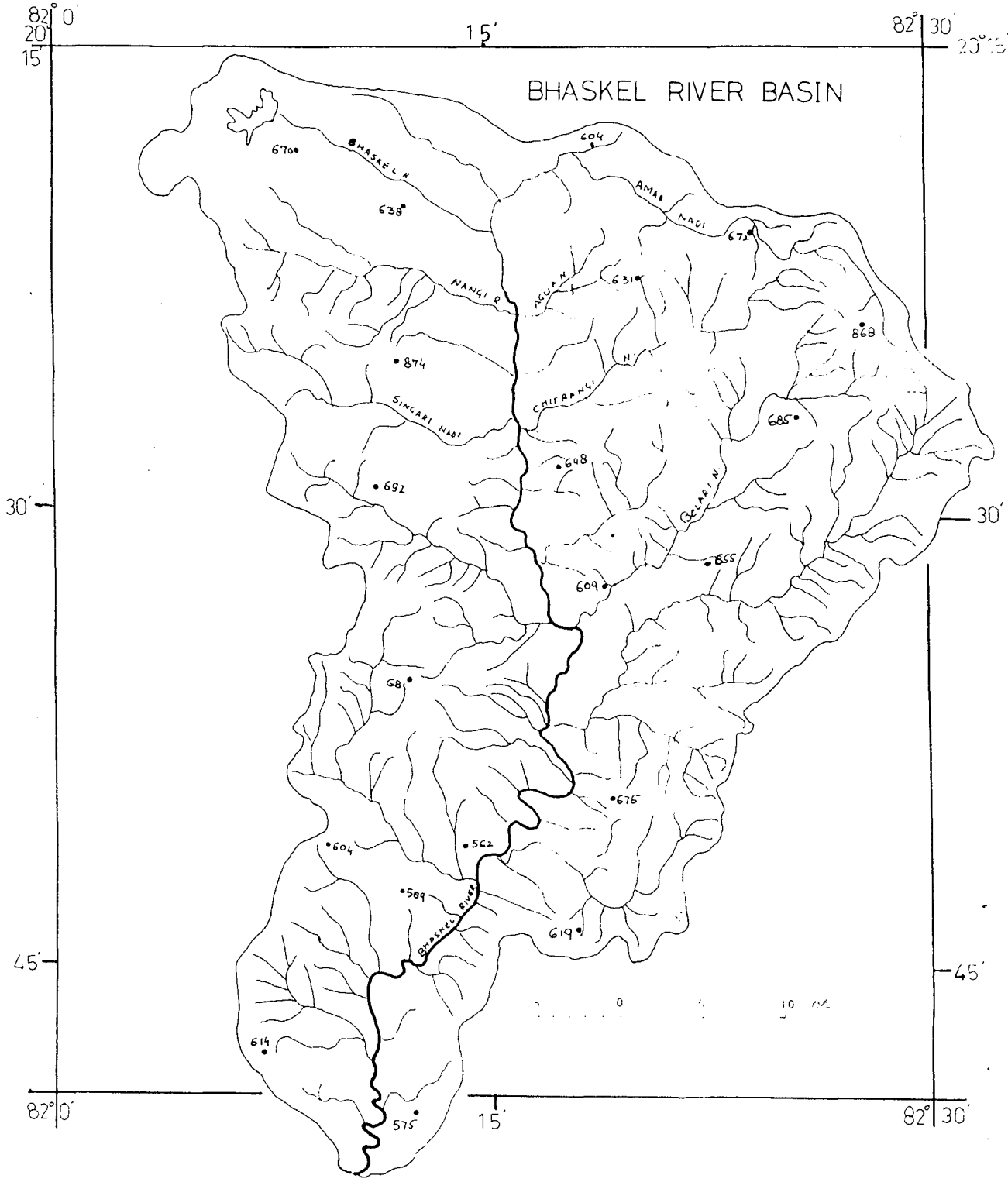
BHASKEL RIVER BASIN
82° 0'
15'
82° 30'
20° 15'
30'
45'
670
BHASKEL R
638
604
AMAB NADI
672
NANGI R
AGUAM
631
868
874
CHITRANGI N
685
SINGARI NADI
692
648
SELARI N
855
609
68
675
604
562
589
BHASKEL RIVER
619
614
575
0
10 KMS

FIG. 4.2

is also visible in north-western part and southern parts of Bhaskel:Nangi river, Singari river are having radial pattern and their height is comparatively, more than other part of the basin. It lies in the crystalline quartzites and Bengpal Gnebssic complex. Irregularities in the initial slopes of domes has given birth to this type of pattern. Head ward erosion and formation of gullies are well developed here. The sub - parallel pattern is also seen due to slope control.

4.2. LINEAR CHARACTERISTICS OF A BASIN UNDER DIFFERENT LITHOLOGY

Stream order and stream number are related to each other in a geometric progression. Inverse relation ship is found in both the variables,from the table we can see that there is no marked difference in stream number whether it is hard or soft:

TABLE 4.1

ORDER NO.	METAMORPHIC	SEDIMENTARY
	ROCK TYPE	
I	78	76
II	15.5	17.25
III	3	4.5
IV	1	1
MEAN	32.17	32.58

Stream number is independent. In soft rocks streams flow freely and give rise to the number of streams in each order. Hard rocks under humid conditions give birth to several streams which also increases numbers. The average value is coming more or less same which determines that geology is not playing much role in the development of stream numbers. There may be another factors like, slope, climate, and vegetation which is more important than underlying lithology.

The coefficient of variation in soft rocks is 46.10% (appendix II) and non - resistence rocks is 22.30% It means that there is no homogeneity between the stream numbers of each order may be because of undulating topography In quartzites and gneisses, well known for their non- resistancy, are having less variations with in the basin giving rise to the inference that underlying topography is more or less same in the whole basin of Gudra.

" If a geometric series exists in a straight line series of points results where numbers of streams are plotted on a logarithmic scale on the ordinate against order numbers of an arithmatic scale on the abscissa"(Schumm). But it is not for any basin except for over all hard rocks of Gudra and VI basin of Bhaskel. All other graphs are showing a marked up - concavity at the lower end, which infers that geometric progression is not closely observed in higher orders whether under lying topography is hard or soft.

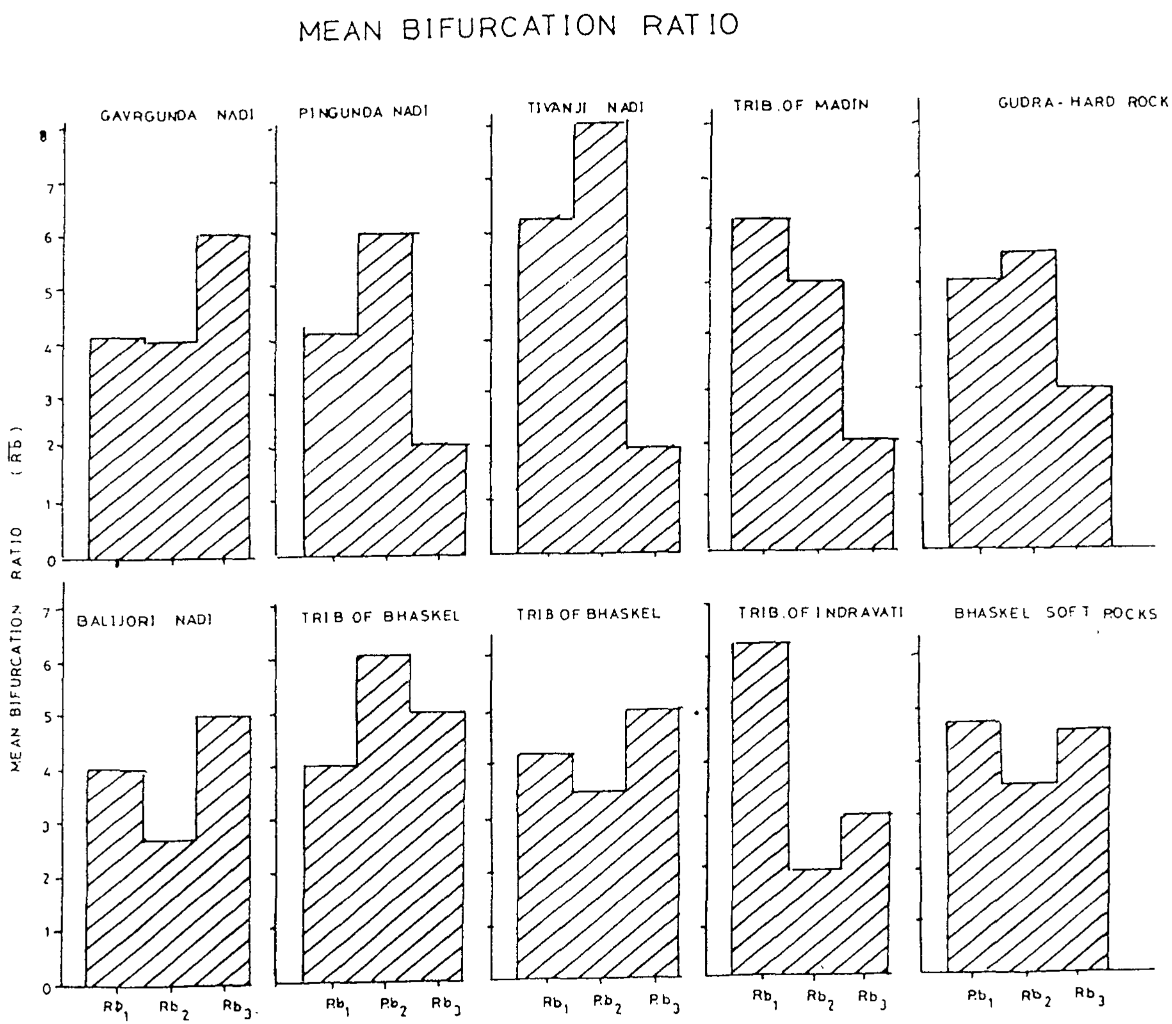
MEAN BIFURCATION RATIO
GAVRGUNDA NADI
PINGUNDA NADI
TIVANJI NADI
TRIB.OF MADIN
GUDRA- HARD ROCKS
BALIJORI NADI
TRIB OF BHASKEL
TRIB OF BHASKEL
TRIB.OF INDRAVATI
BHASKEL SOFT ROCKS
MEAN BIFURCATION RATIO (Rb)
Rb1 Rb2 Rb3

Fig. 4.3

4.3 BIFURCATION RATIO :

Bifurcation is varying from 3 - 5 according to underlying topography. The table is showing mean bifurcation ratio for two difeerent rock types :

TABLE 4.2

BIFURCATION RATIO	GUDRA HARD ROCKS	BHASKEL SOFT ROCKS
Rb_1 (I - II)	5.18	4.73
Rb_2 (II - III)	5.75	3.67
Rb_3 (III- IV)	3.00	4.00
MEAN Rb	4.64	4.13

In Gudra, the hard rocks are having undulating and rugged topography,there is heterogenity with in the basin. In southern parts of Bhaskel which is comprised of soft rocks are showing not much variations wbth in under lying lithology.

Non - resistant rocks exhibit high value of bifurcation ratio in contrast with sedimentary. The values of coefficient of variation (appendix II)are 12.83% in Gudra and 6.40% in Bhaskel. Variations are more in Gudra river than in Bhaskel. As we can see the values of Rb, with in a basin, which is ranging from 5.19 - 5.72 in Gudra and 4.31 - 5.10 in Bhaskel. The Gudra is having ruggedness and

CORELATION
BIFURCATION RATIO & AREA

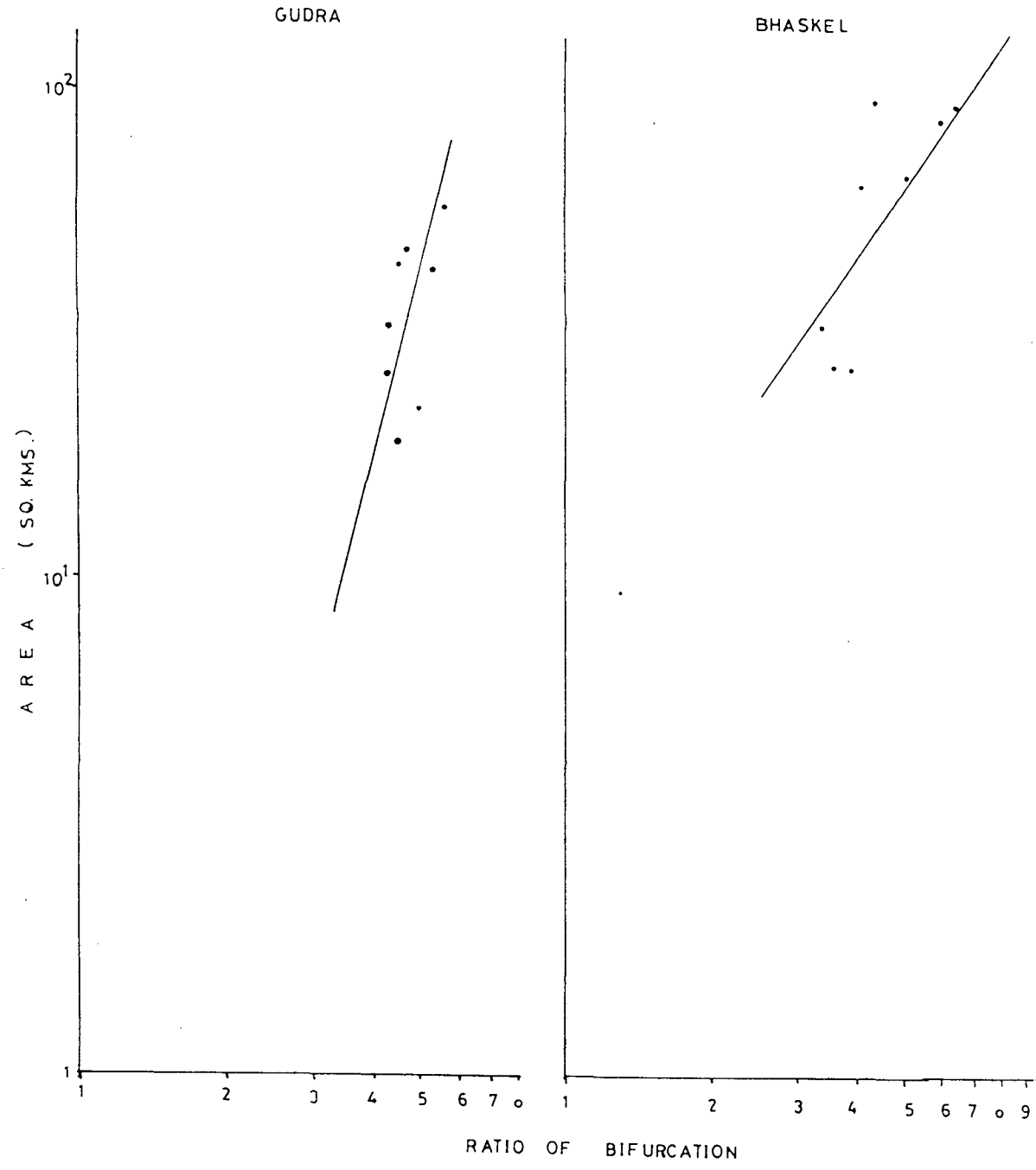

FIG. 4.4

in its underlying lithology.

According to Giutsi and Schneider's hypothesis the Rb with in a basin decreases with the increase of stream ordes:[1]

$$Rb_1 > Rb_k$$

where, k, is successive increasing order.

But it is not supporting this hypothesis in Gudra and Bhaskel basins. Basin I, II, and Iv of Gudra are havinghard underlying rocks. But the above equation ($Rb_1 > Rb_k$) it is not fitting on sedimentary rocks also. It can be seen easily from the graph.

4.3 RATIO OF BIFURCATION AND AREA :

Bifurcation ratio reflects the branching phenomena of drainage net work. The coefficient of correlation between bifurcation ratio and basin area is standing at +0.725 in Gudra and + 0.708 for Bhaskel, which indicates that higher value of mean bifurcation ratio are associated with the bigger areas of the basin and vice versa. The value of metamorphics and sedimentary rocks are showing + 0.31 and +0.44 respectively, confirming positive correlation between area and bifurcation ratio. But in some cases i.e. basin VIII of Gudra is having 47.20 square kilometers of area and mean Rb is 4.71, where underlying lithology is quartzites in contrast with basin III, where area is comparatively lesser i.e. 43.29 square kilometer

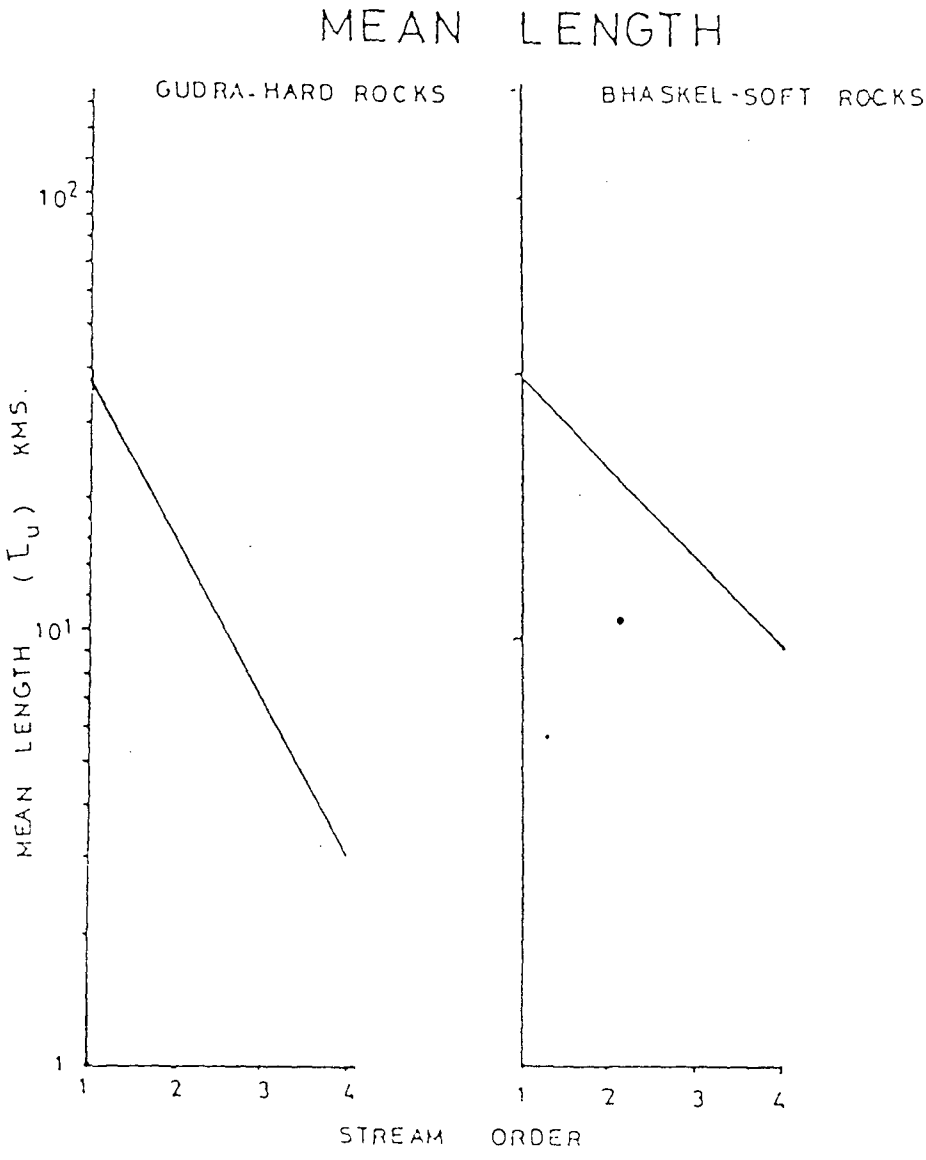
MEAN LENGTH
GUDRA-HARD ROCKS
BHASKEL-SOFT ROCKS
10^2
10^1
1
MEAN LENGTH (L_u) KMS.
1
2
3
4
1
2
3
4
STREAM ORDER

FIG 4.5

and mean bifurcation ratio is 5,10, thbs may be by change or due to local variations.

4.4 VARIATIONS OF STREAM LENGTH:

The length of streams of each order were obtained by measuring all the drainage channels with in a basin of a given order, the length of the fourth order of the selected basins of Gudra and Bhaskel is the total length of all the channels in the basin. Here, streamd are varying from basin to basin :

TABLE 4.3

S.NO.	STREAM ORDERS	HARD ROCKS IN KILOMETERS	SOFT ROCKS
1.	I	38.06	38.21
2.	II	19.69	21.58
3.	III	7.62	15.78
4.	IV	3.97	9.31
5.	MEAN L_u	17.335	21.220

Average length is greater in resist -ant rocks than in non - resistant. Mean length is higher as order increases in soft rocks of Bhaskel basin which infers that stream length reduces as the massiveness and compactness of rock, increases from the figure it is clearly evidenced that the increase in mean length do not form the geometric series as the points are deviating from the line.

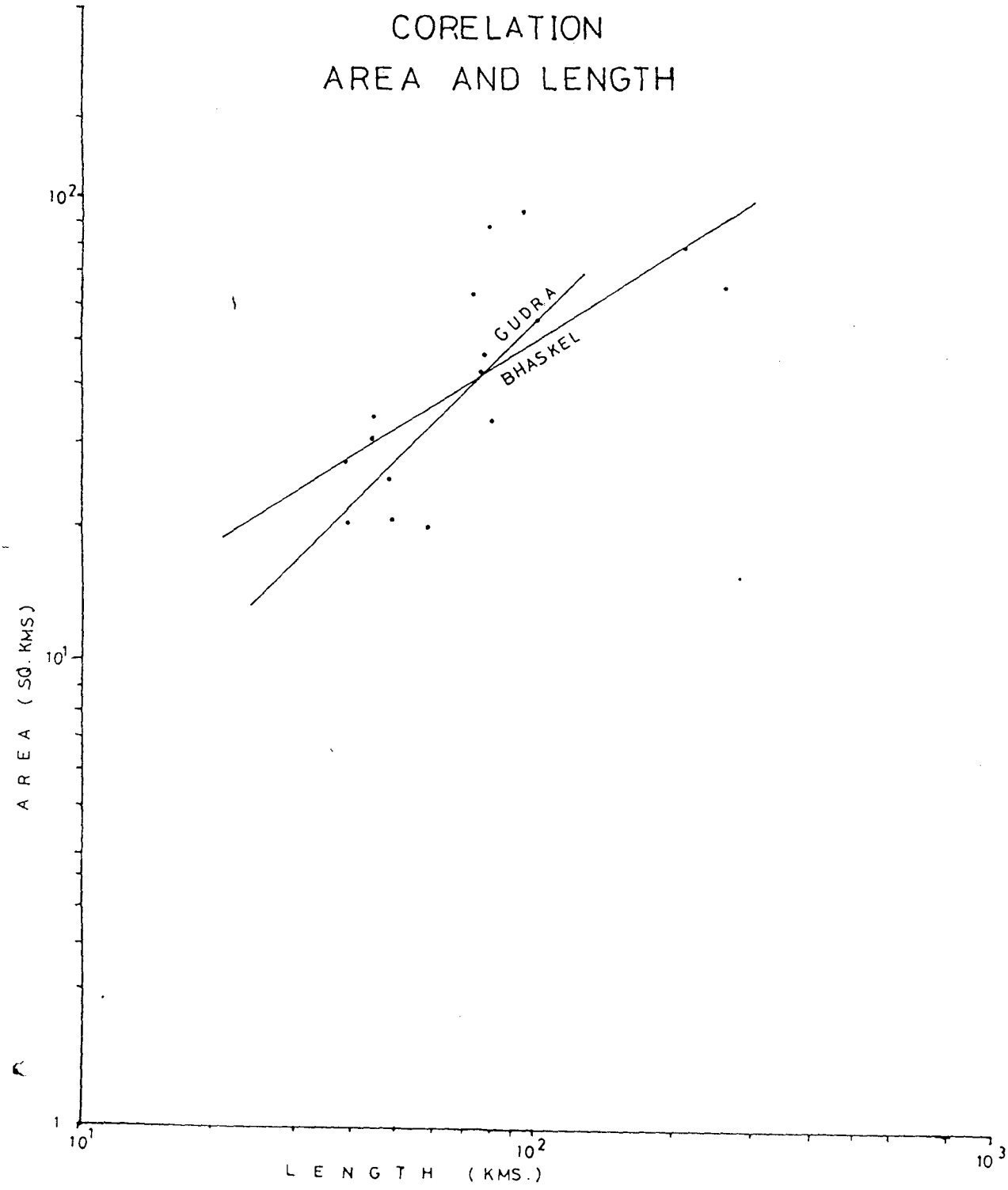
CORELATION
AREA AND LENGTH
10^2
10^1
1
AREA (SQ. KMS.)
GUDRA
BHASKEL
10^1
10^2
10^3
LENGTH (KMS.)

FIG. 4.6

The coefficient of variation is higher in soft rocks,lithology as 40,67% than in hard rocks i.e. 18.58% It means that there is higher variation with in the length of the basin in each order of selected basins of Bhaskel.

According to Schumm, the curve of stream length should be in linear pattern i.e. gentle sloping curves but in some cases we find gentle sloping curves up to III order and then slightly increase because the higher order streams occupy relatively low lying plain area forming meandering courses which create comparatively low difference in higher order streams where as, lower order streams are situated over dissected parts of Abujhmar group of uplands which create sudden increase in the length due to the higher frequency.

4.5 AREA AND LITHOLOGY :

It is an important geomorphic parameters. The differences of mean area in different lithologies are as follows :

table 4.4

ROCK TYPE	AREA IN SQ. KMS.
METAMORPHIC	33.13
SEDIMENTARY	62.58

Basin area of any drainage basin depends upon the degree of headward erosion which is directly related to climate lithology etc. The area per square kilometer is larger in resistant rock.

According to Horton[1] "mean drainage basin areas of each order should form a geometric series. The coefficient of correlationvalue is high in selected basins of Bhaskel river having underlying topography as cohesive and non- resistant i.e, 38.86%

Gudra is having 36.92% of the variation. Both whether hard or soft topography, the ruggedity and undulation as well as, slope increases,the area of a basin.Basin area is governed by climate also. Variations with in the basin area for each order is more or less same in any lithology.

Total stream length having higher value of coefficient of correlation(r= 0.94) in Gudra basin and in Bhaskel (r = 0.80) shows strong control over thebasin area. The positive relation ship can de seen in the graph which shows the trend of distribution. Basins area is directly proportional to stream length, but, some variations may be there either due to local irregularities, or by chance.

4.6 SHAPE INDICES AND LITHOLOGY :

Shape is a geometric structure of drainage and is related to the external shape of the drainage basin.

As drainage basin is governed by geological form tions relief, slope and lithological factors, it is never in extremes i.e., straight line shape or complete circular. The ideal shape is cinsidered to be pear shape.

The coefficient of variation is 10.37% in Gudra basin and 12.63% in Bhaskel. In basin III of Gudra it is having elongation ratio as 0.94, but it cannot be categorised as perfect circular or perfect elongated as it is having both the values higher. Similarly for basin III of Bhaskel river under sedimentary rocks the value of Re = 0.65 and Rc = 0.39, the basin falls into the category of elongated shape but if we look at the map (chapter III) we will find its shape is not perfectly elongated. The basin passes to elongated shape in metamorphic rocks (BASIN, V, IV ,I) where the streams are in initial stage and head ward erosion is dominant. Rest of the basin are giving, comparatively, higher value of circularity denotes early mature stage of the stream.The deoositbon is more and water is moving freely. Latter type of shape is generally found in sedimentary region of south Bhaskel.

In Gudra basin, over all value of circular ratio is higher 0.86 but the variation in each basin exhibits that no basin is perfectly circular or elongated. The basin in higher relief is having more elongated shape than in lower relief. Basin II, III, IV and IX of Gudra are showing higher values of elongation than circulay. Basin

IV is showing perfect circular shape giving circularity ratio as one(1), But it is not so in the map. There is a slight deviation of the shape may be due to local variation. Basin IX is also showing high value of circularity ratio(0.96) and Re (0.73). These both values are not giving shape to this basin as perfect circular.

It is inferred that underlying lithology is dominant in determining the shape of the basin. Climate and relief are also important factors which modifies the shape.

4.7 DRAINAGE DENSITY :

Chorley[1], states that drainage density is directly related to amount and intensity of precipitation and inversely related to the amount of vegetative cover.

The following table shows the variation of drainage density in two different rock types:

TABLE 4.5

DRAINAGE DENSITY IN KM./SQ. KM.

S.NO.	GUDRA	S.NO.	BHASKEL
BASIN II	2.75	BASIN II	1.14
BASIN III	1.68	BASIN III	1.89
BASIN VIII	1.62	BASIN VI	0.99
BASIN IX	2.19	BASIN VIII	1.39
MEAN	2.06	MEAN	1.35

The resistent rocks are showing higher drainage density than the non- resistant one. The mean value is standing at 2.06 km./sq.km.in sample basins of Gudra and 1.35km./sq.km. in Bhaskel. The variation is giving higher values od 22.13%in compact and massive formation in contrast with 8.54% in sedimentary sequence of Indravati, which shows greater variation of drainage density in the basin of Gudra. The is due to the local changes of the underlying rocks in metamorphics.

4.8 DRAINAGE TEXTURE :

Drainage texture which is the influence of underlying lithology, slope, climate and drainage density is ranging from basin to basin. Hard rocks are having coarse texture as the value is low, but ,sedimentary rocks are having values lower than hard rocks. In Bhaskel basin the texture is coarser than Gudra basin. The table shoes the drainage texture in the basins of Gudra and Bhaskel :

TABLE 4.6

S.NO.	HARD ROCKS GUDRA		S.NO.	SOFT ROCKS BHASKEL	
BASIN II	4.33	MEDIUM	BASINII	2.72	COARSE
BASIN III	3.76	MEDIUM	BASIN III	3.73	MEDIUM
BASIN VIII	5.20	MEDIUM	BASIN VI	3.30	COARSE
BASIN IX	4.35	MEDIUM	BASIN VIII	2.24	COARSE
MEAN	4.41	MEDIUM	MEAN	2.76	COARSE

The mean value of texture is 4.41km./sq.km. is in the resistant rocks and 2.75km,/sq.km. in non - resistant rocks. Coarser texture is found where erosion is dominant and overland flow is high.

As the stage of a river increases texture also increases from coarse to fine. Slope also influences texture ratio. Coarser texture are generally found in gentle slopde areas as in the case of basin VI of Gudra where slope is gentle and itis having the value of drainage texture 3.41. Steep slopes can have the fine texture as it is in the case of basin I of Gudra i,e. 7.29 showing highest value than other basin, and lies in the hilly region having the height of 837 meters.

The coefficient of variation is showing 11.65% in Gudra basin and 22.60% in Bhaskel. This exhibits that there is not much variations in the texture of Gudra as they are more or less of medium to fine. In Bhaskel the texture is coarser to medium. There is less uniformity with in the Bhaskel basin.

Drainage texture is related to drainage density. As the drainage density increases texture also increases from coarse to fine. From the coefficient of correlation calculated for the sample basins, Gudra. is having r:- 0.076, a negligible negative value because of basin III and IX i.e. Pingunda nadi and Tivanji nadi. Bhaskel is showing perfect positive correlation, + 0.58 infering high drainage density increases the texture, to medium

In Gudra negative value of 'r' is because of dense forest cover and gentle slope. Hard resistant rocks such as quartzites and gneisses tends to give low drainage density and coarse texture. This is because stream erosion is difficult and only arelatively large channel can maintain itself. Therefore, the first order basins are large and provide large amount of runoff to the channels. In Indravati sedimentary sequence of Bhaskel, weak rocks such as limestone(BASIN II, Baliajori nadi), even smaller water shed can beenough to supply runoff for channel erosion. This type of lithological formations are having higher drainage density and fine texture.

4.8 CONSTANT OF CHANNEL MAINTAINENCE AND LITHOLOGY:

It is the measure of drainage texture similar to the drainage density and expresses the distance for the development and maintainence of stream lines as well as the intensity of surface erosion. Values of constant of channel maintainence in metamorphics of sample basins ranges from 0.34-0.62sq.km.and in Bhaskel it is from 0.53-1.00sq.km.

It shows that hard rocks are having lower average values(0.52) which gives medium to fine texture. Here drainage densityis also high. Theconstant of chamnel maintainence are higher in sedimentary area having low drainage density which shows that drainage texture is coarse to medium.It can be inferred from above study that the metamorphic rocks in Gudra and North of Bhaskel are not totally resistant. Quartzites, crystalline quartzites, gneisses are

and thus making this area highly. So, the streams are not bound to flow along joints. Constant of channel maintainence is inversely proportional to drainage density and stream frequency.

4.6 STREM FREQUENCY AND LITHOLOGY :

Stream frequency gives character of under lying lithology, climate and control of vegetal cover in a particular region. Mean stream frequency is 3.09/sq.km. in Gudra and 1.54/ sq. km. in Bhaskel. It is low in recent alluvial deposits of Indravati basin and higher in quartzites of Gudra. Stream frequency is governed by rain fall intensity, runoff, percentage of bare rock area, erosional proportional rate of evaporation and infilteration capacity. From the table above factor are sinificant, determining the stream frequency.

Stream frequency is maximum in Basin II of Gudra river i.e. a tributary of Madin nadi, and in Tivanji nadi, basinIIIof Gudra, 4.02/sq, km.and 3.92/sq.km. respectively. This area is of higher relief and mixed dense forest exists.In contrast withlower stream frequency 0.99/sq.km. of alluvial deposits of Bhaskel river , where relief is low, sparse vegetation can be seen. Seepage of water through the pores is one of the reason giving rise to less stream frequency.

Coefficient of variation being 18.60% in Hard rocks and 40.15% in soft rocks, in the present case indicates that the standard deviation is 18.60% and 40.15% of the mean which further supports great range of deviation. There is less uniformity of the distribution of stream

frequency with in the basin of Bhaskel than in Gudra.

4.6 BEHAVIOUR OF RELIEF IN DIFFERENT ROCK PATTERN:

ABSOLUTE RELIEF:

Absolute relief is more stable in nature than other morphometric parameters. It influences these parameters, indirectly.The map (chapter III) of selected basins of Gudra and Bhaskel reveals that height of the basin decreases from source to mouth. The area of maximum height lies in quartzites of Gudra basin, 897 meters i.e. Tivanji nadi which lies in the western part of the Gudra basin. The lowest value of 614 meters lies in the tributary of Indarvati basin which is having recent alluvial deposits in its beds.

The mean value of absolute relief is 870 meters(appendix II) in Gudra and 651.5 meters in Bhaskel. The standard deviation being the best measure of dispersion is used in the present study to measure the exact degree of variation from the normal distribution. The calculated standard deviation is standing at 20.285 shows slightly smaller degree of variation in Gudra than in Bhaskel, 24.87. Coefficient of variation being 2.33 % for Gudra and 3.18% for Bhaskel reveals that the standard deviation is 2.33% and 3.18% of the mean which supports the low degree of variation of absolute relief with in thw sample basins.

The analyses of absolute relief depicts that most part of the basin lies in a medium altitude, which

quite obvious because entire basin lies in a plateau and is highly dissected.

4.2 RELATIVE RELIEF :

Another important parameter, relative relief is higher in the Pingunda Nadi of Gudra(BASIN IX) having the value of 328 meters. The lowest value is found in the BASIN VIII of Indravati tributary having only 74 meters of relative relief. Relative relief gives an idea about the inclination of terrain, which reflects the nature of configuration. Relative relief is higher in river valleys and lower near the mouth. It has great degree of variation due to the varying nature of configuration. It varies from 74 - 328 meters.Variation in the relative relief values from the normal distribution has been measured by standard deviation. The values show 52.85 and 17.123 in the Gudra and Bhaskel respectively. Gudra is showing comparatively higher variation of relative relief than Bhaskel. Coefficient of variation being 21.42% in Gudra and 17.88% in Bhaskel further sopports the higher degree of variations in Gudra.

4.3 SLOPE ANLYSES AND LITHOLOGY:

The computation of average slopes from the topographic maps using contours have been attempted by several scholars. In the present study the scheme of Wentworth is used for the slope analysis. The degree of slope in the area is ranging from minimum Of 0° to maximum of 8.55°. The slopes values of all grids in the entire basin has

AVERAGE SLOPE : GUDRA
IV ORDER SAMPLE BASINS

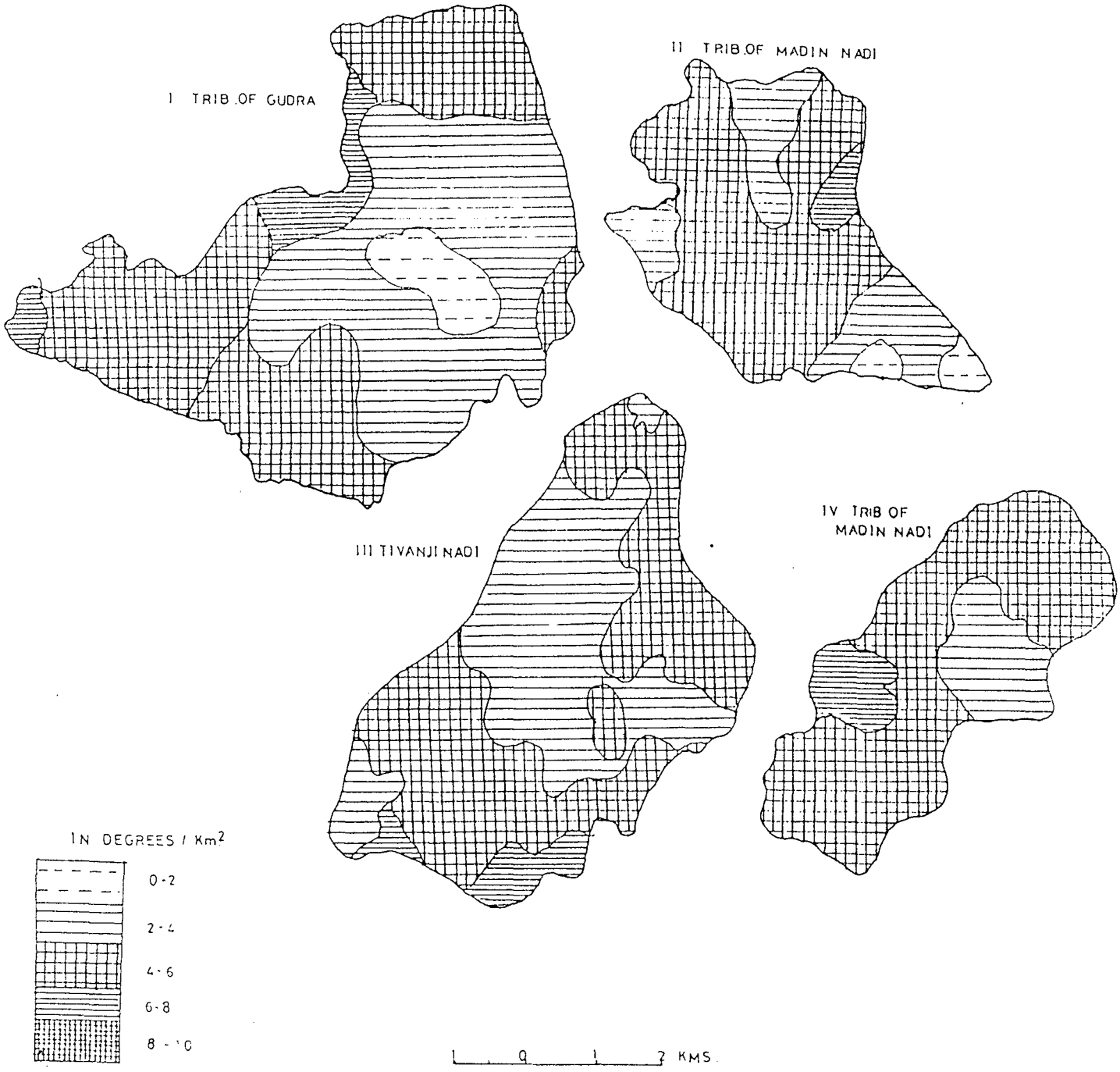

FIG. 4.7

AVERAGE SLOPE : GUDRA
IV ORDER SAMPLE BASINS

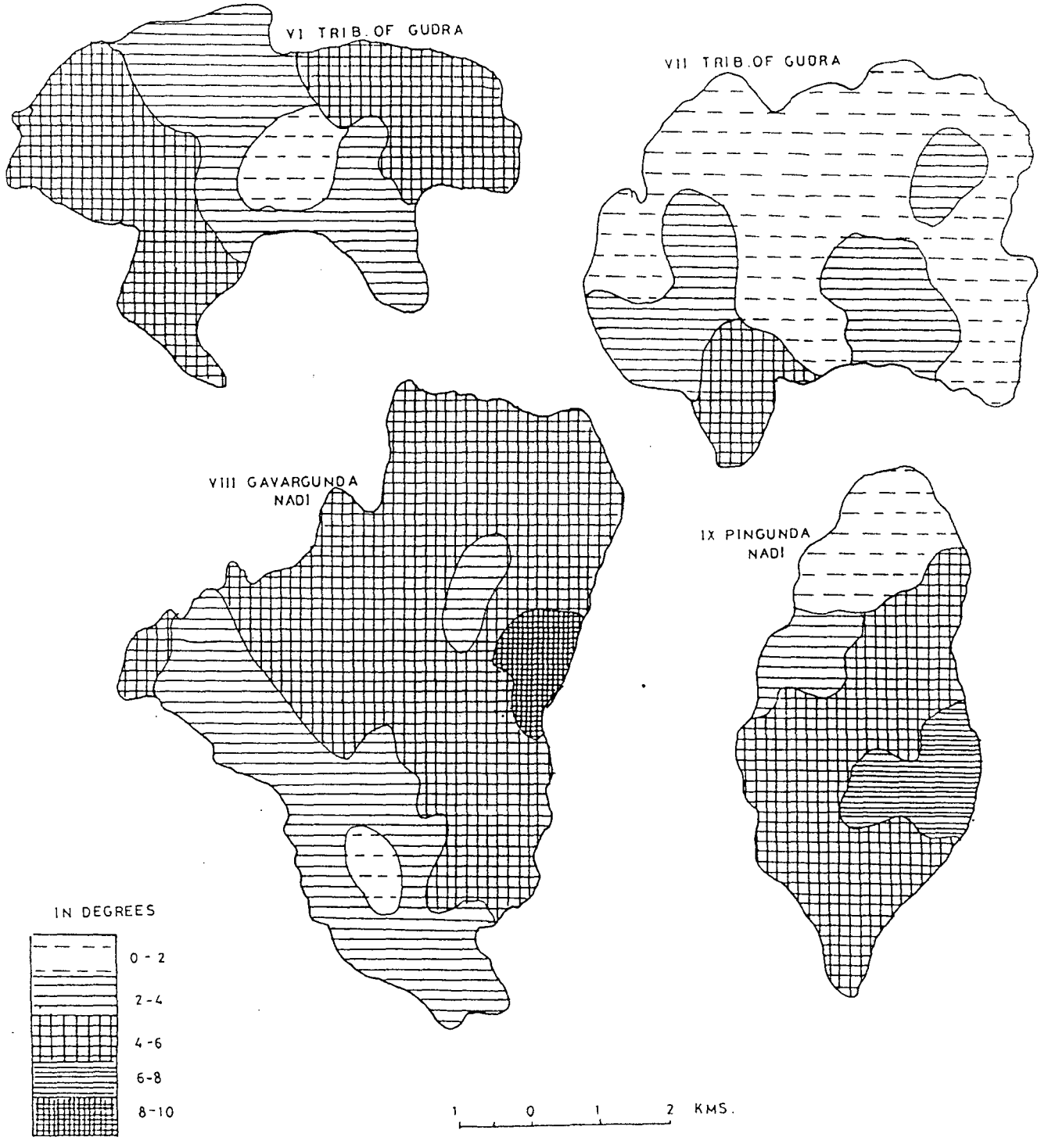

FIG. 4.8

AVERAGE SLOPE : BHASKEL
IV ORDER SAMPLE BASINS

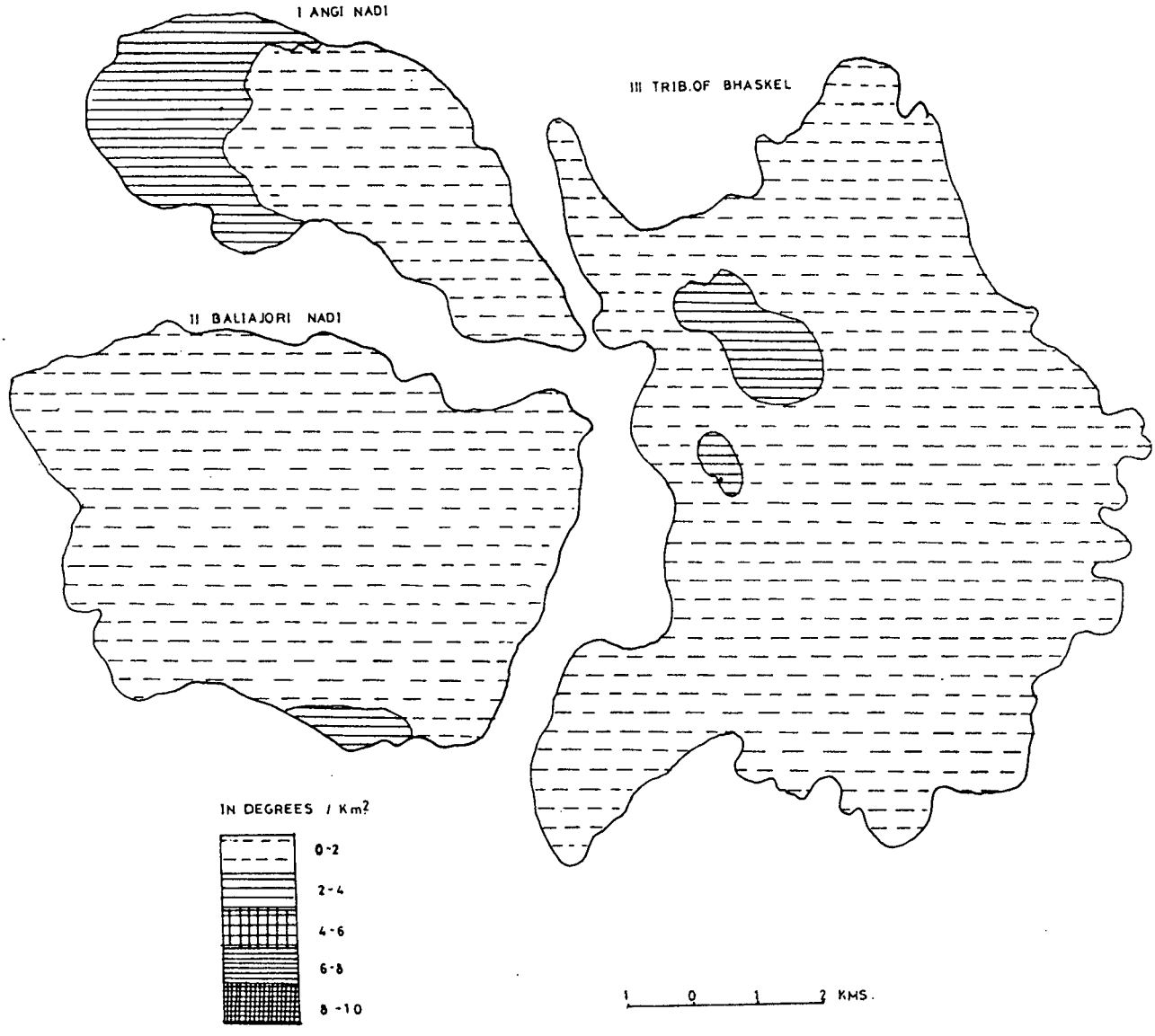

FIG. 4.9

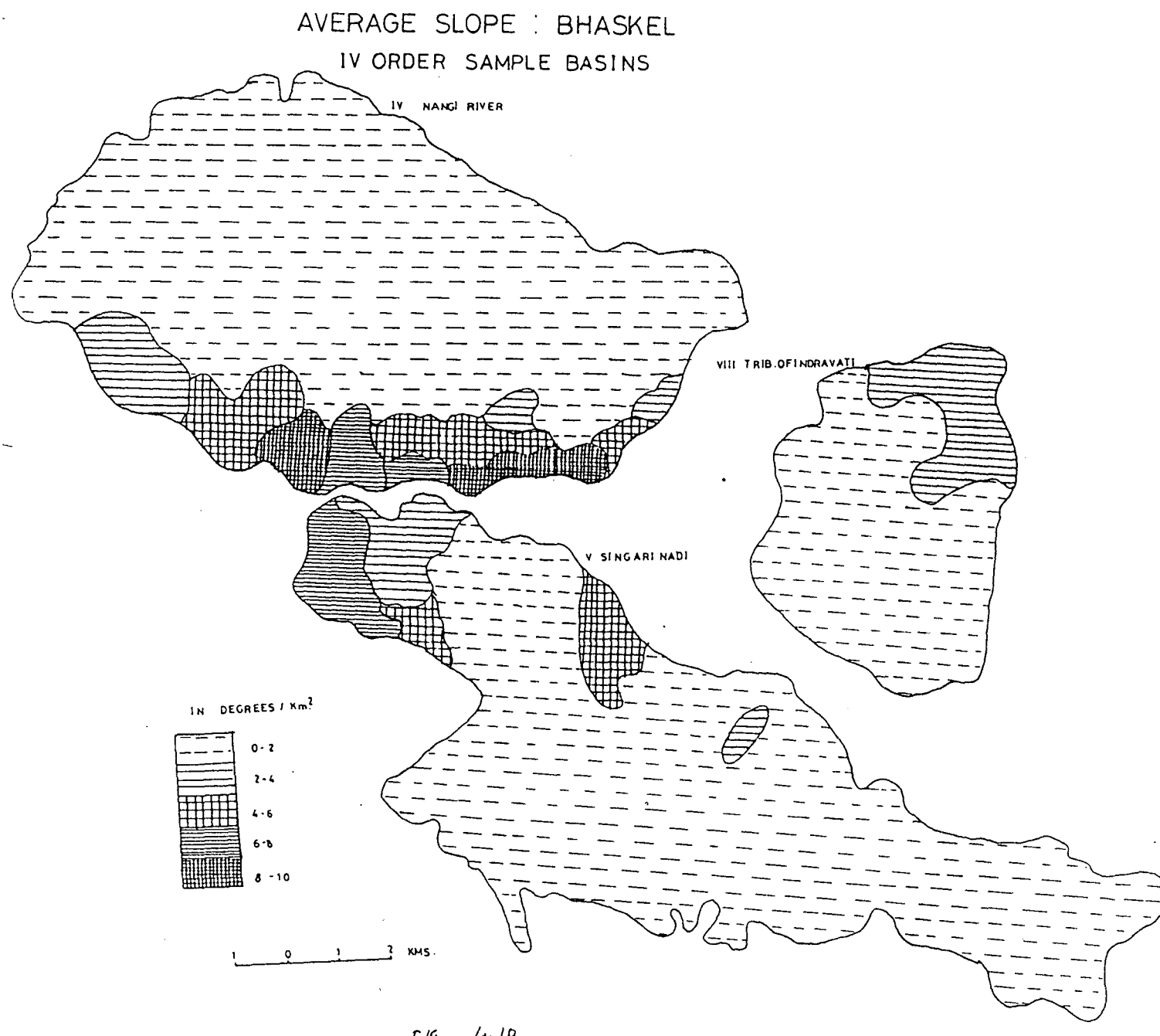
AVERAGE SLOPE : BHASKEL
IV ORDER SAMPLE BASINS
IV NANGI RIVER
VIII TRIB.OF INDRAVATI
V SINGARI NADI
IN DEGREES / Km²
0-2
2-4
4-6
6-8
8-10
1 0 1 2 KMS.

FIG 4.10

been classified into five categories of 2° interval.

AVERAGE SLOPE IN HARD ROCKS OF GUDRA:

Table 4.7

S.NO.		AVERAGE SLOPE
BASIN II	Tributary of Madin Nadi	2°-5°
BASIN III	Tivanji Nadi	1°-5°
BASIN VIII	Gavargunda Nadi	1°-5°
BASIN IX	Pingunda Nadi	0.54°-8°
BHASKEL BASIN:		
BASIN II	Baliajori Nadi	0.54°-3°
BASIN III	Tributary of Bhaskel	0.54°-3°
BASIN VI	Tributary of Bhaskel	0.54°-4°
BASIN VIII	Tributary of Indravati.	0.54°-4°

All the selected basins of Bhaskel and Gudra lies in gentle slope. Slope is the ratio of vertical drop to horizontal distance, measure from the upper end to the lower end of a single stream segment of given order.

Slope of Gudra is Ranging from 0.54°-8° giving, comparatively steep slope in contrast to Bhaskel which

ranges from 0.54° to 4°, only. The Basin Gudra is situated on an elevation comparatively, higher than Bhaskel.Bhaskel* lies in lower elevated region. It makes meandering pattern in its mouth, where, it joins the Indravati river. The whole basin of Bhaskel is in initial stage and the classification stages is only ,comparative, to each other.

4.13 DISSECTION INDEX :

Dissection Index is a measurement of dissected topography in mathematical terms. By dissected topography we mean topography characterised by a definite pattern of incised hills on mountains separated by low lying areas i.e. cut by erosion into a net work of valleys and interfluves.

The calculated mean value of the dissection index stands at 0.305 and 0.148, for the sample basins of Gudra and Bhaskel respectively. Standard deviation of calculated dissection index values standing at 0.0005 and 0.058 for Bhaskel and Gudra, which indicates greater degree of variation in Bhaskel. Coefficient of variation being 19.19% and 14.86% in resistant and non resistant rocks respectively gives greater degree of variations in sedimentary region of Bhaskel. Gudra, though, comparatively lower value, it is also showing high dissected terrain of Abujhmar group

and gneisses having large variations with in the basin.

This analysis brings out that Bhaskel river in general, experienced moderately dissected terrain.

4.14 RUGGEDNESS NUMBER :

Ruggedness number gives an idea about the nature of variation of erosional features of erosional agents engaged in sculpturing the land mass and resulting configuration.

Mean values of ruggedness number of the selected basins are 0.53 for G dra and 0.1725 for Bhaskel Ruggedity is high in resistant rocks comprised, of gneisses Quartzites in Gudra than in the recent alluvial deposits of Bhaskel Basin.

The measure of degree of dispersion i.e. standard deviation is calculated for both of the selected basins. The values are 0.055 for Bhaskel and 0.1129 for Gudra shows a greater of variation in the latter basin. The coefficient of variation being 21,30% for Gudra and 31.72% of Bhaskel further supports a greater degree of variation in Gudra.

C H A P T E R V

SUMMARY AND CONCLUSION

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SUMMARY AND CONCLUSION

Morphometry from early forties is playing a vital role in evaluating the characteristics of river basins in terms of quantification. A similar attempt has been made for the two selected basin of Indravati river. The main emphasis of the present study is on the evaluation of the land surface with the help of selected morphometric parameters.

Several processes are engaged in sculpturing the land forms in a long period of time and under different environmental conditions. Not only lithological conditions but also climate, slope, play an important role.

Lithology as a major factor, though dependent directly or indirectly on other factors has been taken into account to explain the variation in morphometric parameters. The conclusion derived from the study of earlier chapters can be organised as follows ;

A)- The Indravati is the second largest river which covers 13.32% of the area of the largest and the longest river in South India i.e., Godavari. Its catch ment area is about 41,665 square kilometers, of Madhya Pradesh and Orissa. It rises at an elevation

of 915 meters in Kalahandi. It flows west wards The two tributaries, namely, Gudra and Bhaskel of Indravati being of differeht geological formations has been selected for the study.

Gudra stretches from 19°10' North to 19°35' and 82°20' east to 82°30'east of longitudes. It rises at an elevation of 853 meters. It comes under metamorphic rocks.

Bhaskel stretches from 82°10' to 82°21' east and 19°6' to 19°50' north of latitudes It joins Indravati in South near Nagarnar village.

Six lithological formations have been taken into account for the study of the structure and its influence upon selected morphometric parameters. Lithological formations are broadly divided into two groups i.e. sedimentaries and metamorphics.

Sedimentary includes, Indravati sedimentary sequence or the recent alluvial deposits and limestone region situated in South central portion of Bhaskel river.

Metamorphics includes quartzites crystalline quartzites, gneisses, Bengpal gneissic complex and Biotite granite gneisses.

B)- Gudra is showing dendritic amd sub- parallel pattern

in its course andBBhaskel shows sub - parallel and radial pattern, where dome is found giving birth to several finger tips in centripetal form.

C)- Lithology and linear properties: The fourth order basins are selected for the present study and the differnt morphometric parameters are applied. The metamorphic lithology produces high values of the stream numbers of first order. In contrast, with sedimentary particularly, recent alluvial deposits and limestone But the mean stream number is more or less same which concludes that climate and vegetation is also important for thr development of stream number.

Bifurcation ratio is high in the metamorphics in comparision to the sedimentaries but the length is more in soft rocks than in hard. Massive has higher variations among the observations like in Gudra.

Ratio of bifurcation and area shows positive correlation among them. Sedimentary and limestone regions of Bhaskel basins are showing high bifurcation ratio and bigger areas than Gudra.Mean length of the basin is more in soft areas. Stream length reduces as the massiveness and compactness of rock increases. Co-efficient of variation shows higher variations in sedimentaries.

D)- Lithology and areal property: Areas of sedimentary rocks are more than in metamorphics. Basin areas depend

upon the degree of headward erosion which is high in soft rocks. There is a positive correlation between length and area. Basin area is directly proportional to stream length.

Shape of the drainage basin is governed by the geological formations,relief, slope aspects, and lithological factors. No shape is perfectly circular or elongated due to the variation of different factors. Same is in the case of the present selected basin.

Drainage density is higher in hard rocks than soft rocks. It shows high variations in sedimentary rocks. The mean drainage density is 2.06 km./sq.km- in metamorphic and 1.39 km./sq.km. in sedimentary region Drainage density is not only governed by lithology but also by relief, slope, ruggedness number and dissection index.

Drainage texture associated with density. It is high in hard rocks showing medium texture in Gudra than in Bhaskel. There is much more variations in texture in resistant rocks than in non - resistent. Drainage texture is having positive correlation with drainage density, As density increases texture of a basin also increases from coarse to ultra- fine. Stream

frequency is high in metamorphic rocks.It is governed by rain fall intensity, infilteration capacity. rate of evaporation and run off. Second factors are dominant in the lime stone region, decreasing the stream frequency.

Constant of channel maintainence is high in sedimentary rocks than in metamorphics. There is a negative correlation between constant of channel maintainence and drainage density. As drainage density increases constant of channel maintainence decreases.

E)-Lithology and relief characteristics: The absolute relief of the basin varies from 715 meters to 897 meters in Gudra and 614 - 927 meters in Bhaskel basin. The whole region lies in plateau region of Bastar and Abujhmar plateau. Average absolute relief is higher in Gudra than in Bhaskel.

Relative relief of the area has a less degree of variation ranging from 175 - 328 meters in Gudra and 74 - 320 meters in Bhaskel. It indicates the develoment of broad river valleys.

Average slope varies from 0°-8° in Gudra and 0° to 4° in Bhaskel. The area lies in very gentle slopes. The development of slopes in these two basins is a resultant of combination of drainage density stream frequence, relative relief, absolute relief and underlying lithology.

Dissection index stands at 0.305 and 0.148 for hard rocks and soft rocks, respectively. Which denotes the down ward erosion of the bed, predominant. Ruggedness number of the basin provides the roughness of the land surface. It is more in Gudra basin than in Bhaskel. It concludes that in resistant rocks than in non - resistant. There is more ruggedness in Gudra than Bhaskel.

It is concluded from the above study that other environmental conditions being constant lithology controls the distributional aspects of morphometric characters of the two river basins selected for the present analyses.

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APPENDIX II

AVERAGE QUANTITATIVE GEOMORPHIC CHARACTERISTICS. BHASKEL & GUDRA BASIN

OF THE 4th ORDER BASINS OF INDIRAVATI

S.NO.	Hard rock Gudra X		C.V. in %	Soft Rock Baskel X		C.V. in %
Stream number	97.5	21.74	22.30	98.75	45.52	46.09
Stream length	63.1	11.73	18.58	82.81	33.68	40.87
Stream area	33.13	12.23	36.92	62.58	24.32	38.86
Bifurcation ratio	4.65	0.24	5.28	4.30	0.55	12.84
Drainage Density	2.06	0.46	22.13	1.35	0.34	25.04
Drainage texture	4.41	0.51	11.65	2.76	0.61	22.07
Stream frequency	3.09	0.58	18.62	1.54	0.62	40.02
Elongation ratio	0.77	0.77	10.68	0.70	0.13	12.63
Circularity ratio	0.86	0.15	17.92	0.68	0.19	28.62
Absolute relief	870	20.28	2.33	645.5	18.35	2.84
Relative relief	265	48.75	18.39	95.75	17.12	17.88
Dissection Index	0.305	0.06	19.19	0.145	0.02	15.03
Rudggedness Number	0.56	0.12	20.63	0.13	0.03	24.41

Abbreviations

X = Mean of variable
= Standard deviation
C.V. = Coefficient of Variation.

APPENDIX - I

Gudra

S.No.	Basin
I	Tributary of Gudra
II	Tributary of Madin Nadi
III	Tivanji Nadi
IV	Tributary of Madin Nadi
VI	Tributary of Gudra
VII	Tributary of Gudra
VIII	Gavargunda Nadi
IX	Pingunda Nadi

Bhaskel

S.No.	Basin
I	Angi Nadi
II	Baliagori Nadi
III	Tributary of Bhaskel
IV	Nangi River
V	Singari Nadi
VI	Tributary of Bgaskel
VII	Agua Nadi
VIII	Tributary of Indravati