CHAPTER : IV

SOILS OF THE STUDY AREA, THEIR OCCURRENCE, DISTRIBUTION, PHYSICO-CHEMICAL AND GEO-TECHNICAL PROPERTIES

PREAMBLE :

Soils are one of the most precious resources of the earth, while forming a carpet of variable thickness over the land, it has sustained a succession of varied life-forms and civilizations, providing food, fodder, fuel and fibre, storing life-giving water, supporting shelters and dwellings and all other major and minor man-built structures. It is integrally and intimately connected with the rocks beneath, the vegetation growing above and the water percolating through it [Valdiya, 1987].

Soils consist of products of the weathering of rocks, intermixed with living organisms and the product of their decay, the moisture and air filling the interstitial space. It thus, has a microclimate of its own. The silt particles constitute the framework [skeleton] and the clays [such as montmorillonite, illite, kaolinite etc.] and the organic matter [humus] hold together the framework serving as the nutrient base. The colloidal clays and the humus are endowed with the capacity for cation exchange, and are thus chemically active and attract molecules of water which form a sort of atmosphere around the clay particles. It is these water attracting and holding capabilities of the colloidal clays and humus that keep the soil moist even during the drier seasons and permit microbial activities. It is undeniably a living system [Valdiya, 1987].

The definition of soil is a relative term, as a geologist considers it as

the upper part of the weathering mantle [regolith] resting on the bed rock and containing inorganic and organic nutrients. A civil engineer looks upon it as a surficial material which can be easily removed without resorting to blasting by explosives. But according to an environmentalist the soil is a dynamic living layer which forms the foundation of all ecosystems.

METHODOLOGY :

In general, the soils of the study area are of typical fluvial origin. The soil survey was carried out by using 1:50,000 scale Survey of India Toposheet Nos. 46.F/3, F/4 and F/7 as a base map. Traverses were made along available roads or approaches taking into consideration the variation in topography. All permanent reference points such as villages, tanks, temples, cart-tracks, roads etc. indicated on the base map were made use of for the location of sampling sites. During the traverses, auger bores were taken at frequent intervals according to the change in physiographic units, colour, past erosional conditions, slope and the surface condition. Profile pits were dug upto a depth of 180 cm or upto parent material, wherever possible. During profile examination the texture, structure, colour, consistency, the presence of concretions, depth and width of cracks, root zone depth, soil boundary, and other features like slope, depth of the soil, erosion and depth of water table were noted to differentiate one soil type from another. The profiles examined were indicated on the base map and were classified and grouped into soil series and association of soil series according to their morphological characteristics as described by the U.S. Department of Agriculture 7th Approximation Soil Classification System [1967]. The extent and boundaries of the soil series were delineated on the base map by grouping together and enclosing similar auger observations. The soil samples were collected with an aim to evaluate them both chemically and physically in order to augment the morphological studies in the field. Based on the above mentioned data collected, the soil map of the study area was prepared.

The main objective in determining the physico-chemical and geo-technical

properties of the soils in the study area, was to get an appropriate picture of the quality of the soil vis.a.vis utility point of view.

Selected profiles typifying pedons were selected for profile sampling to determine the physio-chemical and geo-technical properties including particle size analysis, specific gravity, pH, dry density, porosity, moisture content, exchangeable cations, consistency of soils, penetration test and electrical resistivity.

The determination of all physico-chemical and geo-technical properties of soils in the study area excluding last two was done in the Soil Mechanics Division of the Gujarat Engineering Research Institute, Baroda.

Particle size analysis :

It is the mechanical analysis of the soils, which determine the size of the grains which constitute a soil and the percentage of the total weight represented by the grains in various size ranges. The most direct method used for separating a soil into grain size fractions is the uses of sieve. Sieving is performed by arranging the various sieves one over the other in order of their mesh openings. [Sieve used are of ASTM specification].

The largest aperture sieve being kept at the top and the smallest aperture sieve at the bottom. A receiver pan is kept at the bottom and a cover is kept at the top of the whole assembly. The soil sample [100 gm] is put on the top sieve, and the whole assembly is fitted on a sieve shaking machine. Whole assembly is shaked for about 10 minutes. The portion of the soil sample retained on each sieve is weighed. The percentage of soil retained on each sieve is calculated on the basis of the total weight [100 gm] of soil sample taken and from these results, percentage passing through each sieve is calculated. The complete grain size analysis is divided into two parts.

[1] Mechanical analysis by sieve [ASTM], grains ranging from 230 [.06

mm] to 4 [5.00 mm].

[2] Grain size analysis of less than .06 mm [230 ASTM sieve] diameter by Shimadzu centrifugal particle size analyzier SA-[P2 Type].

It is based on the liquid sedimentation method, It employs the photometric method for determining particle concentration and uses a centrifuge. The range of particle on this analyzer is capable of analyzing .0001 mm to .060 mm diameter grain size.

In connection with soil classification based on grain size characteristics, different names are assign viz, silt, clay, sand, gravel to different grain size fractions. There are various grain size classification in use, but in this text AASHO grain size classification given in 7th Approximation Soil Classification is followed [Fig. 8].

Textural Classification :

Soil occurring in nature are composed of different percentage of sand, silt and clay size particles. Classification of composite soils exclusively based on the particle size distribution is known as textural classification. The best known tringular textural classification given by U.S. Public Roads Administration [in 7th Approximation Soil Classification 1967] is followed in this text. The classification is based on the percentage of sand, silt, and clay size. [Fig. 8].

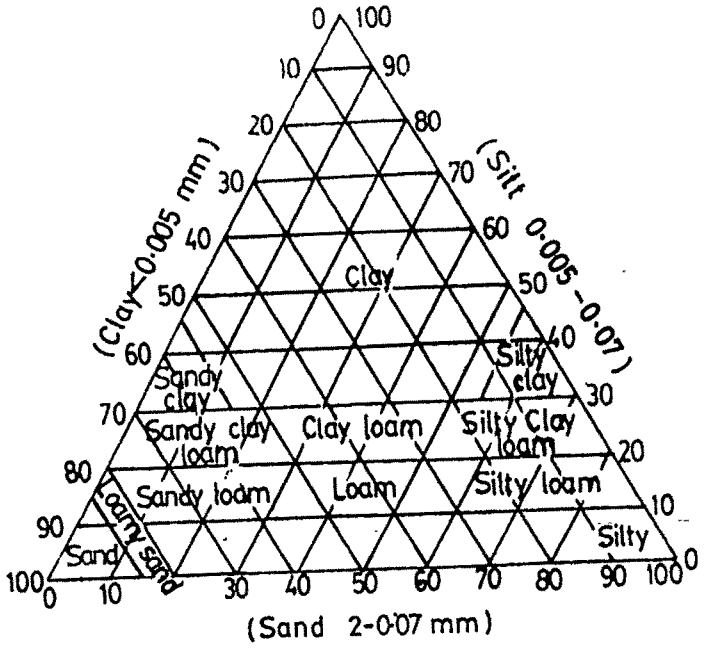
Specific gravity :

It is defined as the ratio of the weight of a given volume of soil solids at a given temperature to the weight of an equal volume of distilled water at that temperature.

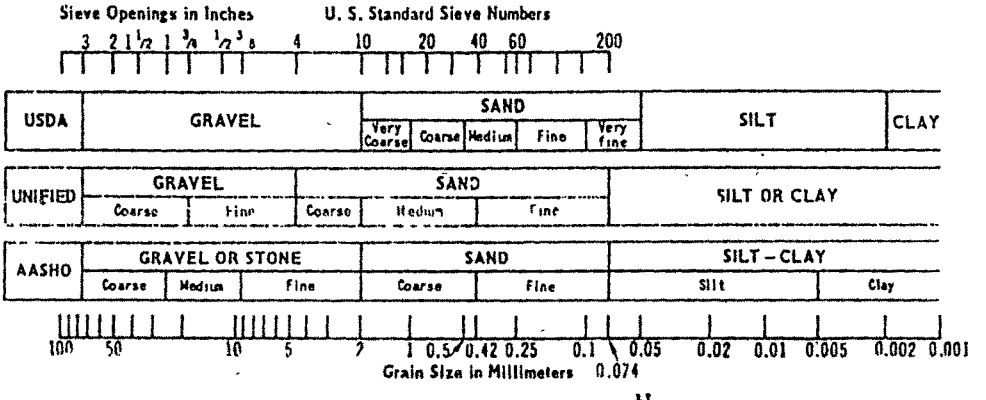
A pycnometer method is used for finding out the specific gravity of the soils. The weight W_1 of the empty, dry pycnometer [bottle] is first taken.

FIG:- 8

GUIDE FOR TEXTURAL CLASSIFICATION IN SOIL FAMILIES



COMPARISON OF PARTICLE–SIZE SCALES



(Source: USDA 7th approximation 1967)

A sample of over dried soil is put in the bottle, and the weight W_2 of the bottle and soil is taken. The bottle is then filled with distilled water gradually, removing the entrapped air by shaking the pycnometer. The weight W_3 of the bottle, soil and water is taken. Finally the bottle is emptied completely and thoroughly washed and clean water is filled to the top and the weight W_4 is taken. Based on these four observations, the specific gravity is computed as follows :

$$G = \frac{W_2 - W_1}{[W_2 - W_1] - [W_3 - W_4]}$$

pH Value :

It is defined as the negative logarithm of the hydrogen ion activity. The hydrogen ion in the soil are present primarily as exchangeable cations. Soil pH is determined with the glass electrode method.

100 gms of soil is placed in a 250 ml beaker, filled with 200 ml of the distilled water. After adjusting the pH meter. Beaker containing soil water suspension is kept under the glass electrode and the pH of the suspension is noted directly from the pH meter.

Dry density :

It is defined as the measure of compaction of the soil or the weight of solids per unit of volume. It is determined by water displacement method.

A small specimen is trimmed to a more or less regular shape, from a larger sample and its weight W_1 is found. The specimen is covered with a thin layer of paraffin wax and the weight W_2 of the coated specimen is noted. A metal container is filled above the overflow level, and excess water is allowed to run-off through the overflow outlet. The coated specimen is then slowly immersed in the container, and the overflowing water is

collected in a measuring jar. The volume V_1 of the displaced water is thus known. The volume V of the uncoated specimen is then calculated from the relation.

$$V = V_1 - \frac{W_2 - W_1}{G_p}$$

Where G_p = density of the paraffin wax [0.908 g/ml].

The dry density of the specimen is determined from the relation

$$V_a = \frac{V}{[1 + W]\ W_1}$$

Where W is the moisture content of the specimen, determined by over-drying method.

Porosity :

The porosity represents the simplest partial characterisation of the soil pore system. It is the ratio, usually express as a percentage, of the volume of voids V_1 of a given soil mass, to the total volume V of the soil mass.

The porosity is calculated from the dry density V_a and the specific gravity G of the soil.

$$n\ \% = \left[1 - \frac{V_a}{G}\right] \times 100$$

Moisture content :

It is defined as the ratio of weight of water to the weight of solids in given mass of soil.

The moisture content of a soil sample is determined by oven-drying method. It is the most accurate method.

A specimen of soil sample is kept in a clean container and is put in a thermostatically controlled oven with interior of non-corroding material to maintain the tempreture between 105° to 110°c. The sample is kept for about 20 to 24 hours in the oven, so that complete drying is assured.

A clean non-corrodible container is taken and is weighed with its lid, [W_1] on a balance. A specimen of the moist soil is placed in the container and the lid is replaced. The container and the content are weighed [W_2]. The container is then placed in the oven for drying. After drying, the container is removed from the oven and allowed to cool in a desiccator. The lid is then replaced, and the container and the dry soil are weighed [W_3]. The moisture content is calculated from the following equation :

$$W = \frac{W_2 - W_1}{W_3 - W} \times 100$$

Exchangeable Cations :

Cation exchange is the physico-chemical process whereby one type of cations adsorbed by the soil are replaced by another type. The total amount of exchangeable cations that a soil can retain is known as the cation exchange capacity, and is expressed in milligram equivalent per 100 gm of soil.

Ammonium acetate is used as the extractant and the exchangeable Ca, Mg,

Na, are determined with flame photometer which works on principle that a metallic salt, drawn into a non-luminous flame, ionizes and emits light of a characteristic wavelength.

Consistency of Soil :

By consistency is meant the relative case with which soil can be determined. This term is mostly used for fine grained soils for which the consistency is related to a large extent to water content. Consistency denotes the degree of firmness of the soil which may be termed as soft, firm, stiff or hard. Fine grained soil may be mixed with water to form a plastic paste which can be moulded into any form by pressure. The addition of water reduces the cohesion until the material no longer retains its shape, under its own weight, but flows as a liquid. Enough water is added untill the soil grains are dispersed in a suspension. If water is evaporated from such soil suspension, the soil passes through various stages or states of consistency. In 1911, the swedish agriculturist. Atterberg divided the entire range from liquid to solid state into four stages [i] liquid state, [ii] Plastic state, [iii] Semi-solid state, and [iv] Soild state.

The Atterberg limits which are most useful for engineering purpose are :

[A] Liquid limit
[B] Plastic limit
[C] Plasticity index

[A] Liquid Limit :

It is the water content corresponding to the arbitary limit between liquid and plastic states of consistency of a soil. It is defined as the maximum water content at which the soil is still in the liquid state but has small shearing strength against flowing which can be measured by standard available means with reference to the standard

liquid limit device. It is defined as the minimum water content at which a part of soil cut by a groove of standard dimension will flow together for a distance of 12 mm under an impact of 25 blows in the device.

Determination of Liquid Limit :

The liquid limit has been determined in the GERI Laboratory, Baroda, with the help of the standard liquid limit apparatus designed by casagrande. The apparatus consist of a hard rubber base over which a brass cup drops through a desired height. The brass cup can be raised and lowered to fall on the rubber base with the help of a cam operated by a handle. The height of fall of the cup can be adjusted with the help of adjusting screws. Before starting the test, the height of the cup is adjusted to 1 mm.

About 120 gm of the specimen passing through 425 micron sieve is mixed thoroughly with distilled water in the evaporating dish to form a uniform paste. A portion of the paste is placed in the cup over the spot where the cup rests on the base, squeezed down and spread into position and the groove is cup in the soil pat. The handle is rotated at a rate of about 2 revolutions per second, and the number of blows are counted until two parts of the soil sample comes in contact at the bottom of the groove along a distance of 10 mm. After recording the number of blows, approximately 10 gram of soil from near the closed groove is taken for water content determination. Since it is difficult to adjust the water content precisely equal to the liquid limit when the groove should close in 25 blows, the liquid limit is determined by plotting a graph between the number of blows as abscissa on a logarithmic scale and the corresponding water content as ordinate.

[B] Plastic Limit :

Plastic limit is the water content corresponding to an arbitary limit

between the plastic and the semi-solid states of consistency of a soil. It is defined as the minimum water content at which a soil will just begin to crumble when rolled into a thread approximately 3 mm in diameter.

To determine the plastic limit, the soil passing 425 micron sieve, is mixed thoroughly with distilled water until the soil mass become plastic enough to be easily moulded with fingers. The plastic soil mass is left for enough time to allow water to permeate through the soil mass. A ball is formed with about 10 gm of this plastic soil mass and rolled between the fingers and glass plate with just sufficient pressure to roll the mass into a thread of uniform diameter through out its length. When a diameter of 3 mm is reached, the soil is remoulded again into a ball. This process of rolling and removlding is repeated until the thread starts just crumbling at a diameter of 3mm. The crumbled threads are kept for water content determination. The test is repeated twice more with fresh samples and the plastic limit is than taken as the average of the three water contents. [1S:2720 (Part V) - 1965 - Determination of liquid and plastic limit].

[C] Plasticity Index :

The range of consistency within which a soil exhibits plastic properties is called the plastic range and is indicated by plasticity index. It is defined as the numerical difference between the liquid limit [A] and the plastic limit [B] of a soil.

$$C = A - B$$

When plastic limit is not determined the plasticity index is reported as NP [non plastic]. When the plastic limit is equal to or greater than the liquid limit, the plasticity index is reported as zero.

Penetration Test :

These tests involve the measurement of the resistance to penetration of a sampling spoon [degree of compactness of the soil in situ] under dynamic or static loadings.

The test [IS:2131/1963] is performed in a clean hole, 55 to 150 mm in diameter. A casing is used to support the sides of the hole. A thick wall split tube sampler of 50.8 mm outer diameter and 35 mm inner diameter is driven into the undisturbed soil at the bottom of the hole under the blows of a 65 kg drive weight with 75 cm free fall. The number of blows required to drive the sampler 30 cm beyond the seating drive is termed as the penetration resistance N and this procedure is referred to as the standard penetration test.

Electrical resistivity :

Soil resistance is the most important factor affecting earthing systems for generator, transformer, transmission lines or distribution lines.

Wenner array resistivity method, which is based on the fact that any variation in electrical conductivity alters the pattern of current flow in the subsurface and bring changes in distribution of the electric potential at the surface, is used for resistivity survey of soil in and around Baroda city.

Four electrodes were placed at fixed equal interval [5 ml] along a common line. The outside two electrodes were used to provide current to the ground, while the inside two were used to measure voltage.

The instrument used is D.C. resistivity meter model GR-DC-3, Hyderabad.

SOIL CLASSIFICATION :

The classification of the soils of the study area has been made as per

TABLE : 4

SOIL CLASSIFICATION OF THE STUDY AREA

Sr. No.	Soil Series	Soil Family	Sub-Group	Great-Group	Sub-Order	Order
01	I_1	I_1 sandy clay loam - (yellowish brown to brown, deep, fine montmorillonitic, well drained, neutral to moderately alkaline, hyperthermic).	Fluventic Ustochrepts	Ustochrepts	Orchrepts	Inceptisol
02	I_2	I_2 sandy loam - (dark brown to dark yellowish brown, very deep, fine, loamy, well drained, neutral, hyperthermic).	Fluventic Ustochrepts	Ustochrepts	Orchrepts	Inceptisol
03	I_3	I_3 clay - (dark brown to dark yellowish brown, deep fine clayey, montmorillonitic, moderately drained, slightly to moderately alkaline, hyperthermic).	Vertic Ustochrepts	Ustochrepts	Orchrepts	Inceptisol
04	I_4	I_4 sandy loam - (dark brown to pale brown, deep, fine, loamy, moderately to poorly drained, moderately alkaline, hyperthermic).	Fluventic Ustochrepts	Ustochrepts	Orchrepts	Inceptisol
05	I_5	I_5 sandy clay loam - (dark brown to dark greyish brown, deep, fine, clayey montmorillonitic, moderately drained, neutral to slightly alkaline, hyperthermic).	Vertic Ustochrepts	Ustochrepts	Orchrepts	Inceptisol
06	V_1	V_1 clay - (dark brown to dark greyish brown, very deep, fine montmorillonitic, imperfectly drained, strongly alkaline, hyperthermic).	Udic Chromusters	Chromusters	Usters	Vertisol
07	V_2	V_2 clay - (dark greyish brown to dark brown, very deep, fine, clayey, montmorillonitic, imperfectly drained, moderately to strongly alkaline, hyperthermic).	Typic Chromusters	Chromusters	Usters	Vertisol
08	E_1	E_1 sandy loam - (pale brown to brown, deep, coarse, loamy, mixed, well drained, to excessively drained, moderately alkaline, hyperthermic).	Typic Ustifluvents	Ustifluvents	Fluvents	Entisol

the norms set down by the U.S. Department of Agriculture 7th Approximation Soil Classification [1967]. 3 orders, 3 sub-orders, 3 great groups, 5 sub-groups, 8 families and series have been identified and mapped [Table : 4 and Fig. 9, 10 & 11]. A possible correlation between the three major geomorphic units, elevational range and soil series is given in Table : 5. This was done by the superimposition of the contour map of the study area made from the numerous benchmarks available in the base map, on the soil map. From the elevational ranges, it can be seen that a stratigraphical column cannot be made as the ranges have a wide variation. This would seem to indicate that soil deposition took place in a fluctuating environment.

The various soil series were named by using the first alphabet of the name of the order to which they belong, followed by numerical notations dependent upon their elevational range as given in Table : 5 e.g. a soil series belonging to the inceptisol order with an elevational range between 20-24 m has been denoted as I_1, while another soil series belonging to the same order but with an elevational range between 24-26 m has been denoted as I_2.

In the inceptisol order there are five soil series, in the vertisol order two are present, while the entisol order is represented by a single series.

DETAILED DESCRIPTION OF INDIVIDUAL SOIL SERIES

The eight series have been described in detail below :

Soil Series - I_1 :

Order	:	Inceptisol
Sub-Order	:	Ochrepts
Great Group	:	Ustochrept
Sub-Group	:	Vertic Ustochrepts

FIG:- 7. CONTOUR MAP OF BARODA CITY AND ITS SURROUNDINGS PREPARED FROM BENCH MARKS AVAILABLE IN SURVEY OF INDIA TOPOSHEET NOs.46 F/3, 4 & 7 [1973-75]

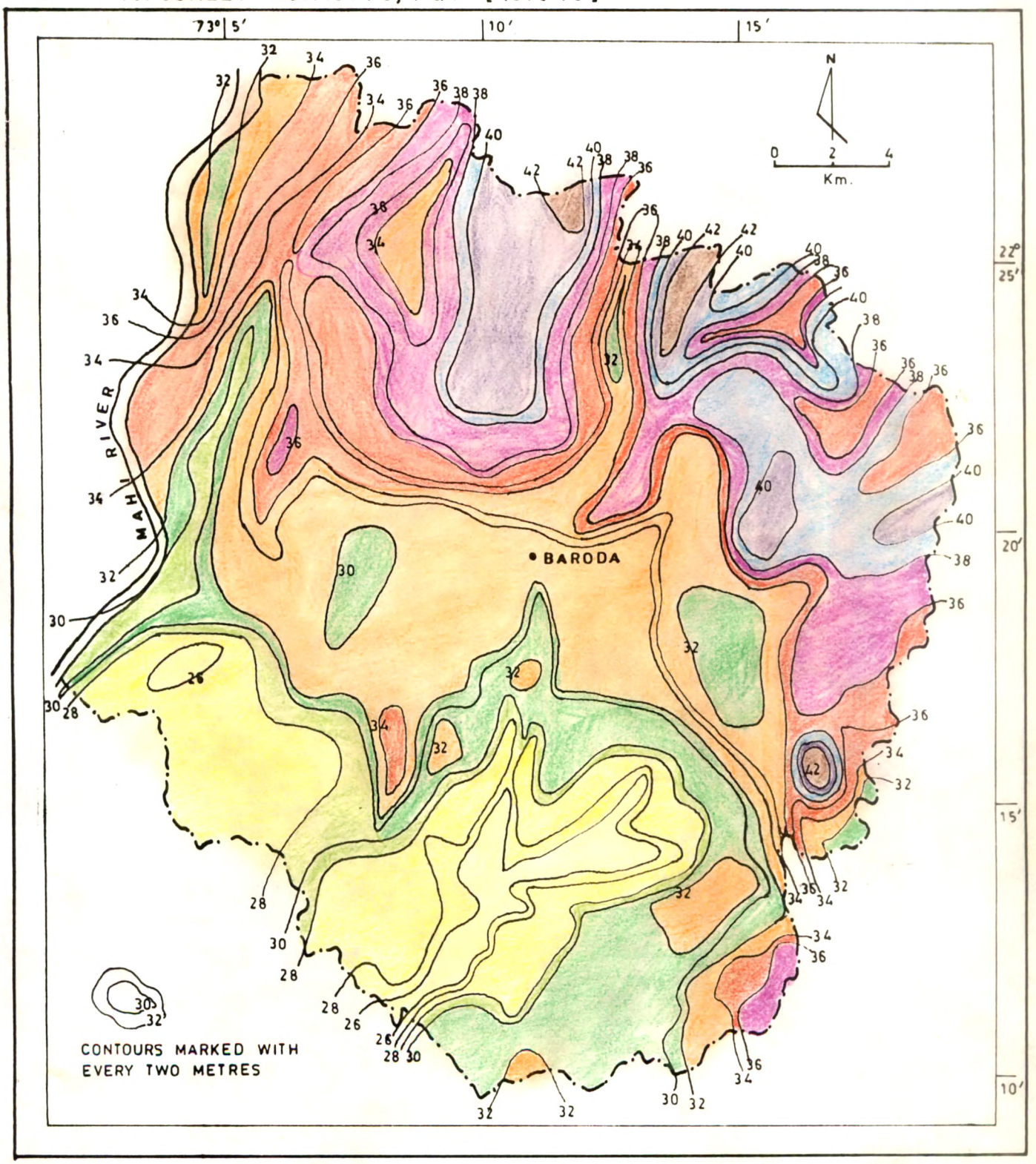


TABLE : 5

A POSSIBLE CORRELATION BETWEEN GEOMORPHIC UNITS, ELEVATIONAL RANGE AND SOIL SERIES

Sr. No.	Soil Series	Elevation Range [in mt]	Geomorphic Units
01	I_1 [Sandy Clay Loam]	26 to 28 36 to 38	Flood plains [terraces T_2 & T_3] of Vishwamitri river.
02	I_2 [Sandy Loam]	28 to 36	Alluvial plain, ravines of Mahi river and flood plain [terraces T_2 and T_3] of Vishwamitri & Mahi rivers.
03	I_3 [Clay]	30 to 36	Alluvial plain and flood plains [terraces T_2 and T_3] of Vishwamitri and Dhadhar rivers.
04	I_4 [Sandy Loam]	30 to 38	Alluvial plain.
05	I_5 [Sandy Clay Loam]	32 to 40	Alluvial plain and flood plains [terrace T_3] of Vishwamitri and Dhadhar rivers.
06	V_1 [Clay]	26 to 30	Alluvial plain.
07	V_2 [Clay]	30 to 32 32 to 36	Alluvial plain and flood plains [terrace T_3] of Vishwamitri river.
08	E_1 [Sandy Loam]	30 to 36	Ravines and flood plain [terrace T_3] of Mahi river.

FIG:-9-SAMPLING STATIONS FOR PHYSICO-CHEMICAL AND GEOTECHNICAL INVESTIGATIONS

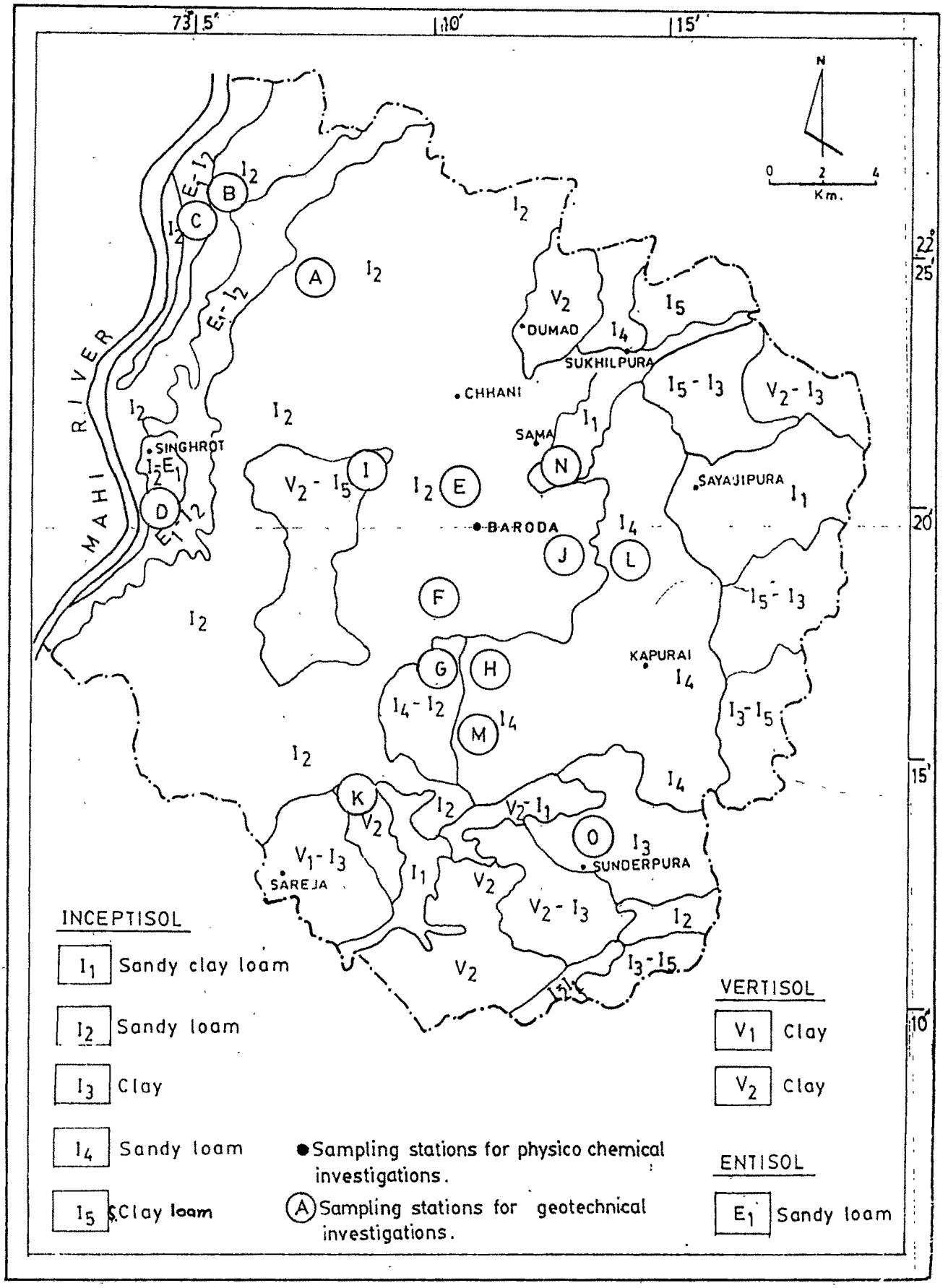


FIG:- 10 SOIL TYPES AND THEIR ASSOCIATION AROUND BARODA CITY

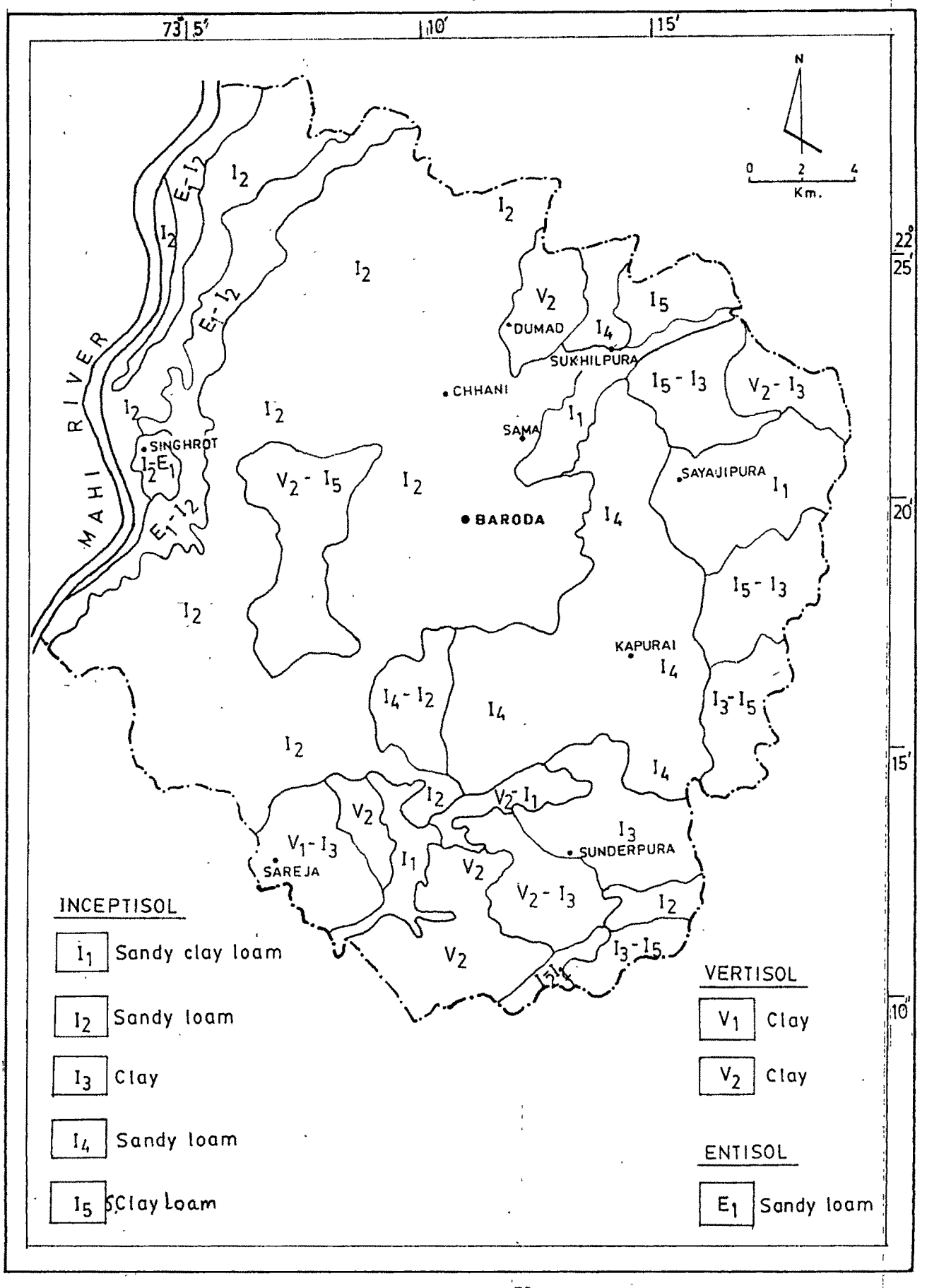


FIG.11. FENCE DIAGRAM OF THE STUDY AREA.

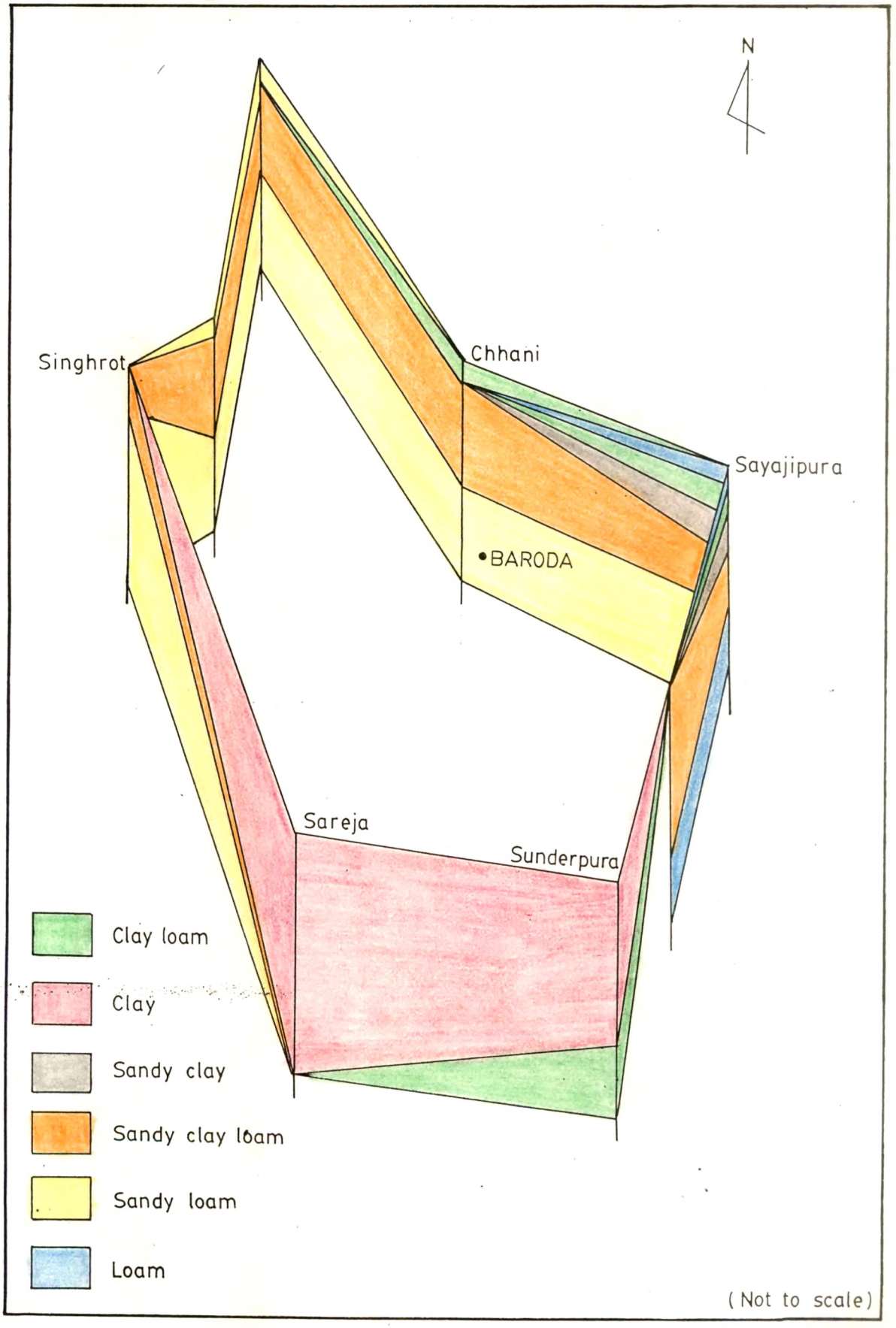


TABLE : 6

STATEMENT OF IMPORTANT SOIL CHARACTERISTICS

SR. NO.	SOIL SERIES	TEXTURE		STRUCTURE		PERMEABILITY	EROSION CONDITION	SLOPE [in degrees]
		SURFACE SOIL	SUB-SOIL	SURFACE SOIL	SUB-SOIL			
1.	I_1 [Sandy clay loam]	Loam, clay loam and sandy clay	Clay loam, sandy clay loam, loam	Weak, columnar, breaks into weak fine to medium sub-angular blocky peds	Weak, columnar, breaks into weak to moderate medium sub-angular blocky peds	Moderately rapid	Moderate to severe erosion, at places very severe erosion	1° to 3°
2.	I_2 [Sandy loam]	Sandy loam, loamy sand and at places sandy clay loam	Clayey loam, sandy clay, sandy clay loam	Weak, medium to fine sub-angular blocky peds	Coarse, prismatic, breaks into weak, moderate to strong, medium angular to sub-angular blocky peds with prominent slickenslide pressure faces	Moderate to rapid	Moderate erosion at alluvial plain and severe erosion at ravines	1° to 3° and 10° to 40° in ravines
3.	I_3 [Clay]	Clay, and clay loam	Clay, and clay loam	Coarse, columnar, breaks into medium sub-angular blocky peds	Coarse, breaks into moderate to strong medium angular blocky peds with indistinct and prominent slickenslide pressure face	Slow to very slow	Slight to moderate erosion	2° - 5°
4.	I_4 [Sandy loam]	Loamy sand, sandy loam	Clay loam, sandy clay, sandy clay loam	Weak, fine sub-angular blocky peds	Coarse, prismatic, breaks into moderate to strong, medium subangular blocky peds	Moderately well	Slight to moderate	3° - 7°
5.	I_5 [Sandy clay loam]	Sandy clay loam, sandy loam	Clay, clayey loam to sandy clay loam	Coarse, columnar, breaks into weak to moderate medium sub-angular blocky peds	Coarse, columnar breaks into weak and moderate medium sub-angular blocky peds with slickenslides faces	Moderate	Slight to moderate	1° - 5°
6.	V_1 [Clay]	Clay	Clay, clay loam	Coarse, columnar breaks into medium sub-angular blocky peds	Coarse, columnar, prismatic, breaks into medium sub-angular blocky wedge-shaped peds	Slow	Slight to moderate	
7.	V_2 [Clay]	Sandy clay loam	Clay loam to sandy clay loam	Coarse, prismatic, breaks into weak to moderate medium sub-angular blocky peds	Coarse, prismatic, breaks into weak, moderate medium sub-angular blocky peds with slickenslide faces	Slow	Slight to moderate	2° - 5°
8.	E_1 [Sandy loam]	Loamy sand, sandy loam	Sandy loam, sandy clay loam, sand	Weak, fine sub-angular blocky peds	Weak, fine, medium sub-angular blocky peds	Rapid	Severe to very severe	10° - 40°

TABLE : 7

ANALYTICAL STATEMENT OF PHYSICO-CHEMICAL PROPERTIES OF SOIL SERIES

Sr. No.	Soil Series	Depth in cm.	Particle Size [mm]					Textural Classification	Specific gravity gm/c.c.	pH	Dry Density gm/c.c.	Pore Space %	Moisture Content %	Exchangeable Cations [in mgm/100 gm]		
			Gravel [2-5 mm] %	Coarse Sand [0.4-2 mm] %	Fine Sand [0.07-0.4 mm] %	Silt [0.005 -0.07 mm] %	Clay [0.005 mm] %							Ca	Mg	Na
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	I_1	0-15	4.00	1.18	63.89	15.21	15.72	L	2.3	8.2	1.4	39.13	2.30	11.4	2.8	0.01
		15-39	3.00	1.48	49.63	15.87	30.02	Cl	2.4	8.0	1.2	50.00	5.60	20.8	4.4	0.10
	Sandy	39-65	5.00	1.43	57.71	5.87	30.67	Sc	2.2	8.1	1.2	45.45	5.60	15.0	5.8	0.02
	Clay	65-105	7.00	2.52	63.80	2.60	24.08	Scl	2.0	8.2	1.2	40.00	5.10	14.0	4.0	0.09
	Loam	105-150+	5.00	3.32	55.00	20.24	16.44	L	2.1	8.2	1.2	42.85	2.60	21.0	3.0	0.22
2	I_2	0-15	-	1.16	78.43	4.09	16.32	Sl	2.3	7.2	1.3	43.47	0.53	13.4	2.6	0.01
		15-26	-	3.65	59.35	10.81	26.10	Scl	2.0	7.9	1.2	40.00	3.05	11.0	4.2	0.03
	Sandy	26-56	-	0.31	64.96	6.84	27.89	Scl	2.3	8.0	1.2	47.82	4.06	13.0	5.0	0.02
	Loam	56-90	-	3.46	69.78	3.14	23.63	Scl	2.3	8.2	1.2	47.82	3.69	12.2	4.4	0.09
		90-120	-	0.32	75.08	6.28	18.32	Sl	2.3	8.1	1.1	52.17	3.53	11.8	5.2	0.10
		120-155	-	0.37	72.94	6.80	19.80	Sl	2.0	7.6	1.2	40.00	3.30	14.0	2.4	0.01
3	I_3	0-22	4.00	0.60	22.00	27.33	46.07	C	2.6	8.6	1.3	50.00	7.55	33.4	8.4	0.20
		22-62	5.00	0.16	25.00	25.41	43.99	C	2.4	8.7	1.3	45.83	7.15	31.4	10.6	0.50
	Clay	62-117	5.00	0.20	22.34	26.04	46.42	C	2.3	9.0	1.2	47.82	7.45	29.6	10.8	0.01
		117-145	2.50	0.11	26.46	28.50	42.43	Cl	2.4	8.8	1.3	45.83	6.45	21.4	11.2	0.01
		145-175+	2.50	0.14	39.80	18.56	38.61	Cl	2.3	9.1	1.3	43.47	4.80	15.4	8.8	0.02
4	I_4	0-20	2.50	1.86	65.40	10.25	20.00	Sl	2.2	8.1	1.4	36.36	1.85	8.0	4.8	0.01
		20-47	2.50	0.10	48.00	12.00	37.40	Scl	2.3	8.3	1.3	43.47	3.80	11.8	6.8	3.40
	Sandy	47-120	3.00	0.52	54.29	14.00	28.19	Scl	2.0	8.5	1.2	40.00	3.65	11.2	7.8	0.40
	Loam	120-140	4.00	1.09	69.41	2.58	26.89	Scl	2.4	8.8	1.3	45.83	2.70	7.0	5.8	2.80
5	I_5	0-20	-	0.92	48.38	20.82	29.58	Scl	2.3	7.4	1.2	47.82	5.40	23.0	9.0	0.01
		20-52	-	1.23	49.71	16.53	32.53	Scl	2.0	7.6	1.2	40.00	5.20	24.8	8.6	0.03
	Sandy	52-95	1.00	0.25	63.16	7.97	27.62	Scl	2.4	7.4	1.3	45.83	5.40	24.4	8.0	0.07
	Clay	95-115	-	0.41	65.68	6.36	27.58	Scl	2.4	7.9	1.3	45.83	4.73	22.4	6.6	0.01
	Loam	115-150	-	0.44	72.63	10.56	16.36	Sl	2.3	8.4	1.2	47.82	4.70	22.0	5.4	0.04

Table : 7 contd.

Sr. No.	Soil Series	Depth in cm.	Particle Size [mm]					Textural Classification	Specific gravity gm/c.c.	pH	Dry Density gm/c.c.	Pore Space %	Moisture Content %	Exchangeable Cations [in mgm/100 gm]		
			Gravel [2-5 mm] %	Coarse Sand [0.4-2 mm] %	Fine Sand [0.07-0.4 mm] %	Silt [0.005 -0.07 mm] %	Clay [0.005 mm] %							Ca	Mg	Na
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
6	V_1	0-18	-	53.70	15.10	1.81	29.39	C	2.0	8.6	1.2	40.00	7.98	33.0	10.6	0.34
		18-41	-	57.20	6.66	1.77	34.37	C	2.0	8.7	1.2	40.00	8.19	35.6	8.4	0.96
	Clay	41-78	1.00	54.07	16.13	1.66	27.14	C	2.1	8.7	1.2	42.85	8.36	30.3	11.0	1.85
		78-130	1.00	54.07	12.14	1.53	31.26	C	2.3	8.8	1.1	52.17	8.55	30.2	11.8	1.83
		130-163	1.00	58.29	9.52	1.04	30.10	C	2.3	8.9	1.1	52.17	9.01	30.3	9.2	2.00
		163-175	5.00	67.53	11.25	1.78	14.44	C	2.4	8.8	1.2	50.00	7.70	30.6	3.4	1.48
7	V_2	0-21	-	0.21	48.26	4.34	47.19	Sc	2.5	7.8	1.3	48.00	6.05	28.0	7.8	0.01
		21-60	-	0.19	35.65	16.81	46.63	C	2.6	8.2	1.3	50.00	7.10	35.6	6.6	0.03
	Clay	60-102	-	0.29	49.17	3.24	47.29	C	2.4	8.1	1.3	45.83	5.50	35.4	5.6	0.09
		102-128	-	0.26	62.67	9.54	27.53	Sc	2.5	8.0	1.3	48.00	4.63	22.0	4.6	0.04
		128-160+	-	0.42	71.58	6.34	21.66	Scl	2.2	8.3	1.2	45.45	3.80	18.0	4.0	0.02
8	E_1	0-14	-	20.31	48.98	9.37	21.34	Scl	2.4	7.4	1.4	36.36	2.04	9.8	2.6	0.05
		14-38	-	22.26	46.25	7.20	24.29	Scl	2.3	7.6	1.4	39.13	1.78	10.2	2.8	0.01
	Sandy Loam	38-78	-	31.78	41.90	9.20	18.01	Sl	2.5	8.2	1.5	40.00	2.29	10.0	2.2	0.09
		78-97	-	0.48	81.59	1.35	16.58	Sl	2.6	8.5	1.4	46.15	1.20	8.7	2.6	0.07
		97-130	-	32.31	46.88	4.50	16.31	Sl	2.6	8.3	1.4	46.15	1.62	8.0	2.0	0.08
		130-160	-	4.94	64.40	13.88	16.78	Sl	2.6	8.4	1.4	46.15	1.91	8.0	2.0	0.06

Cl = Clay Loam L = Loam

Sc = Sandy Clay Sl = Sandy Loam

Scl = Sandy Clay Loam C = Clay

Topography :

Nearly level to very gently sloping flood plain having a slope gradient of 1-3°.

Drainage and Permeability :

Well drained. The soil permeability increases from moderate to moderately rapid with the depth.

Use :

Most of these soils are cultivated while the soils on the river banks are used for pastoral purposes. This has caused soil erosion along the banks resulting into waste/barren land.

Distribution and Extent :

The extent of I_1 series soils is limited and is found in and around Harni, Sukhilpura, Sokhda, Dolatpura and Kajalpur villages.

This series includes deep, well drained, dark yellowish-brown to brown soils occurring on undulating to rolling river levees. As these soils are found along the river banks they are subject to severe erosional hazards. The soil texture usually varies from clay loam, sandy clay loam and loam with the depth of the profile. The substratum is an unconsolidated massive matrix of rock debris, mica, quartz and loamy material. The lime concretions and gravels are distributed throughout the profile, but pockets of their accumulation are prominent in the sub-soil horizons. These soils had earlier been classified as "Alluvial Soils". The climate is warm to sub-humid having a mean annual air temperature of 27.8°C with a mean annual precipitation of 900 mm.

The associated soil series is I_5, which is a deep vertic ustochrepts [inceptisol].

The I_1 series comprises of fine members, montmorillonitic hyperthermic, deep family of vertic ustochrepts.

The typifying pedon : I_1 - sandy clay loam.

A typical 150 cm thick I_1 soil series profile located 0.4 km south of Sayajipura, 0.4 km north of the Laxmi Film Laboratory, near the junction of the Baroda - Ajwa and Baroda bypass roads is described in detail [Table : 6 & 7 and Fig. 10].

Horizon	Depth in cm	Description
A_p	0 - 15	Brown [10 YR 5/3] dark greyish brown [10 YR 4/2]; when moist; weak columns which break into weak medium subangular blocky peds; when dry it is slightly hard, when moist friable, when wet it is slightly sticky and slightly plastic; gravels of quartz mica flakes, sand, etc. are present; few lime concretions [2-4 mm] give effervescence with dilute HCl acid; few, fine roots are seen; clear and smooth boundary; pH - 8.2.
B_{1-1}	15 - 39	Dark brown [10 YR 3/3 D & M]; clay loam; weak columns which break down into moderate medium sub-angular blocky peds; gravels and rock debris seen; few lime concretions [2-4 mm] giving slight effervescence with dilute HCl acid; few, fine roots are seen; clear and wavy boundary; pH - 8.0.
B_{1-2}	39 - 65	Dark brown [10 YR 3/3 M]; sandy clay; weak medium sub-angular blocky peds; when moist

		friable, when wet slightly sticky and slightly plastic; gravels and rock debris present; common [2-4 mm] lime concretions giving slight to strong effervescence with dilute HCl acid; diffused wavy boundary; pH - 8.1.
C_1C_a	65 - 105	Dark yellowish brown [10 YR 4/4 M]; sandy clay loam; weak fine sub-angular blocky peds; when moist friable, when wet slightly sticky and plastic; abundant rock debris and gravels; mica, quartz comprise nearly 35% of the total volume; common [3-7 mm] lime concretions giving strong effervescence with dilute HCl acid; diffused wavy boundary; pH - 8.2.
C_2C_a	105 - 150+	Dark yellowish brown [10 YR 4/4 M]; loam; massive; when moist friable; when wet slightly sticky and plastic; abundant rock debris and gravels, mica flakes, quartz etc. comprising about 40% of the total volume; many lime concretions [3.7 mm] giving strong effervescence with dilute HCl acid; pH - 8.2.

Range of Characteristics :

The solum thickness ranges from 65-100 cm. The soil reaction varies in nature, differing from neutral to moderately alkaline in different layers. The lime concretions [2-10 mm] and coarse sand are also met with in different profiles below a depth of 65 - 80 cm. The $CaCO_3$ content varies between a concentration of 10-20% between a 20-120 cm depth range.

The main soil types are clay loam, and loam. The colour of the soil varies from dark brown to brown of hue 10 YR, values 3 to 5 and chroma 3 to 4 in A_p horizon to very dark greyish brown of hue 10 YR, values

3 to 5 and chroma 4 in the C horizon. The structure of the soil is weak columnar which breaks into weak fine to medium sub-angular blocky peds in the A_p horizon; weak columnar which breaks into moderate medium sub-angular blocky peds in the E_{1-1} horizon; weak to moderate medium sub-angular blocky peds in the B_{1-2} horizon; presence of calcium horizon and weak fine sub-angular blocky peds to crumbs in the C horizon. The distinctive feature of these soils is that the texture gets lighter with the depth. The moisture regime remains at or below wilting point in the control section.

Soil Series - I_2 :

Order	:	Inceptisol
Sub-Order	:	Orchrepts
Great-Group	:	Ustochrepts
Sub-Group	:	Fluventic Ustochrepts

Topography :

Nearly level to very gently sloping alluvial and flood plains having a gentle slope of 1-8° and in the ravines of the Mahi River.

Drainage and Permeability :

Well drained. The soil permeamibity is moderately rapid to moderate with the depth. The lowlying area along the banks of Vishwamitri and Mahi is liable to be frequently affected by floods.

Use :

Most of these soils are cultivated. In NW the area has developed ravines along the banks of Mahi river.

Distribution and Extent :

This soil type is one of the bench marks in the Baroda city and is

distributed in and around Anagadh, Asoj, Bil, Sokhda, Khurd, Hinglot, Padamala, Ranoli, Sevasi and Nandesari villages.

This series includes very deep, well drained, dark brown to dark yellowish brown soils occurring on nearly level, very gently sloping to steeply sloping alluvial plain and ravines. The soil texture usually varies from dark brown to dark yellowish brown fine sandy loam [in A horizon], dark brown, dark yellowish brown sandy clay loam to sandy clay [in B horizon], and dark brown sandy loam to silty loam [in C horizon] with the depth of the profile. The soil is non-calcareous in nature and contains varying amounts of mica flakes, quartz, gravels etc. The weak [less than 1 cm wide] soil cracks extend about 75 cm deep. These soils have been classified earlier as "Alluvial Soils" in India.

The mean annual temperature is 27.8°C and mean annual precipitation is 900 mm.

The associated soil series is V_2 which is a typic chromusterts.

The I_2 series comprises members of fine loamy, mixed, hyperthermic, very deep family of fluventic ustochrepts (inceptisols).

The typifying pedon : I_2 - sandy loam.

A typical 155 cm thick I_2 soil series profile located 0.5 km north-west of Sama village on Sama-Chhani cart track is described in detail [Table : 6 & 7 and Fig. 10].

Horizon	**Depth in cm**	**Description**
A_p	0 - 15	Brown [10 YR 4/3]; and dark brown [10 YR 3/3] when moist; sandy loam which breaks into weak medium sub-angular blocky peds; when

		dry slightly hard; when moist, friable; when wet slightly sticky; abundant fine roots are seen; few very fine mica flakes are present; permeability is rapid; clear and smooth boundary; pH - 7.2.
A_{1-2}	15 - 26	Dark brown [10 YR 4/3] and dark brown [10 YR 3/3] when moist; sandy clay loam which breaks into moderate medium sub-angular blocky peds; when dry hard; when moist friable; when wet sticky and plastic; plentiful fine roots are seen; permeability is moderate, clear and smooth boundary; pH - 7.9.
B_1	26 - 56	Dark brown [10 YR 3/3] and dark brown to very dark grayish brown [10 YR 3/2.5] when moist; coarse prismatic sandy clay loam breaks into moderate coarse angular blocky peds; when dry hard; when moist friable; when wet sticky and plastic; few fine roots are seen; permeability moderate, clear and wavy boundary, pH - 8.0.
B_{2-1}	56 - 90	Dark brown [10 YR 4/3] when moist; coarse prismatic sandy clay loam breaks into moderate coarse angular blocky peds; when dry hard; when moist friable; when wet sticky and plastic; few fine roots are seen; permeability moderate; clear and wavy boundary; pH - 8.2.
B_{2-2}	90 - 120	Dark yellowish brown [10 YR 4/5] and dark yellowish brown [10 YR 4/4] when moist; breaks into moderate coarse angular blocky peds; when dry hard; when moist friable; when wet sticky and plastic; permeability moderate; clear and smooth boundary; pH - 8.1.

C	120 - 155	Dark yellowish brown [10 YR 4/5] and dark yellowish brown [10 YR 4/4] when moist; sandy loam breaks into weak medium sub-angular blocky peds; when dry slightly hard; when moist friable; when wet slightly sticky; permeability moderate, pH - 7.6.

Range of Characteristics :

The solum thickness ranges from 100 to 145 cm. The main soil types are sandy loam and loamy sand, but at some places sandy clay loam are also seen. The sub-soil is medium to slightly heavy. These soils are generally non-calcareous in nature. At a few places, plentiful amount of lime concretions are seen, which gives effervescence with dilute HCl. The colour of the soil in the A horizon is dark brown to dark yellowish brown. In the B horizon the colour of the soil is dark brown to dark reddish brown [7.5 YR 3/4 to 5 YR 2/4]. In the C horizon the colour of the soil is dark brown to strong brown [7.5 YR 3/5 to 2/6]. The structure of the soil in the A horizon is weak, fine, sub-angular blocky peds; coarse, prismatic breaking into weak to moderate sub-angular blocky peds in B_1 horizon; coarse prismatic breaking into moderate angular blocky peds with coarse slickenslide pressure faces in the B_2 horizon and weak to fine medium sub-angular blocky peds in the C horizon. The soil reaction is neutral through out the profile depth. The insect, and ant burrows and krotovines are seen throughout the profile depth. The quartz gravels, mica flakes, sand, gravels etc. are present. The moisture status of the soil is at a wilting point upto 20 to 25 cm depth to the surface, while it is below wilting point in the sub-soil. Weak vertical cracks less than 1 cm wide are observed upto a depth of about 75 cm depth.

Soil Series - I_3 :

Order	:	Inceptisol
Sub-Order	:	Orchrepts

Great-Group : Ustochrepta

Sub-Group : Vertic Ustochrepts

Topography :

Nearly level to very gently sloping alluvial and flood plains having a slope gradient of 2° to 5°.

Drainage and Permeability :

Moderately well drained soils with slow to very slow permeability in wet conditions.

Use :

Most of the area is occupied by transitional land with some waste/barren land in between.

Distribution and Extent :

This soil type is distributed in and around Vara Gamdi, Dhaniyavi, Hansajipur, Sundarpura, Rhaghavpur, Amodar and Navapura villages.

This series includes deep to very deep, moderately drained, clayey soils occurring on gently sloping to steeply sloping flood plains and midlands with a gradient ranging from 2° to 10°. The colour ranges from dark brown to dark yellowish brown. The texture of the solum varies from clay to clay loam in the C horizon. These soils shrink and swell considerably according to the change in moisture content and on drying it cracks deeply and widely. The lime concretions, ferruginous concretions and gravels are found to increase along with the depth of profile. These soils have been earlier classified in India as "Deep Black Soils".

The climate is tropical humid having a mean annual air temperature of 27.8°C and with a mean annual precipitation of 900 mm.

The associated soil series is I_5 which is deep to very deep, vertic ustochrepts [inceptisols]. The I_3 series comprises of very fine, montomorillonitic, hyperthermic, deep family of vertic ustochrepts [inceptisols]. It cracks vertically upto a depth of 90 to 120 cm.

The typifying pedon : I_3 clay.

A typical 175 cm thick I_3 soil series profile located in the south, about 0.7 km away from Sundarpura village is described in detail [Table : 6 & 7 and Fig. 10].

Horizon	Depth in cm	Description
A_p	0 - 22	Very dark grayish brown [10 YR 3/2 D&M] clay; breaks into coarse columnar to sub-angular blocky peds; when dry hard; when moist firm, when wet sticky and plastic; fine porous; few lime concretions [1 to 2 mm] give slight effervescence with dilute HCl. Fine roots are seen; clear and smooth boundary; pH - 8.6.
B_1	22 - 62	Very dark grayish brown [10 YR 3/2 D] clay; coarse slickenslide pressure faces; breaks into medium angular blocky peds with indistinct shining peds; when dry hard; when moist firm; when wet sticky and plastic; few micro-pores are seen; lime concretions [2 to 4 mm] gives slight effervescence with dilute HCl; few fine inped roots are seen; clear and wavy boundary; pH - 8.7.
B_2	62 - 117	Very dark grayish brown [10 YR 3/2] clay; breaks into moderate medium angular blocky

		with prominent shining ped faces; coarse slickenslide pressure faces; when dry very hard; when moist very firm, when wet very sticky and very plastic; few micro-pores are seen; lime concretions [2 to 4 mm] gives strong effervescence with dilute HCl; fine ferruginous concretions are also seen; few fine inped roots are present, clear and wavy boundary; pH - 9.0.
B_6	117 - 145	Dark brown [10 YR 3/3] silty clay loam, breaks into medium sub-angular blocky peds with indistinct slickenslide pressure faces; when moist firm, when wet sticky and plastic; micro-pores are common, lime concretions [3 to 5 mm] gives strong effervescence with dilute HCl. Many ferruginous concretions are seen; clear and wavy boundary; pH - 8.8.
C_1	145 - 175+	Dark brown to dark yellowish brown [10 YR 4-5/4] silty loam; breaks into weak fine sub-angular blocky peds to massive peds; when moist friable, when wet slightly sticky and slightly plastic; many micro- and macro-pores are seen; many ferruginous concretions are present; lime concretions [5 to 7 mm] give violent effervescence with dilute HCl; pH - 9.1.

Range of Characteristics :

The solum thickness [depth to the base of B horizon] ranges from 95 to 145 cm. The dominant soil types are clay, and clay loam. After a thin [1-2 cm] pulverised surface layer of the A_p horizon, at a lower depth, at the base of A_p horizon, coarse columnar blocky structure breaking into

weak medium sub-angular blocky peds is seen; coarse slickenslide pressure faces breaking into weak medium angular blocky peds with indistinct shining ped faces in the B_1 horizon, coarse shining peds having moderate medium angular blocky peds with prominent slicken slides in the B_2 horizon; weak medium sub-angular blocky peds to massive in the C horizon are seen. The colour of A_p horizon is dark brown to very dark grayish brown [10 YR 3/4 to 2/4]: B_1 and B_2 horizon is very dark grayish brown [10 YR 3/2]; dark yellowish brown [10 YR 3/4] in B_c horizon and brown to dark yellowish brown [10 YR 4/5 - 3/4] in C horizon. The lime concretions are found to increase along with the lower part of B horizon transitional to C horizon in size and quantity. Gravels of basalt, quartz and mica flakes also increase along with the depth. C horizon is less compact and pervious in nature, having a medium texture. The soil contains few micro-pores upto B horizon and common micro- and macro-pores in C horizon.

The soil moisture upto the depth of 30 cm below surface is at wilting point. Cracks extend from 90 to 120 cm from the surface. The soil reaction in A_p and B horizon is slightly to moderately alkaline while moderately to strongly alkaline in C horizon.

Soil Series - I_4 :

Order	:	Inceptisol
Sub-Order	:	Ochrepts
Great-Group	:	Ustochrepts
Sub-Group	:	Fluventic Ustochrepts

Topography :

Nearly level to very gently sloping alluvial plain having a slope gradient of 3° to 7°.

Drainage and Permeability :

Moderately to poorly drained. The permeability is moderate to moderately

slow in wet condition.

Use :

Most of these soils are occupied by built-up land and transitional land, while part of them are under pastoral or grass land.

Distribution and Extent :

This soil is one of the bench marks in the study area, and is distributed in and around Aladpur, Makarpura, Baroda, Bapod, Tarsali, Kapurai, Ratanpur, Jobantekari, Maneja, Manjalpur and Virod villages.

This series includes deep, moderately to poorly drained, dark brown to pale brown fine loamy soils occurring on nearly level to very gently sloping mid-land with gradient ranging from 3° to 7°. The surface soil textures are sandy loam, loamy sand and sandy clay loam followed by sandy clay, clay loam and sandy clay loam in the sub-soil. These soils are free from lime concretions in the solum, but a few common lime concretions are seen in the C horizon. The pockets [lenses] and streaks of sand are found in the profile. White patches [1-2 mm thick] formed due to salt encrustation are found on the surfaces. The soil structure is weak fine sub-angular blocky peds in the A horizon, to coarse prismatic breaking into moderate to strong, medium, sub-angular and angular blocky peds in the sub-soil. White ants are seen on the soil surface. These soils had been classified as "Alluvial Soils" in India. The climate is tropical, sub-humid with a mean annual air temperature of 27.8°C and a mean annual precipitation 900 mm.

The associated soil series is I_2 which is fine loamy, hyperthermic, very deep family of fluventic ustochrepts.

This series comprises members of fine loamy, mixed hyperthermic, deep family of fluventic ustochrepts [inceptisols].

The typifying pedon : I_4 Sandy loam.

A typical 140 cm thick I_4 soil series profile located about 0.3 km north of Kapurai village near the village tank on the Baroda by-pass of National Highway No. 8 is described in detail [Table : 6 & 7, and Fig. 10].

Horizon	Depth in cm	Description
A_p	0 - 20	Pale brown [10 YR 6/3] and grayish brown [10 YR 5/2 M] sand loam, breaks into fine sub-angular blocky peds, when moist very friable; when wet, non-sticky and non-plastic; few quartz gravels and mica flakes are seen; insect, ant burrows and kretovines are seen; many micro-pores are present; fine inped roots are seen; clear and smooth boundary; pH - 8.1.
B_{2-1}	20 - 47	Dark brown to brown [10 YR 4/3] and dark brown [10 YR 3/3 M] and grayish brown [10 YR 5/2 M]; sandy clay loam; breaks into moderate medium sub-angular blocky peds; when dry hard, when moist friable, when wet sticky and plastic; lenses and streaks of sand are present; few gravels of quartz and mica flakes are present; insect, ant burrows and kretovines are seen, micro-pores are present; few fine inped roots are seen; clear and wavy boundary; pH - 8.3.
B_{2-2}	47 - 120	Dark brown [10 YR 3/3] and grayish brown [10 YR 5/2 M] and very dark grayish brown [10 YR 3/2 M] sandy clay loam; coarse prismatic, breaks into moderate medium angular blocky

		ped; when dry hard, when moist friable, when wet sticky and plastic; lenses and streaks of sand, few gravels of basalt, quartz, mica flakes are seen; common micro- and macro-pores are developed; diffused and wavy boundary; pH - 8.5.
C_1	120 - 140	Yellowish brown [10 YR 5/4] and dark yellowish [10 YR 4/4 M] sandy clay loam to sandy loam; breaks into fine sub-angular blocky peds; when dry slightly hard, when moist friable, when wet slightly sticky and slightly plastic; many gravels of quartz, mica flakes are seen; many macro-pores are developed; pH - 8.8.

Range of Characteristics :

The solum depth ranges from 70 to 110 cm but at places it is more than that. The dominant soil textures are sandy loam, loamy sand and sandy clay loam followed by clay loam, sandy clay loam, sandy clay and loam in the sub-soil, and sandy loam to sand and sandy loam in the C horizon. The colour of the soil ranges from pale brown to dark brown [10 YR 3/6 and 2/4] in the A_p horizon, dark brown to very dark grayish brown [10 YR 3/5 and 2/4] in the B horizon, and yellowish brown to brown [10 YR 4/5 and 3/6] in the C horizon. Lenses and streaks of sand are found in the B horizon. The structure of soil is weak, fine sub-angular blocky in the A_p horizon; coarse prismatic breaking into moderate to strong, medium sub-angular to angular blocky peds in the B horizon; weak medium sub-angular blocky to massive in C horizon. The solum is completely free from lime concretions, but the C horizon contains a litte amount of acretionary lime nodules and lime concretions giving a strong effervescence with dilute HCl acid. The insect and ant burrows are present. Whiteness due to salt encrustation [1-2 cm thick] was observed in patches on the surface soil. This soil type remains wet around Baroda city as it is

constantly irrigated from the sewage water of the city. The soil reaction is moderately alkaline in different layers.

The moisture status is at wilting point upto about 30 cm depth, while it is below wilting point in the sub-soil.

Soil Series - I_5 :

Order	:	Inceptisol
Sub-Order	:	Orchrepts
Great-Group	:	Ustochrepts
Sub-Group	:	Vertic Ustochrepts

Topography :

Nearly level to very gently sloping alluvial and flood plains having a slope gradient of 1° to 5°.

Drainage and Permeability :

Moderately well drained, permeability is moderately slow to slow along with the depth.

Use :

Most of these soils are occupied by transitional and waste/barren land, while soils on the river banks are used for pastoral purpose.

Distribution and Extent :

This is one of the benchmark soils in the eastern part of the study area, and is distributed in and around Sukhilpura, Amaliara, Bhavpura, Kumetha, Amodar, Pavlepur, Sankarpura, Tartarpura, Navapura, Diwalipura, Ajitpura, Hetampur and Kanadkui villages.

This series includes deep, moderately drained, dark brown to dark grayish brown soils formed in the new alluvium, along the terraces of Vishwamitri and Dhadhar rivers. These soils are found near river or nala banks on plain to very gently sloping land with a gradient of 1° to 5°. They are mostly free of lime concretions but gravels are present throughout the profile. This soil cracks vertically upto a depth of 95 to 120 cm during the dry period. It had earlier been classified as "Deep Black Soils" in India. The climate is tropical sub-humid, having a mean annual air temperature of 27.8°C, and annual mean precipitation of 900 mm.

The associated soil is I_3, which is a moderately deep, vertic ustochrept [inceptisol]. This soil series comprises members of fine, montmorillonitic, hyperthermic deep family of vertic ustochrepts [inceptisols].

The typifying pedon : I_5 - Sandy Clay Loam.

A typical 150 cm thick I_5 soil series profile located about 0.7 km north-east of Sukhilpura is described in detail [Table : 6 & 7, and Fig. 10].

Horizon	Depth in cm	Description
A_p	0 - 20	Dark brown [10 YR 3/3] to very dark grayish brown [10 YR 3/2] when moist; sandy clay loam, coarse columnar, breaks into weak sub-angular blocky peds; when dry hard, when moist firm, when wet sticky and plastic; gravels of quartz, mica flakes and sand are present; few micro-pores are seen; fine roots are present; clear and smooth boundary; pH - 7.4.
B_{1-1}	20 - 52	Very dark grayish brown [10 YR 3/2 D&M] sandy clay loam; coarse columnar, breaks into moderate sub-angular blocky peds with indistinct

		slickenslide pressure faces; few micro-pores are seen; few gravels of quartz and mica flakes are present; fine inped roots are seen; clear and wavy boundary; pH - 7.6.
B_{1-2}	52 - 95	Very dark grayish brown [10 YR 3/2 M] sandy clay loam; coarse prismatic structure; breaks into medium angular blocky peds with prominent slickenslide; when moist very firm, when wet very sticky and very plastic; few micro pores are seen; very fine inped roots are seen; clear and wavy boundary; pH - 7.4.
B_3	95 - 115	Dark brown [10 YR 3/3 M], sandy clay loam; breaks into weak medium sub-angular blocky peds with indistinct slickenslides pressure face; when moist friable, when wet sticky and plastic; common macro- and micro-pores are seen; very few lime concretions [2-4 mm] give slight effervescence with dilute HCl; pH - 7.9.
C_1	115 - 150	Dark yellowish brown [10 YR 4/4] sandy loam, breaks into weak fine sub-angular blocky peds; when moist friable, when wet slightly sticky and slightly plastic; common macro- and micro-pores are seen; few lime concretions [2-4 mm] give slight effervescence with dilute HCl; pH - 8.4.

Range of Characteristics :

The thickness of the solum ranges from 90 to 130 cm [upto the base of B horizon transitional to C horizon] which is the series control section. The principal soil type is clay and sandy clay loam. The structure of

the soil is coarse columnar, breaking into weak, medium sub-angular blocky peds in the A_p horizon, coarse columnar, breaking into moderate medium sub-angular blocky peds with distinct shining ped faces in the B_{1-1} horizon; coarse prismatic structure breaking into moderate, medium angular blocky peds with prominent shining ped faces in the B_{1-2} horizon; weak, medium, sub-angular peds with indistinct shining ped faces in the B_3 horizon; and, weak fine sub-angular blocky peds to massive in the C horizon. The colour of the soil is dark yellowish brown to very dark grayish brown [10 YR 3/5 to 3/4] in the A_p horizon; very dark grayish brown to dark brown [10 YR 3/2] in the B horizon; and, dark yellowish brown to yellowish brown [10 YR 4/5 to 4/3] in the C horizon.

The soil in the control section, within a depth of 100 cm remains saturated for some period in the year. The soil reaction is neutral to slightly alkaline in the upper part of the control section, while it is mildly alkaline in the lower part. Soil cracks are 3 to 5 cm wide and 90 to 120 cm deep in the dry season. The soil moisture within a depth of 30 cm attains moisture status at or below wilting point.

Soil Series - V_1 :

Order	:	Vertisol
Sub-Order	:	Usterts
Great-Group	:	Chromusters
Sub-Group	:	Udic Chromusters

Topography :

Near level to very gently sloping alluvial plain having a slope gradient of 1° to 3°.

Drainage and Permeability :

Poorly drained soils with slow to very slow permeability in wet condition.

Use :

This soil is occupied by transitional and waste/barren land.

Distribution and Extent :

Soils of this series are distributed in and around Bakrol, Patod and Saveja villages in the southern part of the study area.

This V_1 series soils are imperfectly drained, very deep vertisols developed on nearly level to very gently sloping alluvial plains. Colour of the soil is dark brown to dark grayish brown and strongly alkaline clay in the A horizon, grading to very dark gray strongly alkaline clay in the A_1 horizon, and dark brown to dark yellowish brown, strongly alkaline clay in the C horizon. Soil cracks [3-4 cm wide] extend upto 80 cm or more in depth. The climate is sub-humid, with the mean annual air temperature 27.8°C, and the mean annual precipitation being 900 mm. The associated soil is I_3 inceptisol which is a fine, montmorillonitic, hyperthermic, deep family of vertic ustochrepts.

This V_1 series soil comprises members of fine, montmorillonitic, hyperthermic family of udic chromusters.

The typifying pedon : V_1 - Clay.

A typical 175 cm thick, V_1 soil series profile located about 1 km south-east of Saveja village is described in detail [Table : 6 & 7, and Fig. 10].

Horizon	Depth in cm	Description
A_p	0 - 18	Dark greyish brown [10 YR 4/2] and very dark greyish brown [10 YR 3/2 M] clay;

		coarse columnar; breaks into moderate medium angular blocky peds; when dry very hard, when moist very firm, when wet very sticky and plastic; permeability is slow, few lime concretions give slight effervescence with dilute HCl; smooth boundary; pH - 8.6
A_{1-2}	18 - 41	Very dark grey [10 YR 3/1 D&M] clay; coarse prismatic; breaks into moderate to medium angular blocky peds with indistinct slickenslide, when dry very hard; when moist very firm; when wet very sticky and very plastic; permeability is very slow; few lime concretions give slight effervescence with dilute HCl; few fine roots are seen; clear and smooth boundary; pH - 8.7.
A_{1-3}	41 - 78	Very dark grey [10 YR 3/1 M] clay; coarse slickenslides with wedge-shaped peds; when moist very firm; when wet very sticky and very plastic; few lime concretions give slight effervescence with dilute HCl; few fine roots are seen; clear and smooth boundary; pH - 8.7.
A_{1-4}	78 - 130	Very dark grey [10 YR 3/1 M] clay; wedge-shaped peds having prominent slickenslides; when moist firm; when wet very sticky and very plastic; permeability is very slow; few lime concretions give slight effervescence with dilute HCl; clear and smooth boundary; pH - 8.8.
A_{1-5}	130 - 163	Very dark grey to black [10 YR 2.5/1 M]

		clay; wedge-shaped peds having prominent slickenslides; when moist very firm; when wet very sticky and very plastic; permeability is very slow; few lime concretions give slight effervescence with dilute HCl; diffuse and smooth boundary; pH - 8.9.
C	163 - 175+	Very dark greyish brown and dark brown [10 YR 3/2 and 3/3] clay; wedge-shaped peds having slickenslides; when moist firm, when wet very sticky and very plastic; pH - 8.8.

Range of Characteristics :

The solum thickness ranges from 100 cm to 170 cm. The dominant soil type on the surface is clay, while in the sub-soil the dominant soil type is clay and clay loam. Clay content increases with the depth. The clay is montmorillonitic and the structure in the control section is coarse columnar to prismatic, breaking into weak, medium, sub-angular blocky peds with wedge-shaped and slickenslide pressure faces. Soil colour varies from dark grey brown to very dark greyish brown and black in the A horizon. In the C horizon the colour varies from dark brown to dark yellowish brown. Lime concretions are found to increase with depth. Soil cracks [2 to 5 cm wide] extend upto 90 cm deep or more in the dry season. Soil reaction is strongly alkaline.

Soil-Series - V_2 :

Order	:	Vertisol
Sub-Order	:	Usters
Great-Group	:	Chromusters
Sub-Group	:	Typic-Chromusters

Topography :

Nearly level to very gently sloping alluvial and flood plains having a gradient of 2° to 5°.

Drainage and Permeability :

These soils are somewhat imperfectly drained with slow permeability.

Use :

These soils are found in transitional areas which can be used for agricultural purpose.

Distribution and Extent :

V_2 soil series is distributed in limited areas in and around Bhayli, Gotri, Khanpur, Dumad, Morlipura, Chansad, Vadsala, Varnama and Alamgir villages.

This soil series includes deep to very deep, imperfectly drained, clayey soils which occur on nearly level to very gently sloping alluvial and flood plains of the Vishwamitri river. They are dark greyish brown to dark brown sandy clay loam to clay in the A_p horizon, grading to very dark greyish brown to very dark grey, clay. The sub-soil horizons have a moderate, medium, angular blocky, compact, coarse texture with intersecting slickenslide pressure faces. These soils have a high shrink-swell potential with high self-swelling properties and are physically similar to I_5, inceptisol, except in their structure development and clay content. Basalt gravels are found throughout the profile depth. The vertical cracks [8 to 10 cm] extend deeply upto the upper boundary of the C horizon. This soil has been classified earlier as "Deep Black Soils" in India. The common soil associates are I_3 and I_5 soil types which are vertic ustochrepts of inceptisol order. This soil comprises

members of fine, montmorillonitic, hyperthermic, deep family of typic chromusters [vertisol].

The mean annual air temperature is 27.8°C and mean annual precipitation is 900 mm.

The typifying pedon : V_2 Clay.

A typical 160 cm thick V_2 soil series profile located about 1 km north-east of Dumad village near the crossing of the tributary of Vishwamitri river is described in detail [Table : 6 & 7 and Fig. 10].

Horizon	**Depth in cm**	**Description**
A_p	0 - 21	Very dark greyish brown [10 YR 3/2 D] sandy clay; coarse prismatic texture; breaks into weak medium sub-angular blocky peds; when dry hard; when moist firm; when wet sticky and plastic; permeability is moderately slow; few grains of quartz; mica flakes, sand etc. are seen; very few acretionary lime nodules, give slight effervescence with dilute HCl; inped roots are abundant; clear and smooth boundary; pH - 7.8.
A_{1-2}	21 - 60	Very dark greyish brown [10 YR 3/2 D&M] clay; coarse intersecting slickenslide pressure face; breaks into medium angular blocky peds with shining moderate pressure faces; when dry very hard; when moist very firm; when wet very sticky and very plastic; permeability slow; few quartz gravels, mica flakes, sand and gravels are seen; fine inped roots are

		seen; clear and wavy boundary; pH - 8.2.
A_{1-3}	60 - 102	Very dark greyish brown [10 YR 3/2 M], sandy clay; coarse intersecting slickenslide pressure face; breaks into moderate medium angular blocky peds with shining pressure faces; when moist very firm; when wet very sticky and very plastic; permeability slow; few quartz gravels, mica flakes, are present; few micro-pores and inped roots are seen; clear and wavy boundary; pH - 8.1.
A_c	102 - 108	Dark brown [10 YR 3/3 M] and very dark greyish brown [10 YR 3/2] sandy clay loam; texture coarse; breaks into moderate, medium, sub-angular blocky peds with indistinct shining pressure faces; when moist firm; when wet sticky and plastic; permeability moderate; few quartz gravels, mica-flakes, sand and gravels are present; few (2-5 mm) lime concretions give light effervescence with dilute HCl; very few inped roots are seen; diffused and wavy boundary; pH - 8.0.
C_1	128 - 160+	Dark yellowish brown [10 YR 4/4 M]; sandy clay loam; breaks into medium sub-angular blocky peds; when moist friable; when wet slightly sticky and slightly plastic; plentiful quartz gravels, mica-flakes, sand and gravels are present; common macro- and micro-pores are seen; lime concretions [3 to 20 mm] give strong effervescence with dilute HCl; pH - 8.3.

Range of Characteristics :

The solum thickness ranges from 90 to 150 cm. The main soil types are clay and sandy clay loam. The colour of the soil is dark brown to very dark greyish brown [10 YR 3/2] in the A_p horizon, grading to very dark greyish brown to very dark grey [10 YR 2/3 and 1/2] in the sub-soil horizons, dark brown to very dark greyish brown [10 YR 3/4 to 2/4] in A_c horizon and dark brown to dark yellowish brown [10 YR 4/5 to 3/4] in the C horizon. The structure of the soil is coarse prismatic, breaking into weak to moderate, medium sub-angular blocky peds in the A_p horizon; coarse prismatic, breaking into weak to moderate angular blocky peds with indistinct slickenslide pressure faces in A_{1-2} horizons; coarse, breaking into moderate to strong angular blocky peds with shining peds with indistinct slickenslide shining pressure faces in the A_c horizon and weak medium fine sub-angular blocky to massive peds in the C horizon. The quartz gravels and mica-flakes are present throughout the profile depth. The soil permeability is moderately slow. The soil cracks are 5 to 10 cm wide and 100 cm or more deep in the dry season. The soil reaction is moderately to strongly alkaline.

Soil-Series - E_1 :

Order	:	Entisol
Sub-Order	:	Fluvents
Great-Group	:	Ustifluvents
Sub-Group	:	Typic Ustifluvents

Topography :

Undulating alluvial ravines having a slope gradient of 10° to 40° and in the flood plains of the Mahi river.

Drainage and Permeability :

Well drained to excessively drained. The permeability is rapid to very

rapid.

Use :

These soils are found in ravines and flood plain of Mahi river. They are covered by scrubby vegetation.

Distribution and Extent :

The extent of this series is limited and found to occur along the banks of the Mahi river in and around Hinglot, Singhrot, Ampad, Sherkhi, Kotna, Ranoli, Dhanora, Rayaka and Sankarda villages.

This series includes deep, well drained to excessively drained, pale brown to brown soils occurring in undulating to high rolling alluvial ravines of the Mahi. These soils are subjected to severe erosion hazards. The soil texture generally varies from loamy sand, sandy loam, loamy sand. The sub-stratum is an unconsolidated massive matrix of rock materials, mica flakes and quartz gravels. The lighter texture of the surface and sub-soil, along with its physiographic situation is responsible for the severe erosion which has resulted in the formation of deep to very deep and wide to very wide ravines. The lime concretions are completely absent from 36 to 50 cm depth, but increase after that. The presence of white ants is observed throughout the profile depth. These soils had been classified as "Alluvial Soils" earlier in India. The climate is tropical sub-humid with a mean annual air temperature of 27.8°C and a mean annual precipitation of 900 mm.

The associated soil series is I_2, which is a very deep, mixed fluventic ustochrept [inceptisol]. E_1 series comprises members of coarse loamy, mixed sand, hyperthermic deep family of typic ustifluvents.

The typifying pedon : E_1 - Sandy Loam.

A typical 160 mm thick E_1 soil series profile located 0.5 km south-east of Singhrot village on Baroda - Singhrot cart track, is described in detail [Table : 6 & 7, and Fig. 10].

Horizon	Depth in cm	Description
A_p	0 - 14	Dark brown [7.5 YR 4/4 D and 7.5 YR 3.5/2M] sandy clay loam; breaks into weak fine sub-angular blocky peds; when dry slightly hard; when moist very friable; when wet non-sticky and non-plastic; permeability rapid; few mica flakes, quartz gravels, sand and gravels are present; insect and ant burrows and kretovines are present; common fine inped roots are seen; clear and smooth boundary; pH - 7.4.
A_{1-2}	14 - 38	Strong brown [7.5 YR 5/6] and dark brown [7.5 YR 4/4], when moist, sand clay loam; moderate, fine sub-angular blocky peds; when dry hard; when moist friable; when wet non-sticky and non-plastic; permeability rapid; few quartz gravels and mica flakes are present; insect and ant burrows are seen; few fine inped roots are seen; clear and wavy boundary; pH - 7.6.
II C_1	38 - 78	Brown yellow [10 YR 6/6] and dark brown [7.5 YR 4/4], when moist, sandy loam; weak fine sub-angular blocky peds; when moist friable; when wet non-sticky and non-plastic; permeability very rapid; few quartz gravels, mica flakes, sand and gravels are seen; few

		(2 to 6 mm) calcinated gravels give strong effervescence with dilute HCl; insect and ant burrows are present; sand pockets at the lower boundary are present; few fine inped roots are seen; diffuse boundary; pH - 8.2.
III C_2	78 - 97	Light yellow brown [10 YR 6/4] and dark yellowish brown [10 YR 4/6] when moist, sandy loam; when moist friable; when wet non-sticky and non-plastic; permeability very rapid; abundant quartz gravels, mica flakes, sand and gravels give strong effervescence with dilute HCl; insect and ant burrows are seen; diffuse boundary; pH - 8.5.
IV C_3	97 - 130	Light yellowish brown [10 YR 6/4] and dark yellowish brown [10 YR 4/6] when moist sandy loam; when dry loose; when wet non-sticky and non-plastic; permeability very rapid; plentiful quartz gravels and mica flakes are present; common [2 to 5 mm] calcinated gravels give strong effervescence with dilute HCl; insect and ant burrows and kretovines are seen; diffuse boundary; pH - 8.3.
V C_4	130 - 150+	Light yellowish brown [10 YR 6/4] and dark yellowish brown [10 YR 4/6] when moist sandy loam; when moist loose; when wet non-sticky and non-plastic; permeability very rapid; plentiful quartz gravels, mica flakes sand and gravels are present; common [3 to 5 mm] calcinated gravels give strong

effervescence with dilute HCl; insect and ant burrows are seen; pH - 8.4.

Range of Characteristics :

The solum thickness ranges from 35 to 80 cm. The soil reaction varies in nature, differing from mildly alkaline to moderately alkaline. The lime concretions are completely absent in the solum but increase with the profile depth. The main soil types are loamy sand, sandy loam, and sandy clay loam. The colour of the soil varies from pale brown to brown [7.5 YR 4/6 to YR 3/4] in the A_p horizon; dark brown to strong brown [7.5 YR 4/5] in the A_{1-2} horizons and dark brown to brownish yellow [10 YR 4/6 to 7.5 YR 4/6] in the C horizon. The structure of the soil is crumbly to weak, fine, sub-angular blocky in the A_{1-2} and A_{1-3} horizons, while weak, fine, sub-angular blocky to single grained in the C horizon. While ants are observed throughout the profile. The distinctive feature of this soil is that the colour remains more or less similar in the control section while differing in the C horizon, indicating a lithological discontinuity of the profile. The moisture regime remains at wilting point in the control section.

GEOTECHNICAL INVESTIGATION :

A rapid urbanization due to industrial development is envisaged in and around Baroda city. The civil engineering structures in and around Baroda city are to be founded on varied soils, as the bed rock is not available down to 100 m depth. The city is a big urban-cum-industrial complex and is under the process of continuous expansion. High buildings, heavy structures, new roads etc. are coming up very fast in the area necessisating a systematic soil exploration for assessing the strength characteristics of the foundation soils for the structures. Thus the main objective of the study is to asses geotechnical properties of different soil formations in and around Baroda city to facilitate a rational and planned development of fast growing township.

TABLE : 8

STATEMENT OF GEO-TECHNICAL PROPERTIES OF SOILS IN AND AROUND BARODA CITY

SR. NO.	SOIL TYPE	LOCATION AS SHOWN IN FIG. 9	SPECIFIC GRAVITY	DRY DENSITY gms/cc	MOISTURE CONTENT %	ATTERBERG LIMIT			STANDARD PENETRATION TEST Blows/30 cm	RESISTIVITY Ohms/m^3
						LIQUID LIMIT %	PLASTIC LIMIT %	PLASTICITY INDEX %		
1	2	3	4	5	6	7	8	9	10	11
1	I_2 [Sandy Loam]	A	2.65	1.8	3.70	39.57	20.94	18.63	29	3770.3
2	I_2 [Sandy Loam]	B	2.65	1.8	5.10	32.90	19.19	13.71	31	4704.5
3	E_1 [Sandy Loam]	C	2.65	1.8	1.91		Non plastic		30	1568.2
4	E_1 [Sandy Loam]	D	2.55	1.5	2.70	44.81	23.48	21.33	12	1568.2
5	I_2 [Sandy Loam]	E	2.65	1.8	3.10	22.87	14.64	08.23	29	4376.6
6	I_2 [Sandy Loam]	F	2.45	1.6	3.76		Non plastic		12	3800.8
7	I_2 [Sandy Loam]	G	2.55	1.5	2.70	33.88	23.94	09.94	16	1901.8
8	I_4 [Sandy Clay Loam]	H	2.65	1.5	2.70	32.33	19.69	12.64	27	1267.9
9	I_5 [Sandy Clay Loam]	I	2.40	1.7	4.70		Non plastic		09	1267.9
10	I_2 [Sandy Loam]	J	2.55	1.5	3.30		Non plastic		19	2202.1
11	V_2 [Sandy Clay Loam]	K	2.30	1.5	3.80	33.74	20.62	13.12	16	1267.9
12	I_4 [Sandy Clay Loam]	L	2.55	1.6	3.20	32.00	20.16	11.84	10	3770.3
13	I_4 [Sandy Clay Loam]	M	2.55	1.6	5.40	20.75	13.32	07.43	13	1575.0
14	I_1 [Loam]	N	2.65	1.8	2.60	42.70	24.84	17.86	30	4704.5
15	I_3 [Clay Loam]	O	2.45	1.5	4.80	36.84	22.21	14.63	14	2502.4

Engineering geological studies have been carried out for the geotechnical evaluation of the study area.

Reconnoitory traverses have been undertaken in and around Baroda city. Spot sampling of the soils have been done from the open trenches excavated for the construction purposes, kiln factories and natural sections. In the course of investigation about 20 disturbed and undisturbed soil samples have been collected from various localities at 2 m depth for determination of the following engineering properies at the Geotechnical Laboratory, PHEL, Baroda.

- Grain size analysis
- Specific gravity
- Dry density
- moisture content
- Atterberg limits
- Standard penetration test
- Resistivity

Standard penetration test and resistivity test have been performed in the field.

Summarised statement giving the variation of soil types, specific gravity, dry density, moisture content, Atterberg limits, standard penetration test and resistivity values computed at 15 different sites is presented in the Table : 8. The location of the sites is given in Fig. 9.

DISCUSSION :

From Table : 8 it can be seen that there is a vast variation in the geotechnical properties of different soil types. Out of 15 samples, different soil types are sandy loam, sandy clay loam, clay loam and loam. The values of specific gravity ranges from 2.5 to 2.6 which are low to medium. While the value of dry density vary from 1.5 to 1.8 these indicate that

the soils are very loose, loose to medium. The following statement shows the state of the soils [from Punamia B.C., 1988].

Standard Penetration blows/30 cm N	Approx. dry density	Description
-	1.2 - 1.6	Very loose
4	1.4 - 1.8	Loose
10	1.7 - 2.0	Medium
30	1.7 - 2.2	Dense
50	2.0 - 2.4	Very loose

The penetration test values ranges from 09 to 31 which also indicate that the soils are very loose, loose and medium. From Table : 8, it is very clear that I_2 and I_5 soil types i.e. sandy loam occurring on or near the Mahi and Vishwamitri rivers banks are non-plastics and the standard penetration test values are also low.

Thus the cause of low state nature of the soils may be due to the loss of ground vegetation and improper land-use practices.

TABLE : 9

SOIL TYPES : THEIR DISTRIBUTION, CHARACTERISTICS, LAND-USE, PROBLEMS AND REMEDIAL MEASURES

SR. NO.	SOIL SERIES/ SOIL ASSOCIATION	GEOMORPHIC UNITS	AREA (sq.km)	SOIL CHARACTERISTICS	PRESENT LAND-USE	PROBLEMS AND LIMITATIONS	REMEDICAL MEASURES
1	2	3	4	5	6	7	8
1	I_1	Flood plain	30.5	Deep, well drained, dark yellowish brown to brown, occurring on undulating flood plain, subject to severe erosion, texture varies from clay loam to sand loam with lime concretion.	Most of the area is occupied by transitional land but can be used for agricultural purposes. While on the Vishwamitri river banks soil erosion has resulted into waste or barren land.	On the flood plains, soils are subject to severe sheet and gully erosion.	Nitrogen fixing trees should be established along the contours of steep slopes, and food crops that reduce sheet erosion should be planted in between them.
2	I_2	Alluvial plain	228.88	Very deep, well drained, dark brown to dark yellowish brown, occurring nearly level, very gently to steep slope, subject to moderate & at ravines severe erosion, texture varies from sandy loam, sandy clay loam to sandy clay.	Most of the area is occupied by built up land. Toward SW the area is used as agri-cultural land. While in NW the area has developed ravines along the banks of Mahi river.	Soils on alluvial plains are subject to moderate erosion. While on the river banks soils are subjected to severe to very severe gully erosion.	Clearing, levelling, bench terracing of side-slopes, plugging of tributary gullies, earthern and brick checkdams at intervals. Structures should be protected by grassing.
	$I_2 - I_1$	Flood plain	7.1				
3	I_3	Alluvial plain	35.9	Deep to very deep moderately drained, dark brown to dark yellowish brown, occurring on gently sloping to steeply sloping, moderate erosion, texture varies from clay to clay loam, lime concretions increase with depth.	Most of the area is occupied by transitional land but it can be utilized for agri-cultural purposes. While in between the area is occupied by waste barren land.	Soils are moderately drained, subject to moderate erosion.	Application of recent agronomic practices with proper use of fertilizers. Deep ploughing should also be carried out.
	$I_3 - I_5$	Alluvial plain, flood plain	43.2				
4.	I_4	Alluvial plain	100.6	Deep, moderately to poorly drained, dark brown to pale brown fine loamy soils, occurring on nearly level to very gently sloping, texture varies from sandy loam, loamy sand to sandy clay loam.	Majority of the area is occupied by built-up land and transitional land. Few patches of agricultural land are found in the area.	Soils are ill drained, subject to moderate erosion.	Judicious irrigation with less duty. Opening of suitable open drains for irrigation purposes.
	$I_4 - I_2$	Alluvial plain	12.4				

SR. NO.	SOIL SERIES/ SOIL ASSOCIATION	GEOMORPHIC UNITS	AREA [sq.km]	SOIL CHARACTERISTICS	PRESENT LAND-USE	PROBLEMS AND LIMITATIONS	REMEDICAL MEASURES
1	2	3	4	5	6	7	8
5	I_5	Alluvial plain	4.2	Deep, moderately drained, dark brown to dark, grayish brown, occurring on alluvial plain and flood plains, subject to moderate to severe erosion, texture varies from sandy clay loam to sandy loam.	Majority of the area is occupied by transitional and waste/barren land but, few, patches can be used as agricultural land.	Soils have moderate drainage, subject to moderate to severe erosion near flood plains.	Controlled agricultural practices. Closure to grazing and other biotic disturbance.
	$I_5 - I_3$	Alluvial plain	21.6				
6	$V_1 - I_3$	Alluvial plain	25.6	Very deep, imperfectly drained, dark brown to dark grayish brown clay, strongly alkaline, occurring on nearly level to gently sloping plain.	Majority of the area is occupied by transitional and waste/barren land, few patches of area are used for agricultural purposes.	Soils have imperfect drainage, subject to moderate erosion.	Follow recent agronomic practices. Afforestation, preferably with local species.
7	V_2	Alluvial plain	48.7	Deep to very deep, imperfectly drained, dark grayish brown to dark brown, occurring on nearly level to very gently sloping plain, texture varies from sandy clay, clay to sandy clay loam.	Most of the area is occupied by transitional land but can be used for agricultural purpose.	Soils have imperfect drainage, subject to moderate to slight erosion.	Judicious irrigation with less duty. Opening of suitable open drains for irrigation purposes.
	$V_2 - I_3$	Alluvial plain	33.3				
	$V_2 - I_5$	Alluvial plain	29.2				
8	$E_1 - I_2$	Ravines	30.2	Deep, well drained, pale brown to brown, occuring on rolling high alluvial ravines, subject to severe erosion to very severe erosion, texture varies from sandy laom to loamy sand.	Majority of the area is occupied by ravines.	Soils are well drained to excessively drained, subject to severe to very severe erosion hazard.	Closure to grazing and other biotic disturbance. Peripheral bunding and diversion of water to a masonary spillway. Lateral earthen bunds at proper intervals guard against breach of the contour bund. Bunds are protected by grassing. Afforestation preferably with local species.
	$I_2 - E_1$	Flood plain	3.1				