CHAPTER - VIII

RESOURCE MANAGEMENT STRATEGIES

As has been discussed earlier, the Gir Wildlife Sanctuary is the sole remaining large forested area in an otherwise predominantly semi-arid zone. The regional climatic regime has an imprint on this forest area, thereby causing several geo-environmental problems viz. erratic rainfall, a rough 4-5 year drought cycle, water scarcity during the drier months, etc. Apart from the above mentioned problems, human interference along the peripheral zones is also one of the most troublesome and worrying aspects contributing to the plethora of problems facing this fragile ecosystem. Secondary problems facing this area, but having a direct influence on the previously mentioned primary problems are, the highly rugged topography, thin soil cover, high erosion during the monsoon and the absence of primary porosity in the Deccan Trap basalts.

In the course of suggesting management practices to ameliorate the above mentioned problems, it would be worthwhile describing each one briefly, followed by suggestions.

(I) CLIMATE AND RAINFALL

Though the study area receives an average annual rainfall of

800 mm, a large portion of this is lost via high run-off which is due to the highly rugged terrain and the absence of primary porosity in the underlying Deccan Trap basalts. The problem is further accentuated by the erratic rainfall and the 4-5 year drought cycle (Fig.51).

Drought in technical terms is the prolonged absence of moisture which adversely and substantially affects the physiology of plants. As a rough yardstick for the study area, a minimum of 1000 mm of average annual rainfall is required to ensure adequate growth of range plants. Drought is a built in factor in arid to semi-arid ecosystems but its occurrence is unpredictable. Its impact is mediated through the range, wildlife and livestock management in vogue so that good management practices will lessen the adverse effects of drought, while poor management makes the ecosystem all the more vulnerable.

The impact of drought has a carry-over-effect which lasts for 2-3 years after it has passed. Its influence is felt in the following inter-related aspects of the semi-arid ecosystem :

plant life,
water availability,
animals (wild and domestic), and
people.

A closer inspection of the processes controlling the structure and composition of a forest reveals that the

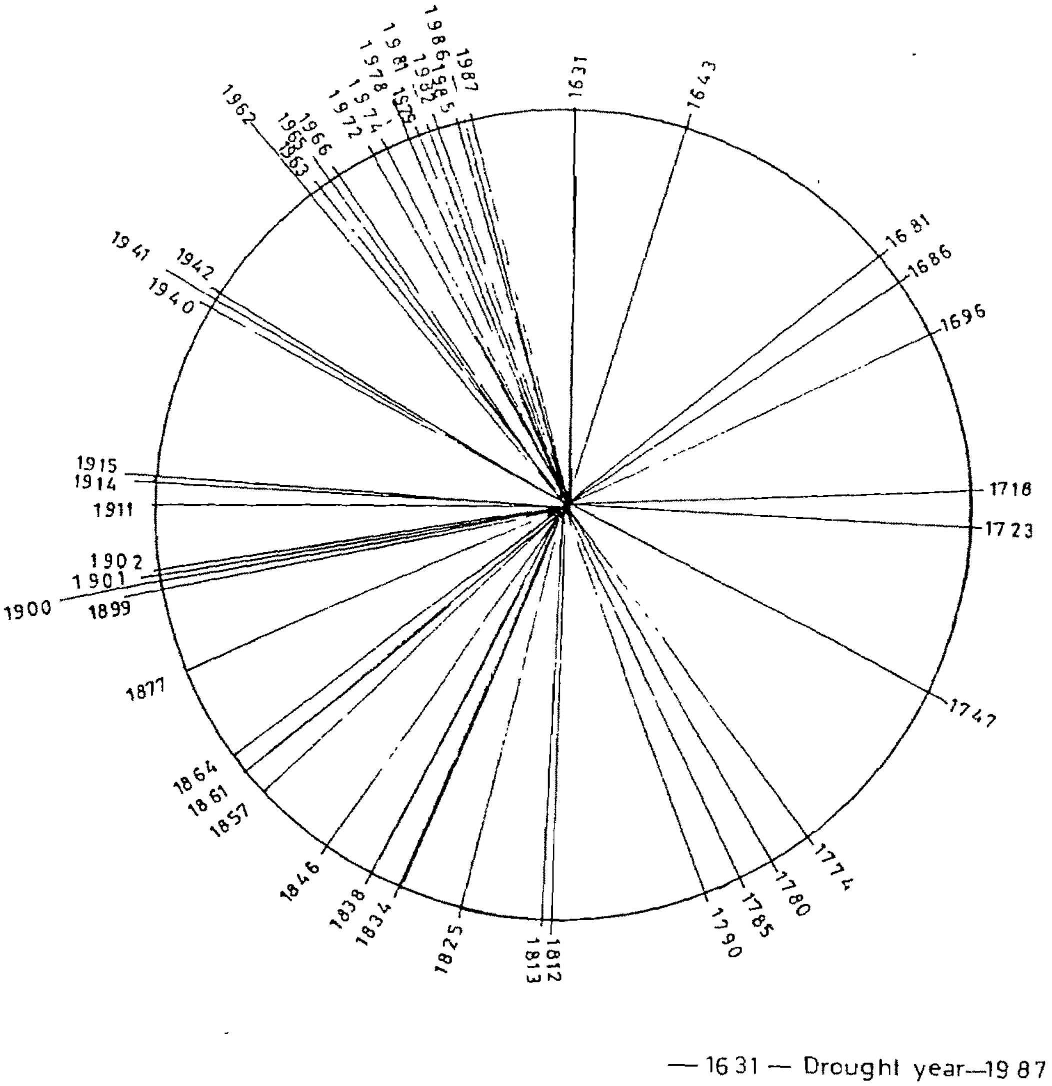


FIG. 51. DROUGHT ANALYSIS (1630-1990)

SOURCE: Gazetter of Junagadh dist, 1975,
Census handbook - Junagadh dist. 1981, 1982,
Govt of Gujarat, 1988

mechanisms that could be altered by climatic change are numerous and of great potential importance. Changes in climate could be expected to alter differentially the regeneration success and the growth and mortality rates of tree species. Alteration in the competitiveness of the various taxa is most likely to be manifested as a change in the forest composition. Changes in moisture conditions could alter fire probabilities and rates of wildfire spread.

Insects are very sensitive to climatic factors. Any change in the climatic variables such as temperature, rainfall, humidity, wind, sunshine, light, etc. has a definite effect on the development of insects. The population of teak defoliator (Hyblea puera) in a teak zone builds up to epidemic proportions during the hottest period of the year, namely from the last week of June to July, but gradually declines with the onset of monsoon; simultaneously, the population of skeletonizer (Eutectona machaeralia) increases and causes widespread defoliation during August to October (Beeson, 1991).

Seth (1954) discussed the pattern of drought damage and pointed out that two definite cycles could be discerned. One was a long-term effect, climatic and ecological in origin, leading to gradual xerophytism and consequent annual mortality. The other effect was a short-term one, depending upon sudden variations in local climatic factors, e.g. rainfall, leading to sudden mortality.

Teak (Tectona grandis) has been found to suffer badly in abnormal droughts but the damage is fatal especially in young saplings (Tewari, 1992).

A climatic gradient exists across the Gir and the eastern part receives at least 200 mm less rainfall as compared to the west. This discrepancy in rainfall input has been largely responsible for the disappearence of teak from the eastern portion (Berwick, 1974).

During 1986 and 1987, the Gir experienced severe droughts. There was high mortality among the populations of several plant species. Khan (1990) reported that the extent of tree mortality in different stratas of the Gir was to the mark of 20.01%. The plant species of girth classes 0-20 cm and 20-40 cm showed significantly high mortality.

Suggestions

Climate and rainfall pattern in any area do not have any human remedial measures.

The problem of erratic rainfall which has a direct influence on the availability of water in the Gir can be tackled by harnessing whatever precipitation that falls in the area. Therefore, adequate and appropriate water harvesting structures are a must. These are discussed, in detail, in a later part of this chapter.

For enhanced localized rainfall, cloud-seeding methods would be useful for this area. In fact, the state Government is going to embark on this mission, especially in the arid zones of Gujarat.

At least five well managed meteorological stations should be established in the study area. Long term monitoring of the climatic parameters would be of great help in the shaping of future management policies and strategies.

(II) SOILS

Soil and vegetation are integrally linked in a closed cycle, the damage or destruction of one brings about the demise of the other. The vegetation of the soil determines its micro-climate and also provides an umbrella against the attack by denuding water and wind. The roots of the trees and shrubs impart shear strength to the soil mantle.

The Gir Wildlife Sanctuary is predominantly composed of a rugged terrain. Precipitation is confined between the months of July-September when the area receives nearly 95% of its annual average rainfall. Within a short time span the large amount of rainfall, coupled with the ruggedness of terrain and absence of primary porosity in the underlying rocks, results in high soil erosion, especially along hill slopes and overgrazed areas around maldhari settlements.

Roads passing through the hills have exposed the soil profiles. Because of rain-splash erosion the roots are exposed (Plate. 40) and ultimately, the trees are uprooted. Such trees are susceptible to cyclonic winds which occasionaly sweep the Gir area during the post monsoon period.

In the post-monsoon period, for road repairing, soil is dug-out unevenly from road sides without considering the steep slopes. This augments soil erosion during the next monsoon.

Suggestions

Road-side slopes should be stabilized by a cover of rubble and fast-growing floral species. For road repairing, soil should be dug out by making rectangular pits in level lands along the road. Such pits will retain washed out soil, allow part of the rainwater to percolate in the ground and thus, decrease soil erosion as well as replenish the aquifers.

Other remedial measures like check dams, contour ridging, etc. are discussed in the water management aspect of this chapter.

(III) WATER RESOURCES

The optimal utilisation of water resources of any area involves sequential planning of a variety of aspects related to the terrain characteristics, socio-economic fabric, eco-environmental parameters and the existing practices of management. Before envisaging any management strategy to mitigate the demand it is essential that the problem and its magnitude be thoroughly understood.

PROBLEM PROFILE

In this context, the author has carried out an indepth study of various aspects controlling the distribution and availability of water resources. Their subsequent scrutiny has helped the author in the categorisation of the problem as under.

(A) Climate based

(1) All the water resources in the study area are exclusively rain-based, which is of highly erratic nature.

(2) The study area is under the influence of a rough 4-5 year drought cycle.

(B) Terrain based

(3) The terrain is highly rugged and a large area falls under the 'steep slope' category, thereby causing more surface run-off.

Plate 40 - Roots exposed by the construction of roads followed by soil erosion.

Plate 41 - Concentration of Chital (Herbivores) at an artificial cement-lined waterhole.

(4) Higher drainage density and affluent characteristics contribute towards more run-off.

(5) The predominance of geomorphic characteristics over the lithostructural fabric of the area has resulted in an unequal and localised availability/distribution of water resources.

(C) Resource based

(6) Low infiltration of rainwater due to thin veneer of soils.

(7) High order of fracture frequency and their subsequent interception at hill slopes have further reduced the water holding capacity of the aquifers by causing large scale sub-surface run-off.

(8) Rainfall being the only source, the study area experiences an acute shortage of water, particularly during the period between February to June.

(9) The availability of water is highly localised, dominantly confined to valley regions.

(10) In some parts of the study area, the groundwater has a high level of nitrate contamination, thereby rendering its quality unfit for drinking purposes.

(D) Eco-environmental based

(11) The localised availability of surface water is a limiting factor and causes unequal distribution of wildlife and ultimately, unequal utilisation of range resources.

(12) Due to paucity and limited number of waterholes, wildlife experiences local migration.

(13) During the drier months between February and June, the herbivores increase their group size at water holes and occupy shaded habitats close to it (Plate. 41).

(14) The concentration of herbivores around the water sources during the summer months causes a temporary shortage of forage in the area.

(15) Water deprivation changes the feeding habits of ungulates (Berwick, 1974).

(16) In the Gir forest seasons of breeding and birth of wild ruminants are closely related to periods of good forage and ample water (Berwick, 1974).

(17) thin an individual lion pride's territory, there are certain core areas which the lions prefer for resting and hunting. Such areas are usually located around water sources like pools (Plate. 42) or streams (Sinha, 1987). Water scarcity is one of the reasons for lions

Plate 42 - Lion pride resting near water pool in the core area of their territory.

Plate 43 - Over-grazing and lopping of trees around a maldhari settlement resulting in degradation of the eco-system.

wandering outside the sanctuary area. Water is usually the cause of internal lion territorial fights, and also clashes of interest between lions and people/livestock.

(E) Socio-economic based

(18) The sanctuary area also houses numerous pastoralists (locally known as 'the Maldharis'), and their settlements are located near perennial sources of water supply. This has resulted in a routine conflict between the Maldharis and wildlife.

(19) Overgrazing and lopping of trees has degraded the ecosystem within a 2.0 sq.km area around the permanent Maldhari settlements (Chavan, 1992, pers. comm.), thereby causing rapid soil erosion (Plate. 43).

(20) Some of the important perennial water springs are occupied by temple communities. Places like Tulsishyam, Banej and Kankai, attract thousands of devotees and tourists, thus disturbing the natural habitat of wildlife.

(21) These temple communities have their own livestock which adds to the pressure on wildlife.

(22) The unregulated tourists dispose-off their garbage, including polythene bags, into the nearby streams. They

also carry out their daily rituals in the streams, which in turn spoils the aesthetic value of the area while depriving the wildlife from using the scarce water resource.

(F) Management based

(23) The water resources in the study area are poorly recharged.

(a) Almost 90% of the total surface water input remains untapped and simply flows as stream run-off.

(b) Barring a few dug-wells and handpumps, the groundwater resources are largely underdeveloped.

DEVELOPMENT STRATEGIES

As has been discussed in the preceeding pages, the occurrence, distribution and duration of availability of water resources in the study area is attributed to a variety of parameters. Water being highly scarce, its impact on the eco-environmental regime has been witnessed. Hence, it would be worthwhile that before embarking on any developmental techniques, the gravity of the problem is fully understood. Having realised this very fact, the author's entire conceptualization of water resource development and management is based on the following principal objectives :

(i) As the study area is under the influence of a rough 4-5 year drought cycle, water scarcity is a major geo-environmental problem. In order to protect the endangered wildlife, the Forest Department has to transport water to more than 400 waterholes (Pathak, 1990; pers.comm.). Various types of containers of water have been used by the officials, as is evident in Plate. 44, 45 & 46. In order to mitigate the drought situation, the first consideration in water management should be the provision of adequate water points for wildlife.

(ii) These water points should be well distributed to facilitate the even distribution of wildlife, resulting in an even range utilization, thereby minimising heavy pressure in a particular zone.

(iii) The provision of adequate water for the human population and their livestock residing within the study area, to reduce the pressure on scarce natural water resources.

(iv) The study area has got a tremendous potential of surface water resource, but more than 90% of the total input remains unutilised.

Plate 44 & 45 - Various types of containers of water used for wildlife by the officials in the Gir.

Plate 46 - Artificial water hole provided by the officials in the Gir.

(v) The area provides excellent terrain conditions for harnessing this surface run-off.

(vi) Groundwater resource remains underdeveloped and the possibility of tapping the deeper aquifers are yet to be explored.

(vii) The area experiences an acute shortage of water during February-June months.

(viii) Its highly localised availability, has caused a tremendous eco-environmental imbalance.

(ix) Any development strategy to be adopted should help in releasing pressure from the physical and biological environment of a particular zone.

(x) The adopted technique should be of a sustainable nature, and distributed at all the altitudinal zones.

(xi) Multipurpose and cost-effective strategies involving the utilisation of locally available material should be adopted.

(xii) The maintanence should be with minimum efforts, and should contribute towards the microlevel development of the catchment areas.

APPROACH AND METHODOLOGY

The entire approach of tackling this aspect is based on the author's own hydrogeological framework of the study area and its subsequent categorisation from the view point of its groundwater potential. Seasonal and erratic water input, diverse terrain attributes, favourable litho-structural set-up and other geo-climatic parameters point towards the fact that no one uniform strategy is applicable for the study area. Hence, the author has adopted an '**Integrated Approach**' for water resources development.

The results of the studies on the water potential indicate that adequate water resources exist in the study area. Studies also indicate that there is adequate water, and hand pumps and dugwells would adequately cater for the water needs of the study area for which priority should be given. However, the sole aim should be to provide water at the surface for wildlife. Ideally, there should be one water point in every 4-5 sq.km area.

The attempted methodology of groundwater potential categorisation is founded on three basic factors viz. lithology, structural set-up and the geomorphic parameters. In the present set-up wherein the hydrogeological regime owes much of its characteristics to the geomorphic parameters, the identified categories of high, moderate and low potential reflect a simple water balance equation i.e. the factors governing the recharge and run-off. All the three categories have the following geomorphological relations and characteristics :

Categories	Characteristics
1. High potential	Valley fills, thick alluvial cover, gentle slopes, high infiltration, less run-off.
2. Medium potential	Pediments, shallow soil veneer, moderate to high slopes, balanced infiltration and run-off.
3. Low potential	Hill slopes, negligible soil cover, high to steep slopes, high surface run-off.

However, the following adverse and favourable factors have to be kept in mind :

Adverse features inhibiting the groundwater storage

1. Absence of primary porosity.
2. Steep slopes which favour high run-off and low infiltration.
3. Enhanced run-off due to poor soil cover.
4. High density of drainage network which facilitates rapid run-off.
5. Topographic constraints help in providing spring conditions, draining away the upper aquifers.

6. High intensity of fractures which favours spring discharge and seepage.
7. Affluent nature of rivers and streams which continuously draw water from higher level saturated zones.
8. Paucity of dykes running across the main flow direction of groundwater.

Favourable factors for the availability of groundwater

1. Top weathered layers of lava in flat areas tend to form phreatic aquifers.
2. Localized fractures and shear zones produce sizable aquifers due to increased secondary porosity.
3. Lava flow contacts and miliolitic limestone along valleys form fairly extensive lateral aquifers.
4. Dykes running across the major fracture direction of lava flows check and store groundwater.
5. Intersection of dykes/lineaments which govern the groundwater flow.

The previously mentioned categorisation depending upon adverse and favourable factors provides an important basis for scrutinising the study area. Hence the author's adopted 'Integrated Approach' for water resources development is simply based on the logic that :

(i) The area exhibiting low groundwater potential can only be developed by means of harnessing the surface water resource.

(ii) The category of medium groundwater potential can be developed by managing surface water resources supporting the aquifers through continual recharge.

(iii) The high potential category has got better recharge conditions and their homogenity in the hydrological parameters can be exploited in a better way. Further, more groundwater resources can be developed by exploring the deeper fracture controlled aquifer systems.

Thus, this proposed inter-dependent rainall and groundwater management strategy in the study area would be of double benefit. During the drought years, one can depend upon the assured availability of groundwater. The excess water e.g. available during an unexpected downpour in a short duration; instead of allowing it to be lost as simple run-off, could be used to recharge the aquifers adequately. The conjunctive use of the water would provide an important mean of water resources management.

Conceptually to achieve an assured supply of water round the year, a short period input of a few rainy days has to be harnessed. Meagre groundwater resources can be improved with surface water development schemes. Delayed recharge from surface schemes will provide a sustainable supply to the groundwater.

RAINWATER HARVESTING STRUCTURES

The rainwater harvesting structures have got multifold objectives viz :

(i) They enhance the groundwater recharge, thereby facilitating a net increase in groundwater storage.

(ii) They provide additional surface water storage facilities.

(iii) Help in minimising the surface run-off.

(iv) They are an excellent mode of mitigating soil erosion, flood hazards, etc.

(v) Help in checking high evaporation losses.

(vi) They serve as an important mean of catchment area development.

The terrain characteristics and feasibility of rainwater harvesting structures in the study area are :

(1) Surface runoff occurs during a very short duration, while the subsurface runoff extends for a few months following the monsoon.

(2) Topographic and drainage conditions are suitable for runoff harvesting.

(3) Small scale operational units in terms of catchment, storage and capital investment.

A summary of different types of rainwater harvesting structures alongwith their requisite site conditions and engineering features are given in Table : 29.

WATER DEVELOPMENT

In order to have sustainable utilization of water resources, a number of rainwater harvesting structures have been suggested.

Rainwater Harvesting Structures can be classified as below :

(1) Surface type
   - Structures storing surface water.

(2) Combination type
   - Structures for harnessing surface as well as subsurface water.

(3) Subsurface type
   - Structures for exploiting groundwater only.

A few important rainwater harvesting structures of the above three categories are briefly discussed below.

SURFACE TYPE

(1) Storage Tank (ST)

This structure is similar to a village pond. However, the

Table - 29

Geotechnical features of rainwater harvesing structures (modified after Tiwari & Patel, in press)

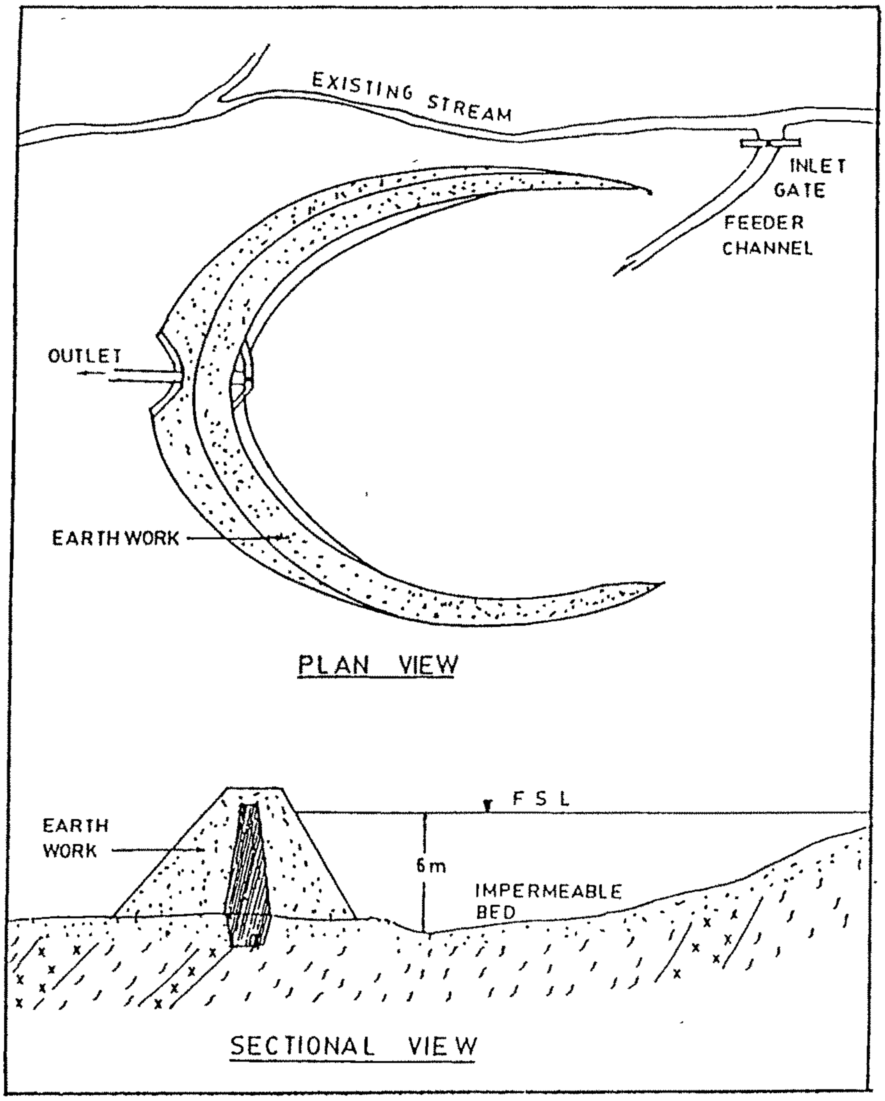
STRUCTURE	PURPOSE	SITE CONDITIONS	ENGINEERING FEATURES
Storage tank (ST)	Open storage for wildlife/cattle needs and forestry purposes.	Rocky impervious bed, well defined stream channel and catchment.	Oval or rectangular shape, approx. 5000-10000 sq.m area and about 5-8 m deep. Adequate spillway provision.
Storage Trough (STr)	To store rainwater for wildlife.	Gently sloping topography or plateau conditions; ill-defined catchment.	Oval or cresent shaped sloping trough with an approx. dimension of 20x10x5 m and foliage cover for preventing the evaporation losses.
Check Dam (CD)	Recharge to aquifer, forestry operations and soil conservation.	Well defined stream channel and banks, sizable catchment, river bed essentially rocky.	2-4 m bank height, masonry structure, provision for monsoonal discharge, partial treatment to foundation.
Gully Plug (GP)	Recharge to aquifer and soil conservation.	Narrow stream channel, substantial thickness of alluvium, well defined banks.	5-8 m height, masonry structure with central spilling arrangement, guiding and training of walls.
River Well (RW)	Harnessing river base-flow for forestry, wildlife and domestic needs.	Well defined stream banks, natural pool/flow conditions.	2-5 m deep, 4-5 m diameter masonry structure, suitable pumping, reasonable lead and lift.
Percolation Tank (PT)	Recharge to aquifer and surface storage for wildlife/domestic need.	Porous and permeable bed, well defined broad stream channel and or large ground depression, away from habitation.	3-5 m depth, 5000-10000 sq.m area, shallow cut-off, earthen bunding, silt trap barrier in catchment, spilling arrangement, provision of an open well in the downstream of this tank.
Contour Ridging (CR)	Check surface run-off and soil erosion, augment soil moisture content, plantation on hill slopes.	Moderately sloping terrain with good soil cover.	Trenching and ridging of 1 m height at an interval of 5-10 m.
Subsurface Dam (SD)	River base-flow conservation and recharge to aquifers, domestic needs, protection to evaporative losses.	Broad flat sandy-gravelly stream bed, well defined channel and underflow.	Providing an impervious barrier across the sandy-gravelly bed.
Natural Pool (NP)	Open storage for wildlife, recreation purposes.	Knick point, water fall, pot holes, sandy river channel located in rocky river bed.	Excavation and/or little training-guiding of the sides.

structure differs from area to area as per the conditions. It needs about a 5-6 m deep excavation through overburden and top weathered rock, and the excavated earth is to be used for bunding (Fig. 52). The bund can have an impervious cut-off and core. A regulating sluice gate can ensure controlled filling arrangements from a nearby stream. The storage will have least amount of seepage looses but the evaporation loses are inevitable.

In hilly savanna, with a sparse tree cover and impermeable basalts as the base, nearly all the rain runs off and is rapidly lost in the pediments surrounding the hills. In such areas, an additional input can be made by building 25-30 cm high masonry walls to guide the run-off into the storage tank.

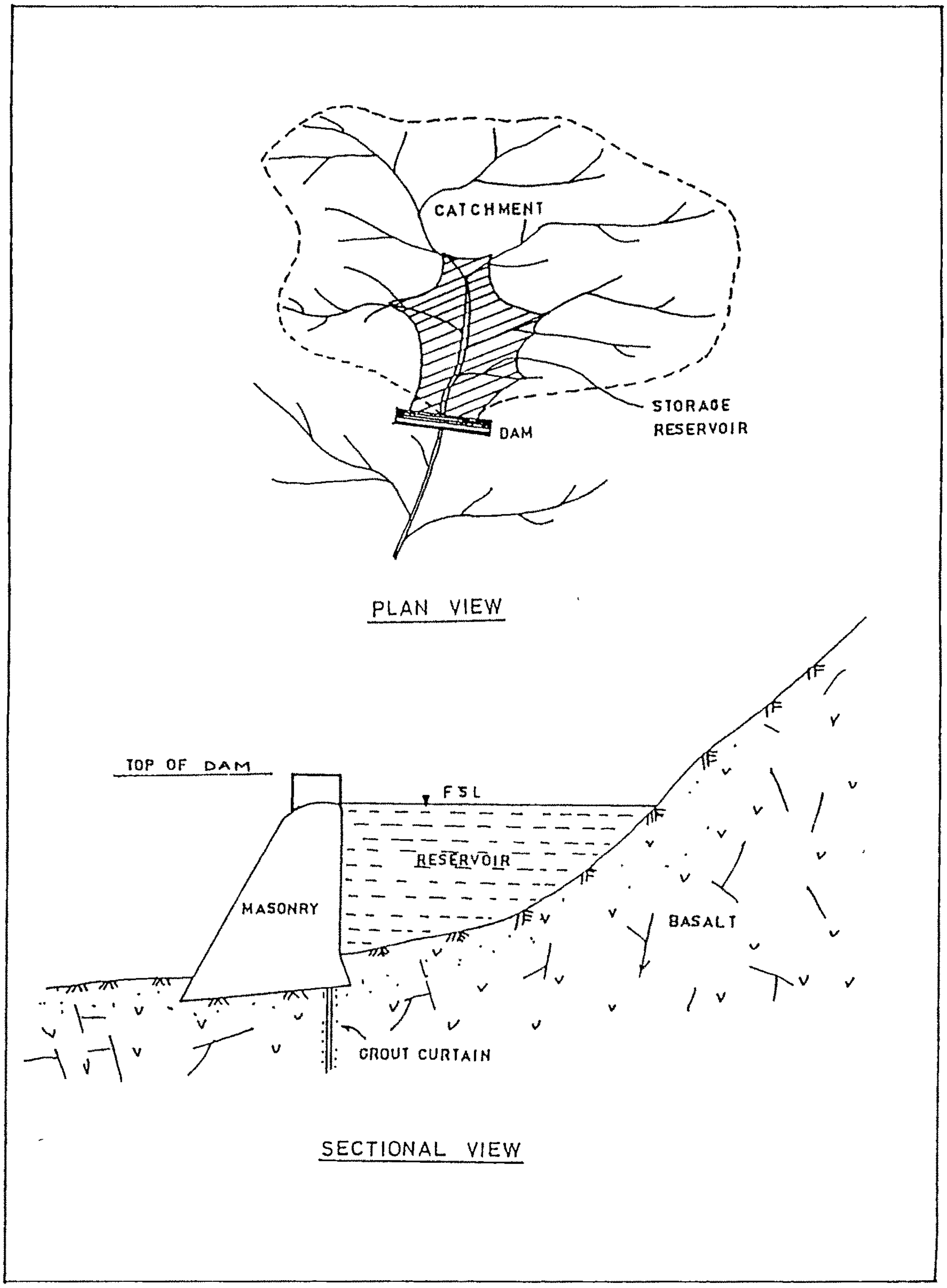
(2) Storage Trough (STr)

This structure can be constructed in areas having gently sloping topography or plateau conditions, with an ill-defined catchment. An oval or crescent shaped sloping masonry structure with an appropriate dimension of 20 x 10 x 5 m is usually located on the rolling topography (Fig. 53). A bamboo/wood and foliage cover is provided for preventing evaporation losses.



(after Tiwari & Patel, 1988)

FIG. 52. SCHEMATIC DIAGRAM OF STORAGE TANK



(after Patel & Tiwari 1987)

FIG. 53 SCHEMATIC DIAGRAM OF STORAGE TROUGH

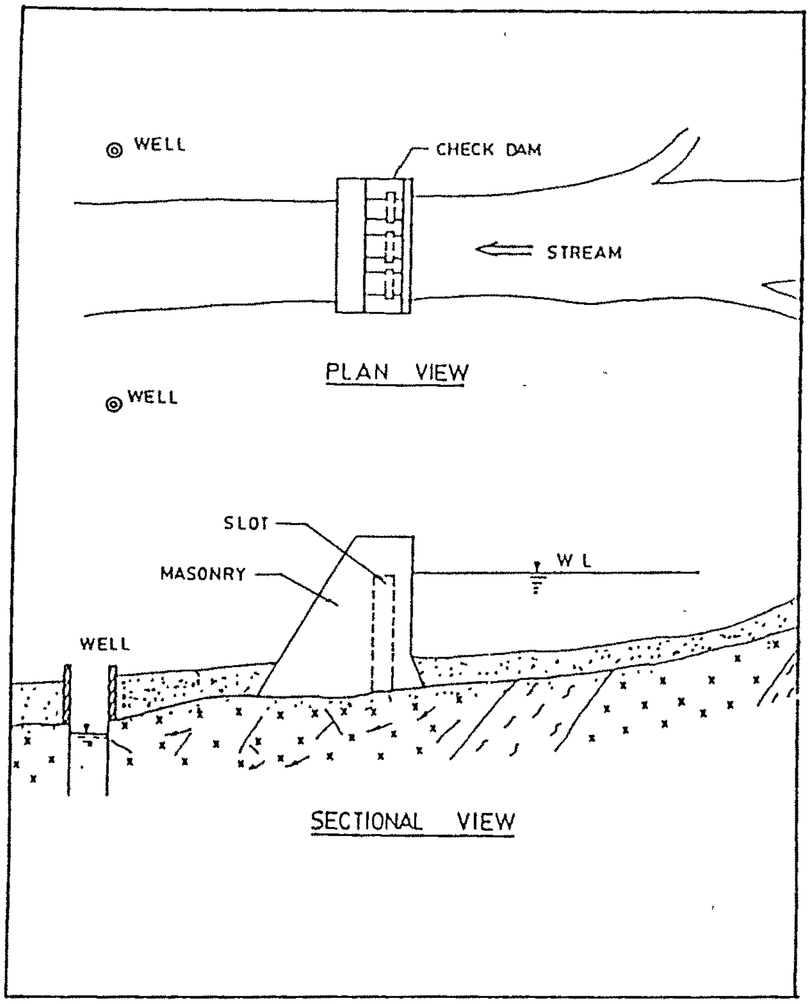
(3) Check Dam (CD)

Check dam is a masonry barrier across a defined 3rd/4th order stream channel, with 3 to 4 m high banks (Fig. 54). This structure can be erected in the straight segment of a channel. It needs a shallow foundation with fresh rock conditions and very little or no foundation treatment. The sluices provided in the structure, allow the flow to be collected behind the dam by plugging the slots with wooden planks. Alternatively, the structure can be of monolithic masonry work, wherein the excess floodwater can simply spill-over. Such a structure can be a bit costly, but it does not need any man power for managing the sluices.

The water storage seeps through the stream bed and it continues to recharge the adjacent aquifers till the stream under flow is active. This creates delayed recharge conditions, generating a groundwater command in the neighbourhood. Water supply can be planned by providing open well/ handpumps in the command.

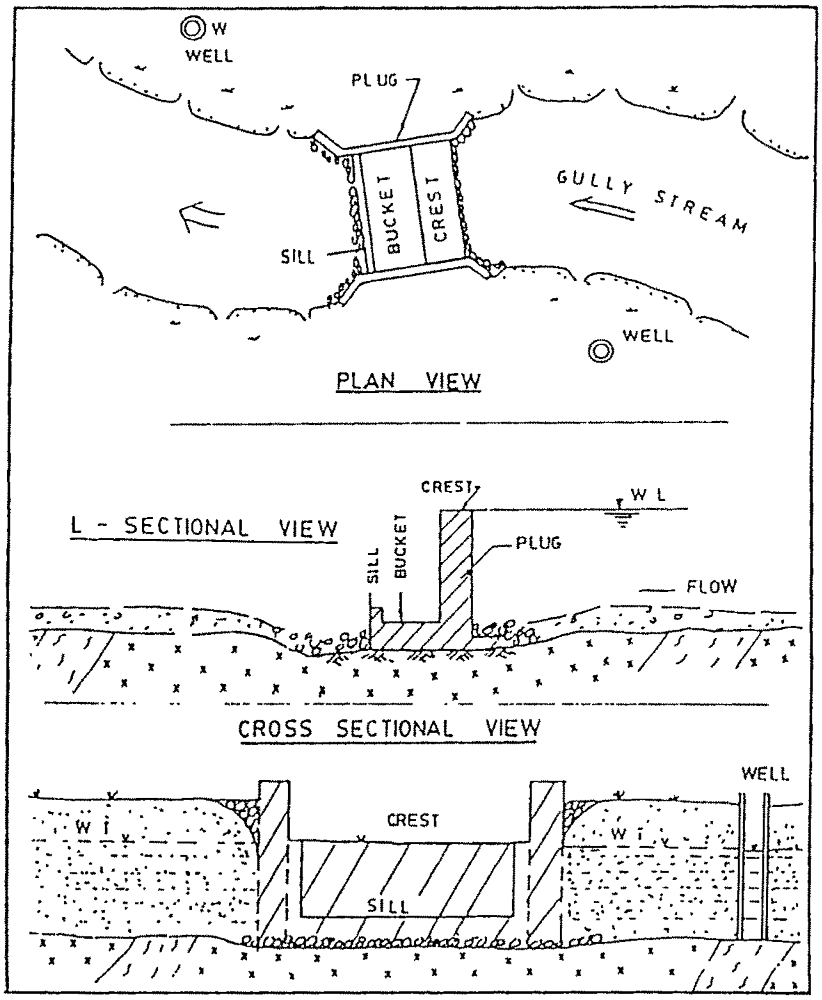
(4) Gully Plug (GP)

Deeper channel cuttings by the streams can be utilized for augmenting groundwater recharge. These structures are of overflow type viz. weirs, founded on the bed rock across the gully (Fig. 55). The gully banks are generally 4 to 6 m high. In some cases, the steep banks rise more than 10 m high. The



(after Tiwari & Patel, 1988)

FIG. 54. SCHEMATIC DIAGRAM OF CHECK DAM



(after Tiwari & Patel, 1988)

FIG. 55. SCHEMATIC DIAGRAM OF GULLY PLUG

earth on the bank is made up of softer and highly porous permeable material. The plug creates a small water pool along the channel and the stored water recharges the groundwater in the vicinity. The wells in the recharge zone can be developed on the same lines as the check dam supported wells.

COMBINATION TYPE

(5) River Well (RW)

It is a common technique being practised by the farmers and can be grouped under combination type. Such a scheme should meet certain site conditions as below :

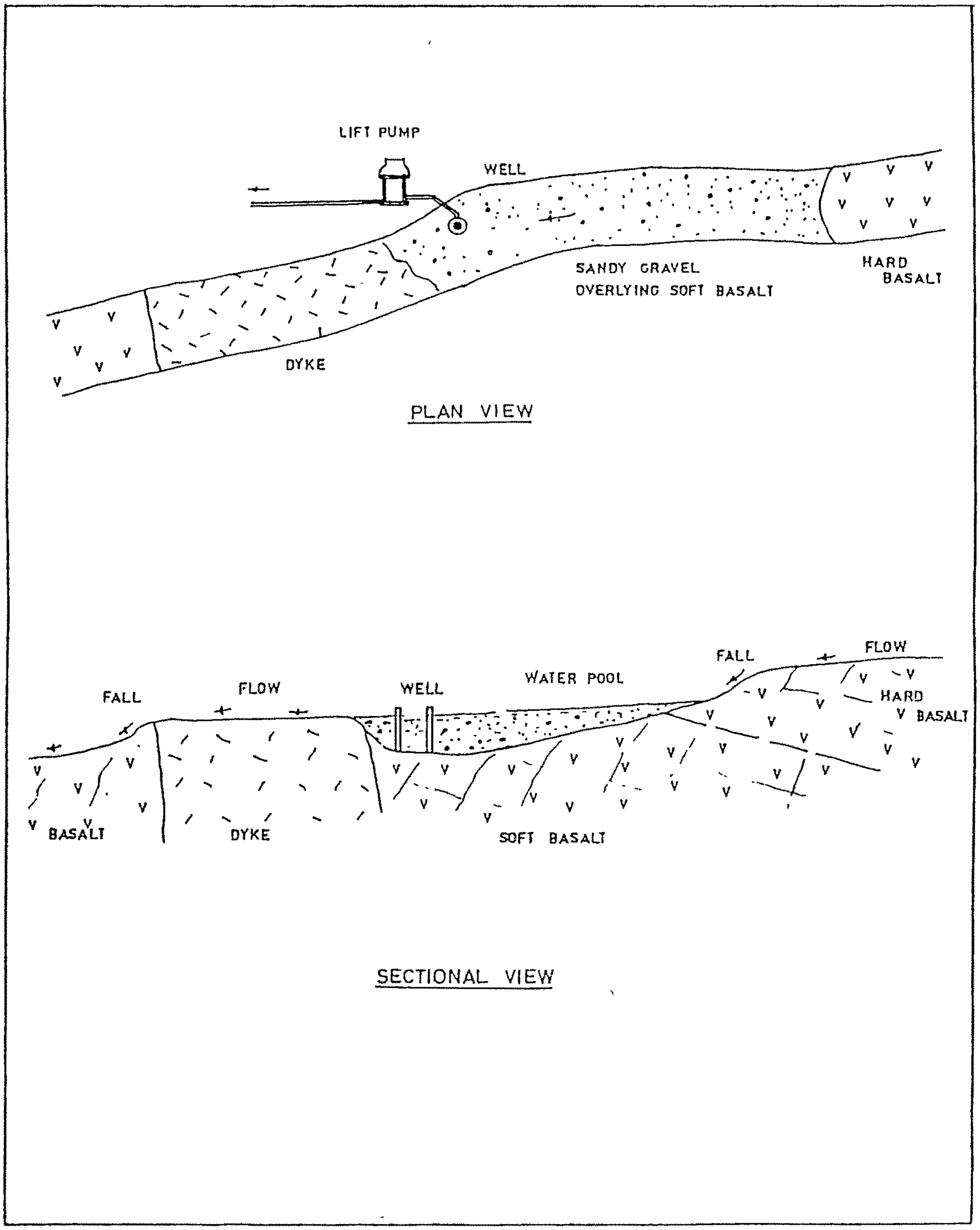
(i) lead and lift should be of minimum order, and

(ii) cliffy river bank with a thick cover of sand-gravel.

These river wells (Fig. 56) can be fitted with diesel engines to draw the water for filling up the troughs/water points and other requirements.

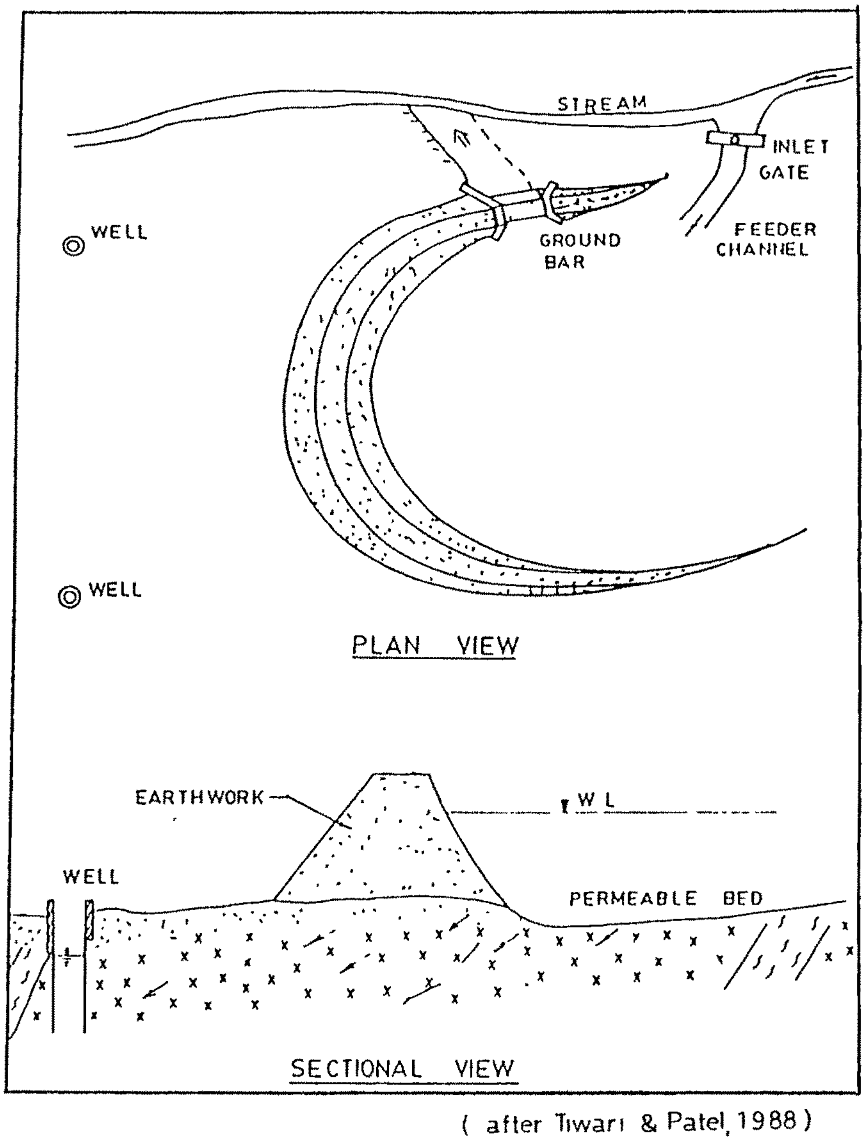
(6) Percolation Tank (PT)

This is a storage-cum-recharge structure (Fig. 57). A direct open outlet for forestry purposes can be provided from the free storage, and the bed seepage from the tank can augment recharge to the aquifers. The groundwater storage can be utilized during summer.



(after Patel & Tiwari, 1987)

FIG. 56. SCHEMATIC DIAGRAM OF RIVER WELL



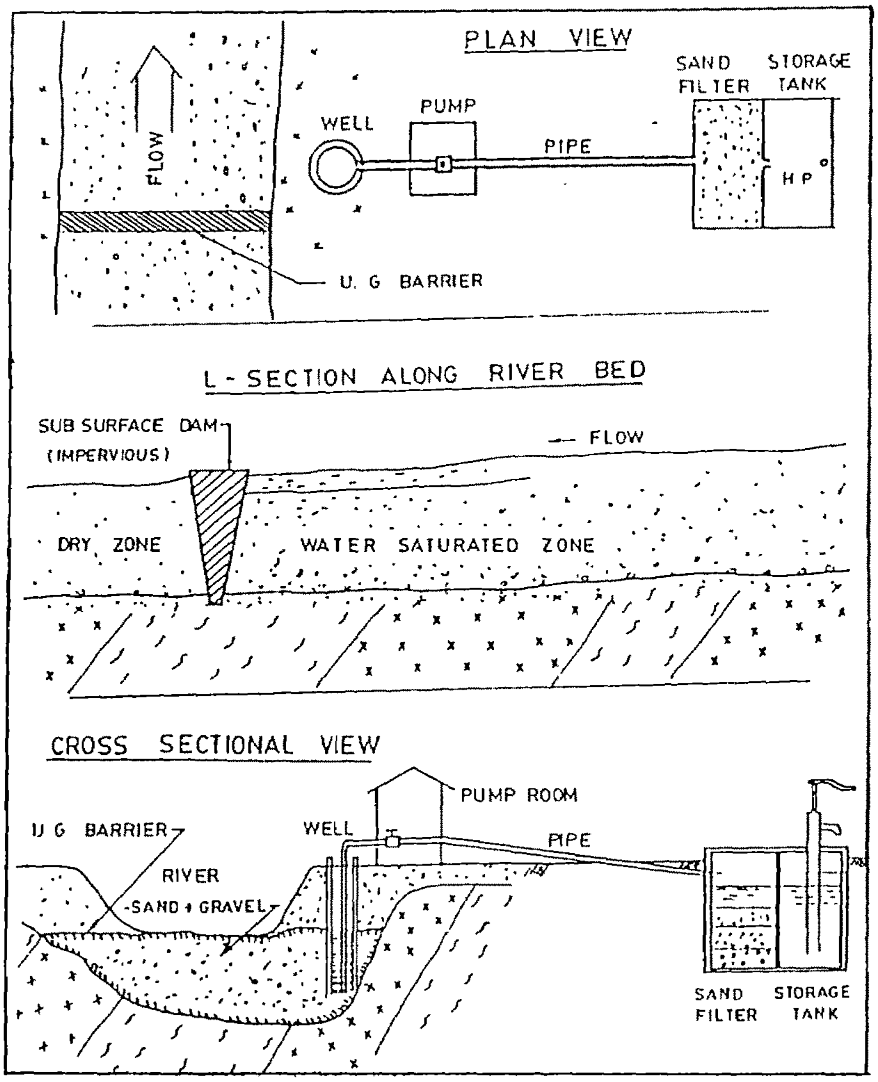
(after Tiwari & Patel, 1988)

FIG. 57. SCHEMATIC DIAGRAM OF PERCOLATION TANK

The site for a percolation tank can be selected in an open degraded land. The overburden above the bed rock is removed and used for bunding. The exposed rock is generally capable of high percolation rate, recharging the surrounding aquifers. Nearby streams can be used for constructing a feeder channel. Proper overflow arrangements should be provided. In some cases, 2nd/3rd order streams, with porous and permeable beds, can also be utilized to develop a percolation tank.

(7) Subsurface Dam (SD)

This is a simple technique of checking the underflow/base-flow of the river and storing it within the sandy bed (Fig. 58). A trench across the identified river bed section with a thick sand/gravelly pocket is excavated upto the bed rock depth - and back filled with impervious soil/clay. The width of the trench can be 1 to 2 m, depending upon the site conditions. The soil filling can be raised upto the top of the sand bed, and a protective rubble pitching cover could be provided. The subsurface impervious clay barrier will act as a dam, storing water within the sandy bed. These subsurface barriers are beneficial as they serve dual purposes viz. (i) they are an important source of good quality water, (ii) as the stored water is within the intergranular spaces of the sand/gravel, its evaporative loss is extremely low.



(after Tiwari & Patel, 1988)

FIG. 58. SCHEMATIC DIAGRAM OF SUBSURACE DAM

(8) Contour Ridging (CR)

On a gently sloping ground or rolling topography, the rocks are covered with a very thin cover of soil and weathered rock debris. The monsoon water is hardly retained in the subsurface zones. There are extensive areas of such types of landforms. Various designs exist for micro-catchment development through contour ridging and trenching. As shown in Fig. 59 & 60, they may be simple ridges running parallel to the contours on steeper slopes, or squares with one corner pointing down the slope. In each case, the effect is the same i.e. the runoff is concentrated and allowed to infiltrate. A series of appropriately spaced trenches keep the ground wet and moist for a longer period. Such a system can be used to recharge the groundwater. The increased moisture content thereby helps grassland and/or scrub development.

(9) Natural Pools (NP)

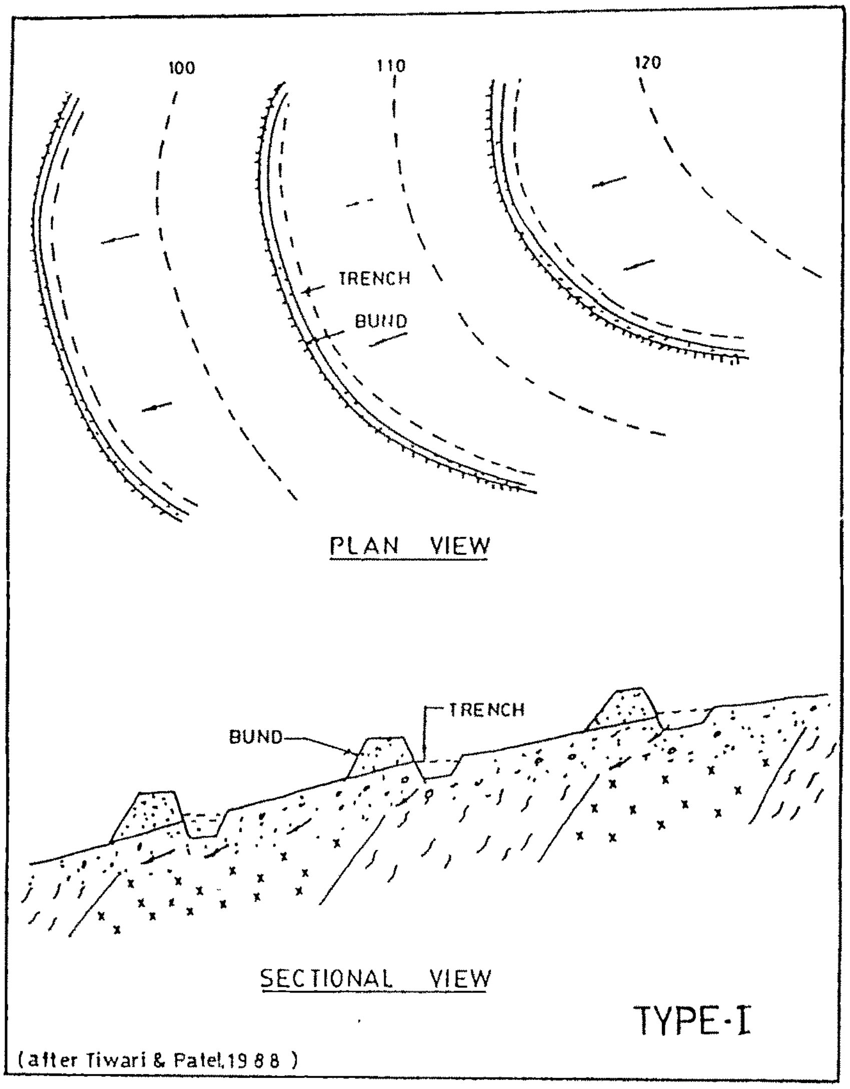
Natural water pools in the study area owe their presence to two vital parameters viz. lithostructural setting and topographic ruggedness. The formation/development of these natural water bodies is attributed to the following factors :

(i) the presence of knick points (Plate. 47),

(ii) presence of water falls,

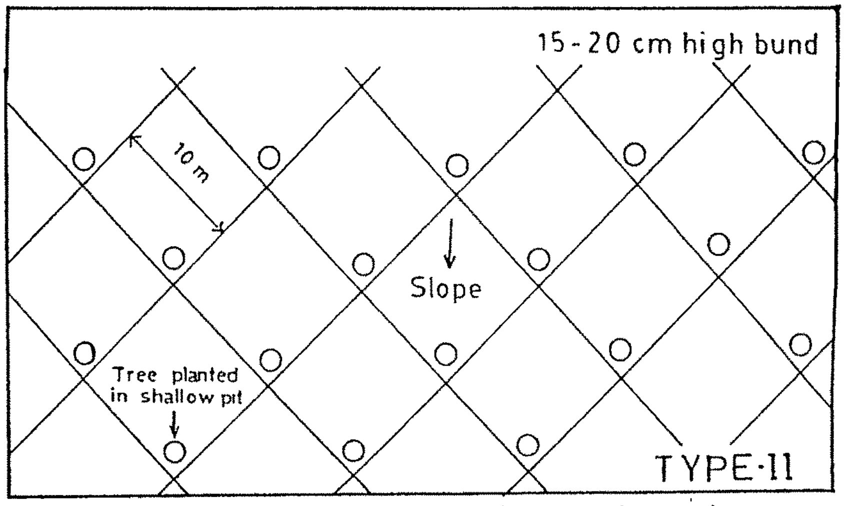
(iii) depressed channel segments between projected rock masses (Plate. 48), and

FIG. 59.



SCHEMATIC DIAGRAM OF CONTOUR RIDGING

FIG. 60.



(after Lusigi, 1983)

Plate 47 - Natural water body formed by knick point.

Plate 48 - Depressed water channel.

(iv) large sized pot holes (Plate. 49).

In the study area all the major streams are riddled with numerous pools of large and small dimensions, and constitute an important source of water for the wildlife. However, barring some big pools, a majority of them are ephemeral in nature. The author has observed that these ephemeral pools can serve as an important mean of surface water storage. This can be achieved by careful selection of pools, whose dimensional surficial area can be enlarged by means of excavation and/or little training-guiding of the sides. These modified pools will certainly help in mitigating the water shortage.

Catchment protection

Catchment protection involves activities which are undertaken mainly in the upper reaches of stream networks in order to preserve the natural hydrological characteristics of the catchments. At the same time, soil loss from the catchment is reduced and the vegetation cover is maintained or increased. Typical activities involve (working in a downstream direction) constructing heaped stone checkdams in small, headwater gullies at intervals of, say, 30 m; weirs in channels of over 4 m width at intervals of about 10-200 m; and dams on the larger stream channels of upto 30 m width.

The purpose of these structures is basically to reduce the sediment yield in the rivers by slowing the velocity of the water. More water is thus made available for use by wildlife, vegetation and for recharge of shallow depth aquifers. The duration of flow in the ephemeral streams can be prolonged if more water is initially retained in the soil and sediment, and then released more slowly.

To be effective, catchment protection works must be intensive and widespread. Soil conservation activities on slopes should be integrated with the work in the stream channels.

Protection works should begin with badly degraded catchments and the areas around settlements where gully networks are forming, especially near roads.

GROUNDWATER RESOURCES DEVELOPMENT

As mentioned earlier, the study area possesses a high potential for groundwater resources. Being a sanctuary area, with many restrictions, this vast resource has not been explored/exploited fully. This has been proved by the presence of dugwells in the study area, of which many are perennial in nature. The unequal distribution of groundwater resource and unsustainable yield, is attributed to the strong influence of geomorphic characteristics over the hydrogeologic regime of the study area.

Plate 49 - Four-horned antelope at a water pool formed in a pot-hole.

Plate 50 - Cemented dug-well.

However, at places, the combination of litho-structural set up and geomorphic parameters have produced a conducive environment for the development of a potential aquifer system. Of course, such potential zones are few but, a systematic approach of exploring the possibilities of such aquifers would certainly help in minimizing the water scarcity.

The author's approach of groundwater resource development is based on the following points :

(i) The study area being in Deccan Trap country, comprises of numerous lava flows.

(ii) Interflow surfaces, vesicular basalt, fractured and weathered basalt are the ideal locales of potential aquifer systems.

(iii) The terrain exhibits a strong influence of tectonism, and is reflected by the high order of fracturing, high lineament density and the large number of dykes. All these have rendered the rocks more porous and permeable.

(iv) The sanctuary area is not having a single well tapping the deeper aquifers, but the possibility of encountering such aquifers cannot be ruled out.

(v) The area being a typical hard rock one, the entire channelisation and storage of groundwater is dominantly regulated by the fractures and joint systems.

(vi) Study area being categorised under the semi-arid climatic zone, has ample scope for the use of "Hydro-botanical Indicators", in groundwater exploration.

(vii) The overall maintenance cost of groundwater extraction structures is lesser than any surface water scheme, and the water is generally of good quality.

The proposed groundwater structures are briefly discussed below.

(1) Dug-Well

Dug well (Plate. 50) is the most common and popular mode of groundwater extraction. It has been greatly favoured as it is shallow in depth, taps a large aquifer volume, and is a highly cost effective technique. Usually a dugwell penetrates the soil, weathered rock, fractured rock and ultimately reaches the massive rock i.e. the `aquifuge'. Basically these wells are tapping the vadose water, a resource subjected to seasonal fluctuation, and have a moderate yield. However, a well located at a proper site can be a source of a copious supply of water. Basalt being one of the most favoured rock from the potential aquifer point of view, obtaining an ideal well location is not a difficult task.

Depending upon the nature of the rock type of the well bottom, if conditions are favourable, a well can be improved either by deepening, or by putting radial bores (Fig. 61) from the bottom i.e. dug-cum-bore well.

Following improvement measures are possible in a dug well :

(1) Radial horizontal drilling at the bottom, if fractured rock is available. This technique is being practised very commonly in the Trappean terrain of Saurashtra.

(2) Augmenting the recharge through a nearby rainwater harvesting structure, like percolation tank, check dam, gully plug, etc.

(3) Location of a new well after proper hydrogeological and geophysical studies.

(4) Appropriate selection of the pump to match the hydraulic characters of the aquifers.

In some cases, fractured rock is found around the well site. If horizontal drilling from the bottom of the large diameter well is carried out, this would cross the fractures of the adjacent rock. Water from these fractures can be tapped into collector well. Several such holes can be drilled in a radial manner for appropriate lengths. This is a promising technique for achieving high potential and/or revitalization of the well yield.

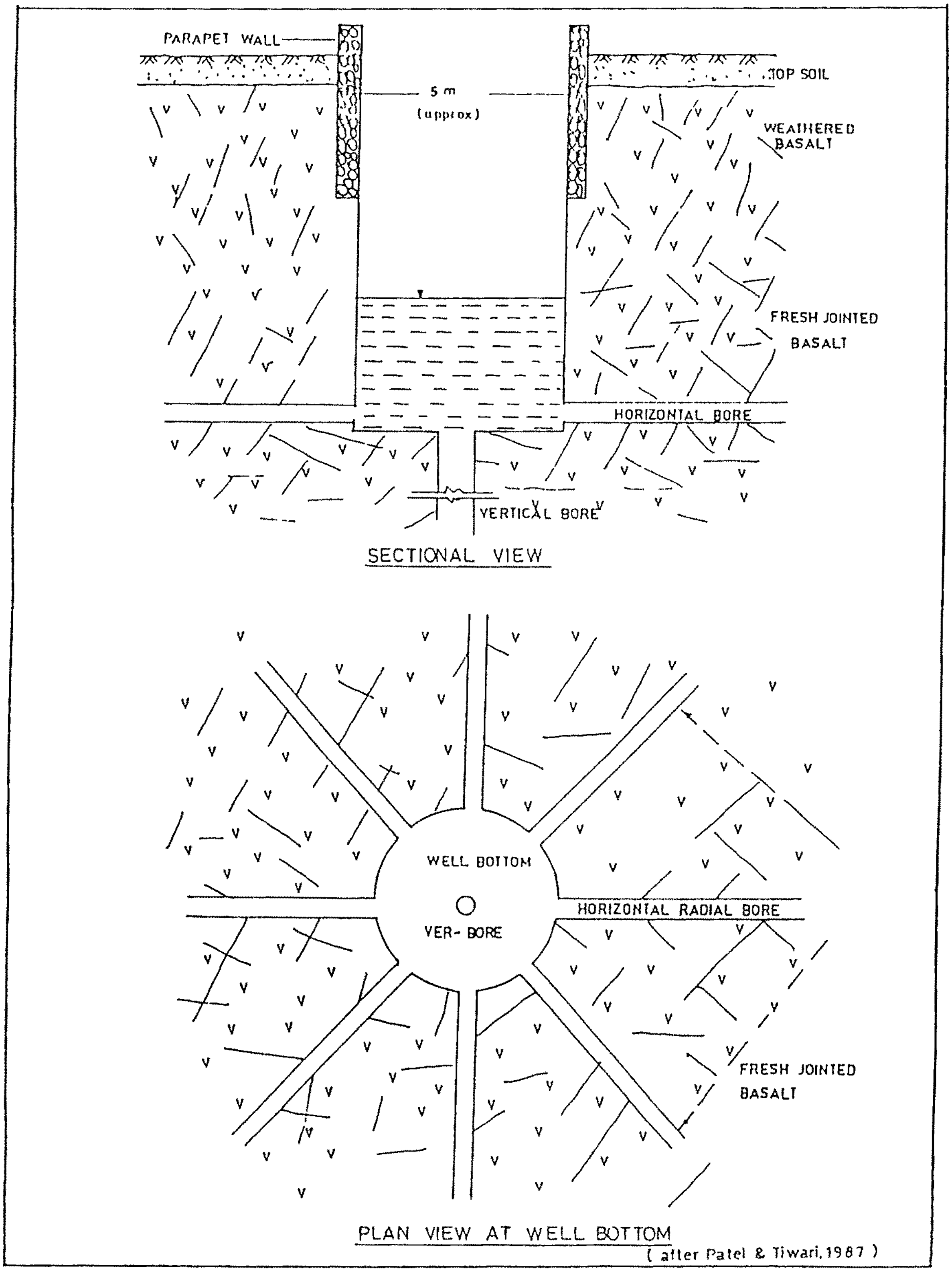


FIG. 61. SCHEMATIC DIAGRAM OF OPEN WELL WITH RADIAL BORES

(2) Bore Holes and Handpumps

Bore holes and handpumps (Plate. 51) in this area are important because the successful ones are a reliable source of water supply. Deeper aquifers with semi-confined conditions can be tapped by drilling bore holes to a depth of 100-130 m or so. There is a very good scope for locating some more bore holes, to which handpumps can be fitted. The study area does contain quite a good number of hand pumps, but many of them require proper maintenance.

In order to draw the water from a bore hole, the advantage of non-conventional energy sources like wind and sun light can be harnessed. The study area's climatic data shows that the average annual wind velocity is > 10 km/hr, which is highly favourable for operating a wind mill. The possibility to install a few wind mills can be explored by monitoring this resource at various localities in the study area.

Methodology for well site selection/groundwater prospecting

In order to select a potential site for sinking a dug well or bore well, it is essential to review the available data. The hydrogeological categorisation of the study area shows that all those areas falling under high potential category can meet the water demand in a `shortage period'. For achieving this objective, proper identification of the well site is of prime importance. Geological methods can help in scrutinizing

Plate 51 - Hand pump which is commonly used for exploiting groundwater.

the area, but to have a pin-point location, it has to be further substantiated by other techniques viz. hydrobotanical and geophysical surveys.

The use of bioindicators in search of potential groundwater locales has been practised since Vedic times. Varahmihira (A.D. 505-587), in his magnum opus Brihat Samhita (Master Collection), through certain fundamental laws of tropical ecology, has described the hydrologic indicators consisting of various biologic and geologic interactions in a microenvironment overlying a groundwater reservoir in an arid or semi-arid region (Prasad, 1984). He has identified numerous plants and other life forms, and has considered them as 'the sinoquin' of potential aquifer system. His study has been based on certain observed characteristics and floral anomalies attributed to morphological and mutational changes, symbiotic growth and relative positioning of the plants. Varahmihira (A.D. 505-587) has further categorised these bioindicators from the point of view of the aquifer position, direction, depth, yield and its potability.

The occurrence of 'termite mounds' and their position has been considered as one of the important indicators for groundwater prospecting. The author while doing his fieldwork had observed this fact, and an attempt was made to check the validity of these bio-indicators by other scientific techniques, especially geophysical methods.

The study area being a hardrock terrain, the movement and storage of groundwater is predominantly confined to the fractures. It is also a known fact that all the fractures are not water bearing. Only a few fractures of regional continuity are water bearing and are commonly known as "hydrofractures".

Termites are well known as highly heat sensitive pests, and for colonization and mound construction, they favour areas of high moisture content with a cool subsurface. In the study area, the author had observed a large number of termite mounds of various shapes and sizes (Plate. 52). These termite mounds exhibited a consistent linearity in different orientations, which were essentially indicative of the presence of buried hydrofractures.

In order to establish a correlation between the streaks of termite mounds and aquifer conditions, the author had selected two different site conditions :

(1) sites located at the intersection of two termite streaks, and (2) sites located away from the termite streaks.

Vertical electrical soundings (VES) (Plate. 53) were carried out at both the site types. The subsequent interpretation of the data generated has yielded the following results (Table : 30 & Fig. 61a&b) :

Plate 52 - Termite mounds : A bio-indicator of groundwater in the study area.

Plate 53 - Vertical electrical soundings used to verify the validity of bio-indicators

Table – 30

Results of resistivity soundings

Geo-electrical details		Site types & Locations									
		At the intersection of termite streaks					Away from the termite streaks				
		Devaliya	Tahdi	Dudhala	Karamdadi	Wansali	Kansvidi	Loki Nes	Sasan	Lilapani	Gola
Layer-I	A	370.00	052.00	058.00	032.00	023.00	095.00	040.00	025.00	027.00	260.00
	B	001.50	002.10	003.00	010.00	004.00	001.50	010.00	009.50	004.00	006.10
Layer-II	A	092.50	294.00	031.20	128.40	075.90	380.00	280.00	008.50	189.00	1040.00
	B	010.53	005.25	042.00	025.00	010.00	030.00	022.50	015.00	012.00	039.65
Layer-III	A	185.00	126.00	071.80	2432.00	1442.10	760.00	532.00	321.00	3591.00	520.00
	B	052.50	007.90	042.00	∝	040.00	030.00	022.50	060.00	018.00	∝
Layer-IV	A	495.00	188.00	406.00	–	2884.00	∝	425.00	∝	10000	–
	B	026.00	015.75	031.00	–	∝	–	016.90	–	013.50	–
Layer-V	A	405.00	1700.00	332.00	–	–	–	∝	–	1000.00	–
	B	∝	015.75	∝	–	–	–	–	–	∝	–
Layer-VI	A	–	2077.00	–	–	–	–	–	–	–	–
	B	–	∝	–	–	–	–	–	–	–	–
Recommendations :		Bore well	Dug well	Bore well	D.C.B.	Dug well	Bore well	Bore well	Bore well	Dug well	Bore well(?)

A = Resistivity in ohm/m **B = Layer thickness in m**

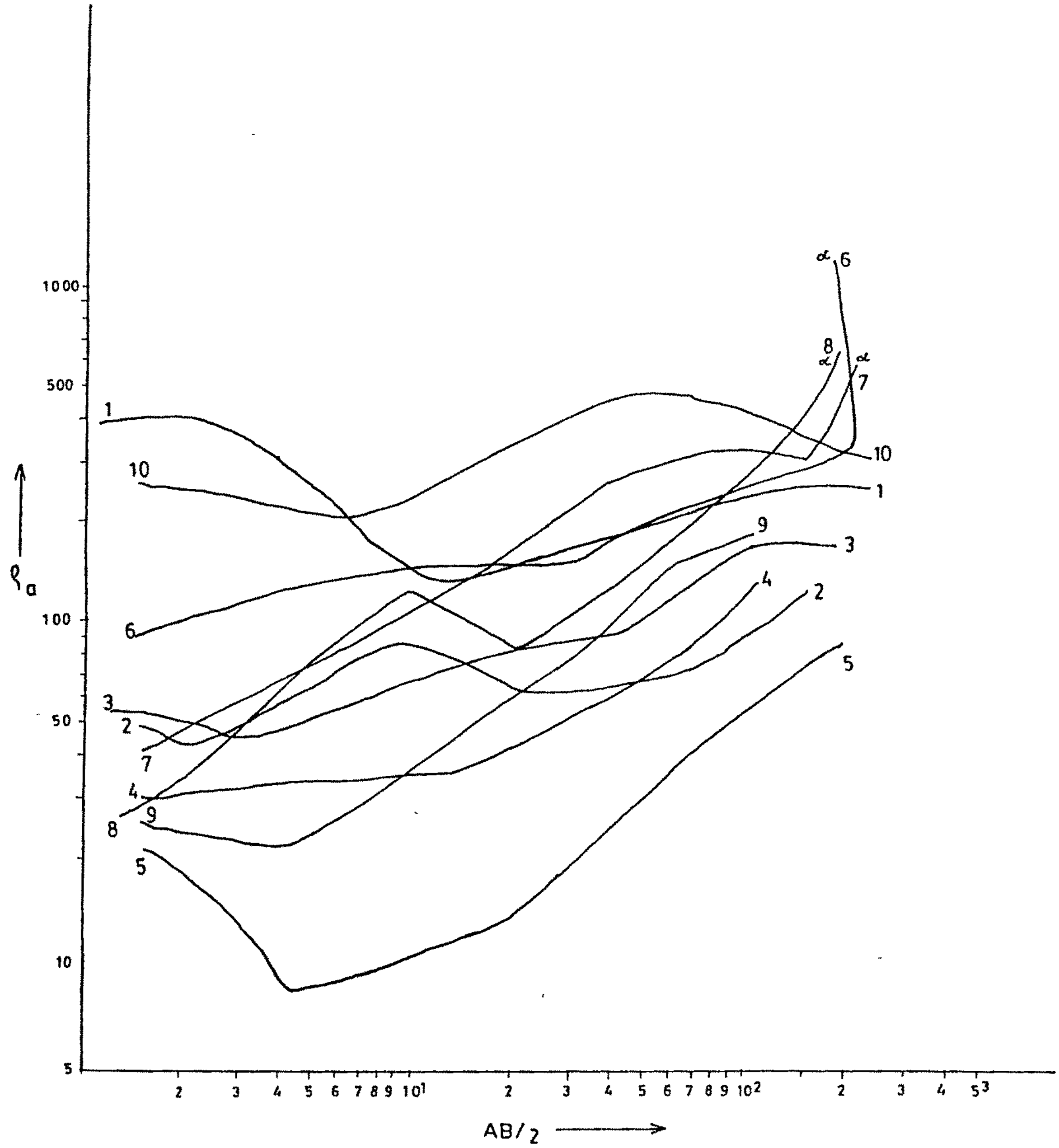


FIG. 61a **VES** CURVES (1- 10)

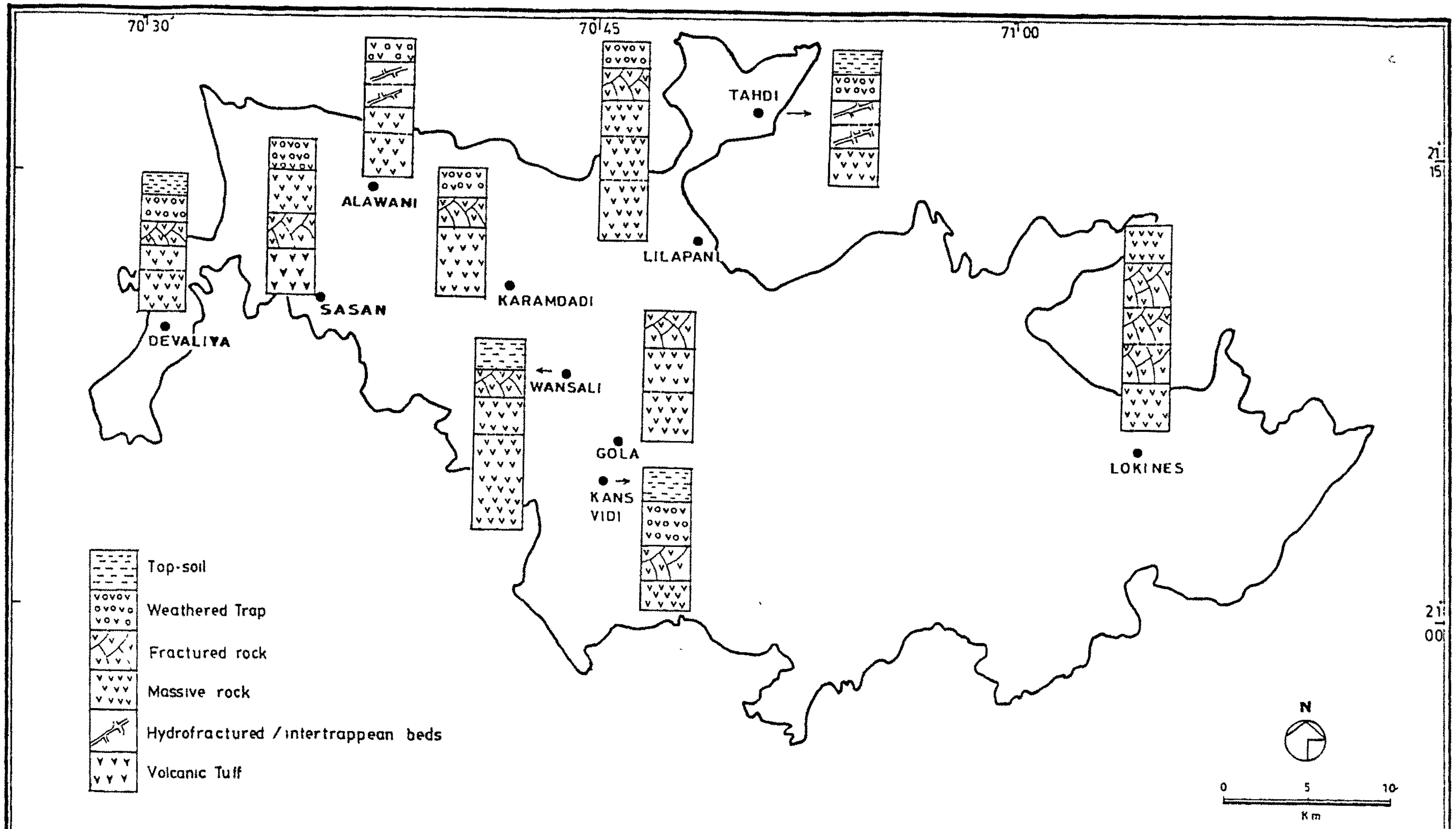


FIG. 61b. LITHOLOGICAL SECTIONS AS DETERMINED BY RESISTIVITY SURVEYS

It is amazing to observe that the data obtained at spot-1 i.e. the intersection of termite streaks, are highly favourable from the view point of groundwater potential and well sinking.

The approach adopted by the author has not only established the validity of bio-indicators in deciphering the groundwater source but, also curtailed the quantum of efforts (i.e. resistivity profiling) to be put in site selection.

(3) Springs

The study area possesses a large number of springs of different nature viz. hot water sulphur springs and normal water non-sulphur springs. Almost all the sulphur springs are perennial in nature, while the normal water springs are of perennial as well as ephemeral types. Springs are an important source of water. It is observed in the study area that a majority of these springs discharge their load in the lower reaches of the river valleys or at the bottom of hill slopes. Their proper channelization through some drain system and suitable storage would certainly help in mitigating the water shortage, while providing surface water to the wildlife.

Case Study

As a case study, the National Park area which is supposed to face extreme water scarcity, has been taken up for the demarcation of specific rainwater harvesting techniques depending upon the the terrain and stream characteristics, and ground water extraction structures (Fig. 62).

(IV) FOREST FIRE

Fire, so important an element in the early stages of the earth's history, is now, as a natural occurrence, of comparatively minor importance. However, man-made fires make a greater impact, if only because species have become adopted to the natural fire frequency and are likely to suffer if man increases the rate of burning.

The vegetation communities in the Gir have been affected by fires (Plate. 54) for a long time and this has played a partial role in their successional pattern. Considerable time and energy is wasted every year to prevent fires in Gir, however, past records suggest that the number of fire incidences are high. The early fires result in fresh grass growth which largely enhances the feeding resources for ungulates.

Fires may be useful as a management tool locally, and occasionally, their short-term effect on the vegetation may also be beneficial. But in the long run, annual burning is detrimental to the soil, the vegetation and the animals. It reduces the nitrogen content and the organic matter in the

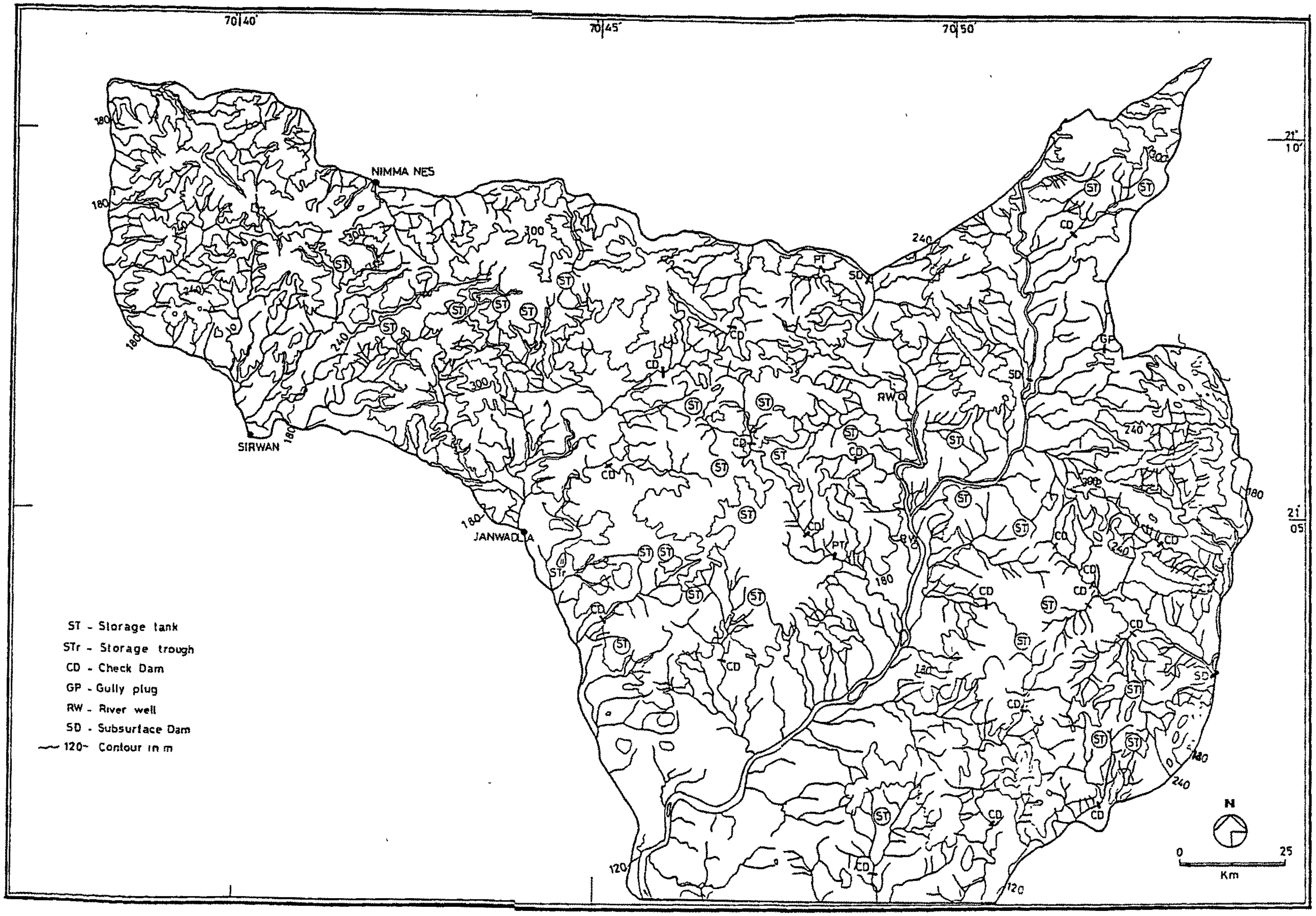


FIG. 62. PROPOSED WATER MANAGEMENT STRATEGY

Plate 54 - Forest fire at the base of the hill in the background.

topsoil, impoverishes the vegetation, and destroys a number of animals in and on the soil. It also leaves many animals without food. In short, annual indiscriminate fire slowly reduces the general fertility (regeneration capacity) of the area.

During early winter, repeated fires in the Gir affect the tree communities in the following ways (after Khan, 1990) :

(a) The repeated fire sets in the retrogression in the tree communities, and the reduction in tree cover leads to dry savanna conditions, e.g. Kans Vidi area in the National Park.

Even if surface water is available, a fire created savanna is inhabited by a low density of herbivores.

(b) Fires promote the thorny as well as fire resistant species. Teak (Tectona grandis) which is a fire resistant species, however shows a decrease in its regeneration in Gir.

A fire hazard map (Fig. 63) based on IRS-1-A satellite imagery (LISS 2, Band 2,3 & 4, March & April' 1990) was prepared (Plate.55) to detect the areal extent of fire in the Gir. From the satellite imagery it can be discerned that the zones covered by earlier fires occupied an area of 355.31 sq.km, while recent fire zones occupied an area of 153.63

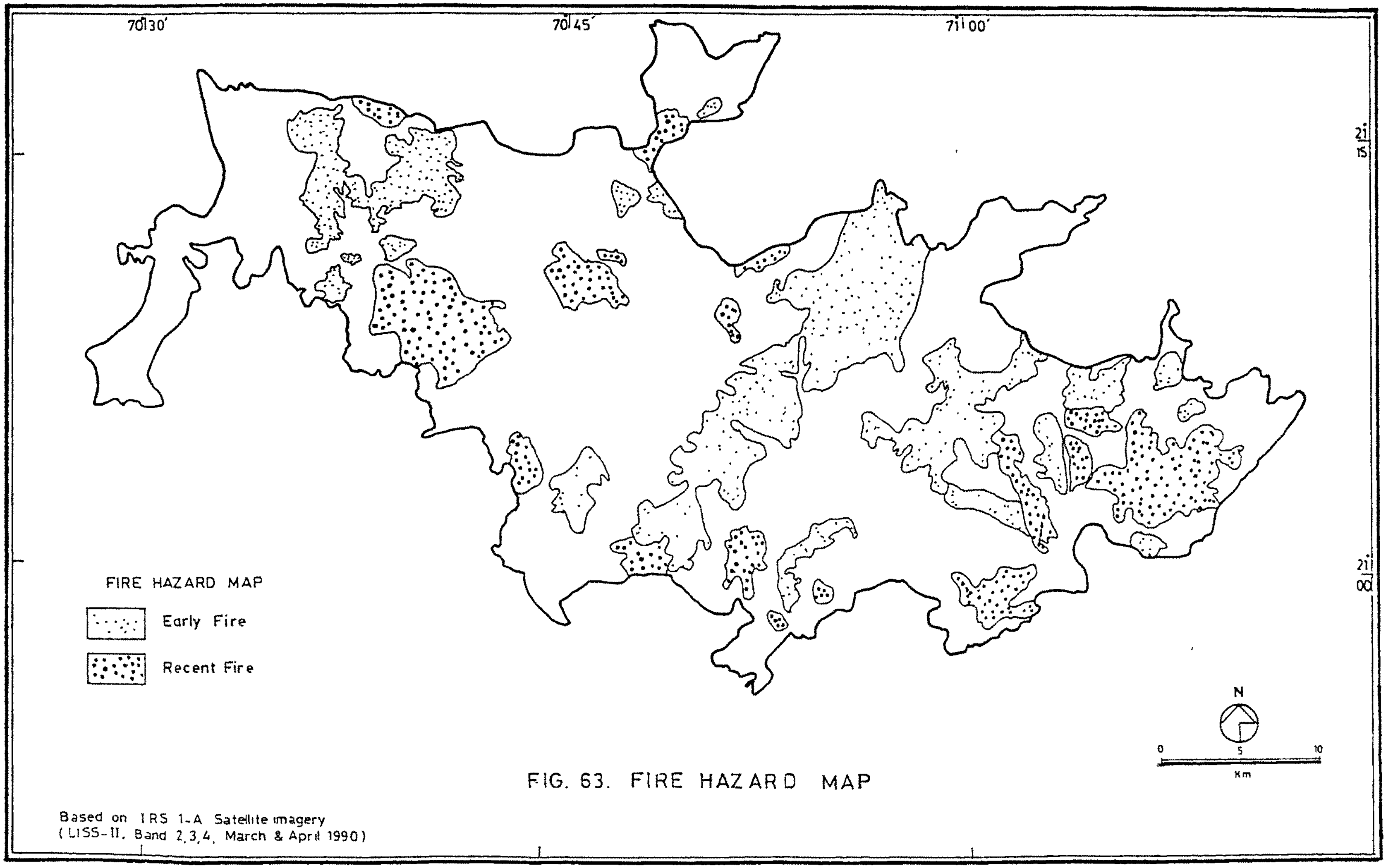


FIG. 63. FIRE HAZARD MAP

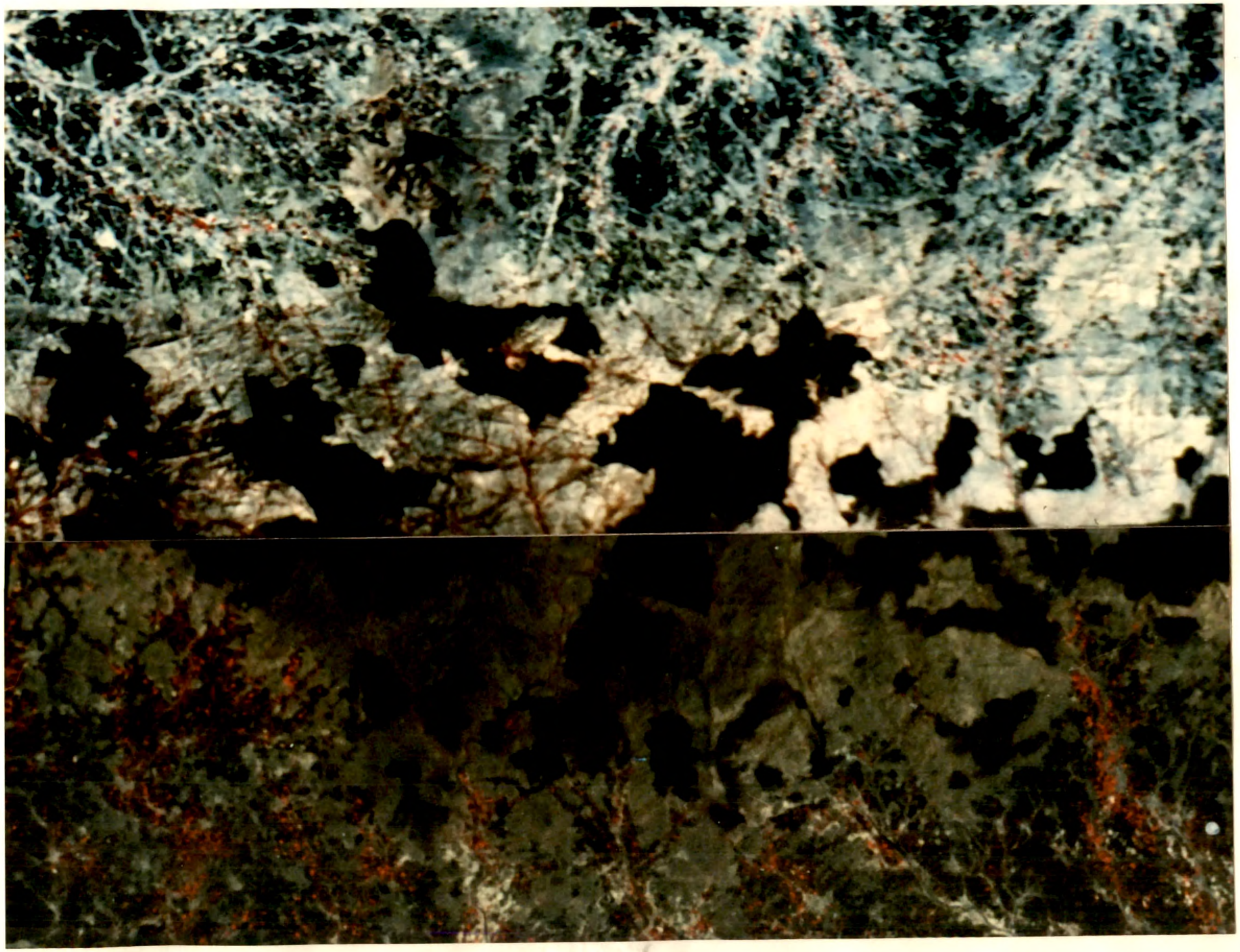


Plate 55 - Dark areas depicting fire zones on the satellite imagery of the Gir area.

sq.km. Further, it can be seen from the tonal difference that in both the zones vegetal cover has been damaged, as compared to the surrounding areas.

Suggestions

Some man-made fires will always occur, but the soundest conservation policy is either to forbid delibrate burning altogether, as in Etosha National Park, or to minimise its use, while not preventing natural fires (Fitter, 1986).

A more vigilant and expanded fire-watch squad with extensive communication network is essential in the Gir.

(4) BIOTIC PRESSURE

The Gir Wildlife Sanctuary, though a conserved zone, faces biotic pressure from both within and outside the sanctuary area. The resident 5752 human population with their 16755 cattle population is localized in 72 `nesses´ (Forest Dept., 1988) in the sanctuary area, apart from tourists and devotees who throng the five main temples and places of pilgrimage inside the area.

In order to understand the problem, a land-use map for the Gir Sanctuary and its peripheral zone (Fig. 64) was prepared. From this it is clear that nearly 70% of the boundary of the sanctuary is occupied by settlements and agricultural fields.

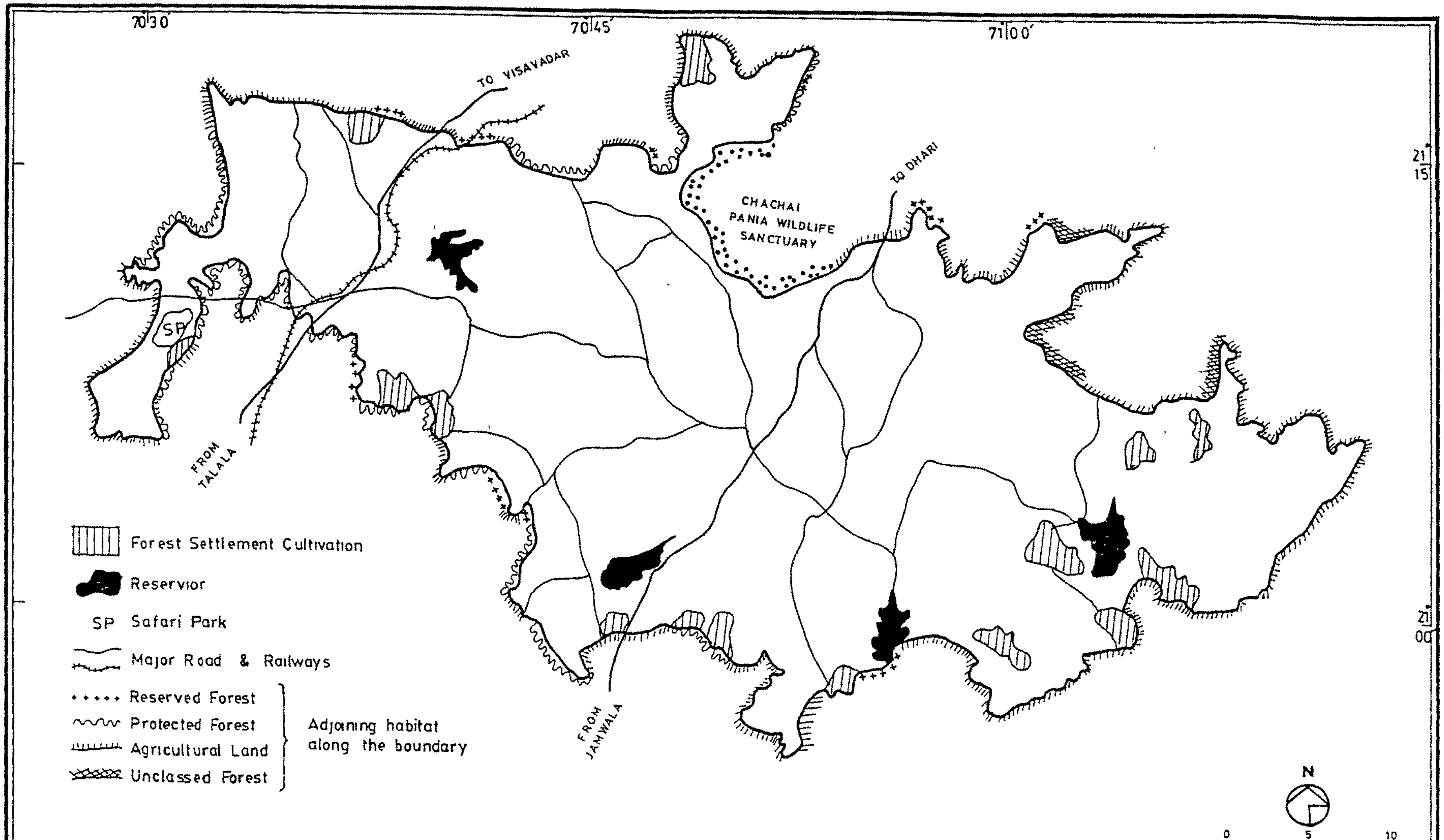


FIG. 64. LAND-USE MAP OF THE GIR AND ITS PERIPHERY

In fact, there are 54 villages within a 2-5 km belt around the sanctuary boundary. Large number of people living in these places often create situations, such as, extension of cultivation in the sanctuary, illicit wood cutting, unauthorised grazing and sheltering of poachers.

The livestock (Plate. 56) of the 72 nesses graze inside the sanctuary area and also drink from water pools located within. Moreover, there is constant pressure for fuel wood, fodder and water from peripheral settlements. During the drier months and drought years, the maldharis drive their cattle deeper into the sanctuary in search of fodder and drinking water. As the surrounding region is a semi-arid one, and as the sanctuary area has relatively more water sources, domestic livestock converges into this zone. In fact, in the 1986-87 drought, as many as 1.5 lakh cattle heads were forcibly driven into the Gir, causing unprecedented biotic pressure as well as the risk of introducing diseases alien to the Gir.

Overgrazing results in soil erosion, compaction of top soil, affecting water percolation and the loss of soil fertility and ground cover. The ultimate effect of overgrazing is the xerification of the habitat which adversely affects the wildlife.

Recently, there are frequent reports of lions wandering out of the sanctuary. This problem is accentuated by the

Plate 56 - Livestock inside the dried up Kamleshwar (Hiran) reservoir in the Gir.

peripheral land use pattern. Nearly 70% of the bordering land is cultivated (Plate. 57). Whenever the lions reach the peripheral zone, they suddenly land into an agricultural field. At times, they foray into the farmlands in search of prey or water which is abundant in the sugarcane fields. This results in a conflict between the lions and the villagers. Thus an improper land-use pattern outside the sanctuary has proved to be a set-back to the conservation movement.

Suggestions

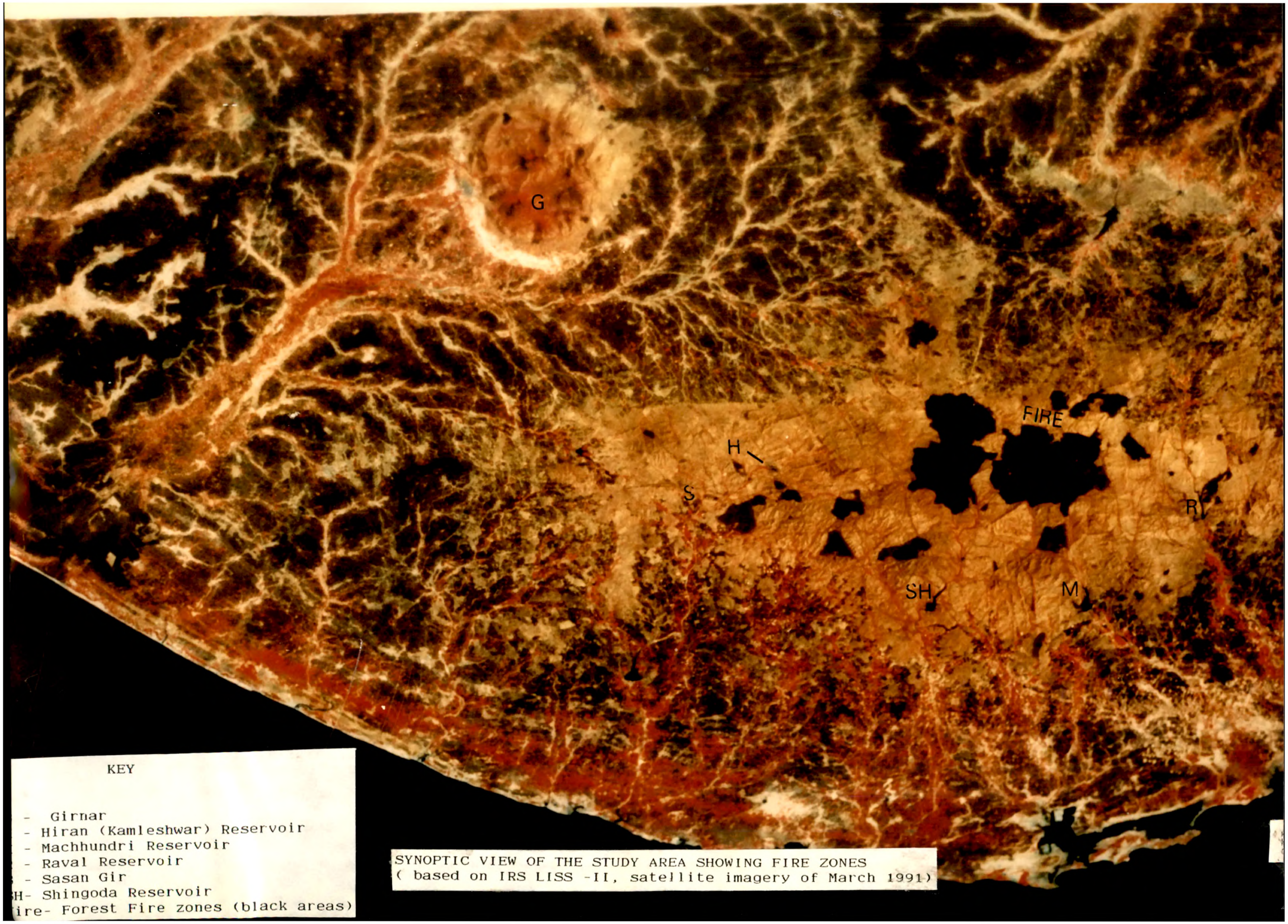
To lessen the wandering of predators outside the sanctuary area as well as to check the influx of grazing livestock, it is suggested that a 0.5-1.0 km wide buffer zone/transition zone be created all along the boundary outside of the sanctuary.

Due to limited space and the concentration of predators in the western part of the sanctuary, primarily due to the availability of water, there is a constant conflict between the predators and the people and their livestock. To ameliorate this problem, it is suggested that a second core area be established in the eastern part of the sanctuary, where the terrain is more suitable for the lions, but faces water scarcity relative to the western and southern zones. This can be done only after the various suggestions for water harvesting, described earlier, are implemented to ensure

Plate 57 - Cultivated land bordering the Gir Sanctuary area.

adequate water supply. This would decrease the concentration of predators in the western part, and would also attract the ungulate population, thereby minimizing the incidences of `spill-over' of lion population.

As a matter of fact, a couple of prides (group of lions) have stabilized in the adjoining Mitiyala forest (in the N.E.) and Babara `Vidi' (grassland). There is no perennial water source in these areas and this has resulted in the absence of natural prey species, making these two prides dependent on livestock for their food. Adequate water management followed by re-introduction of wild herbivores and establishment of `satellite sanctuaries' will ensure better prospects for the survival of the threatened `Asiatic Lion'.



SYNOPTIC VIEW OF THE STUDY AREA SHOWING FIRE ZONES
(based on IRS LISS -II, satellite imagery of March 1991)