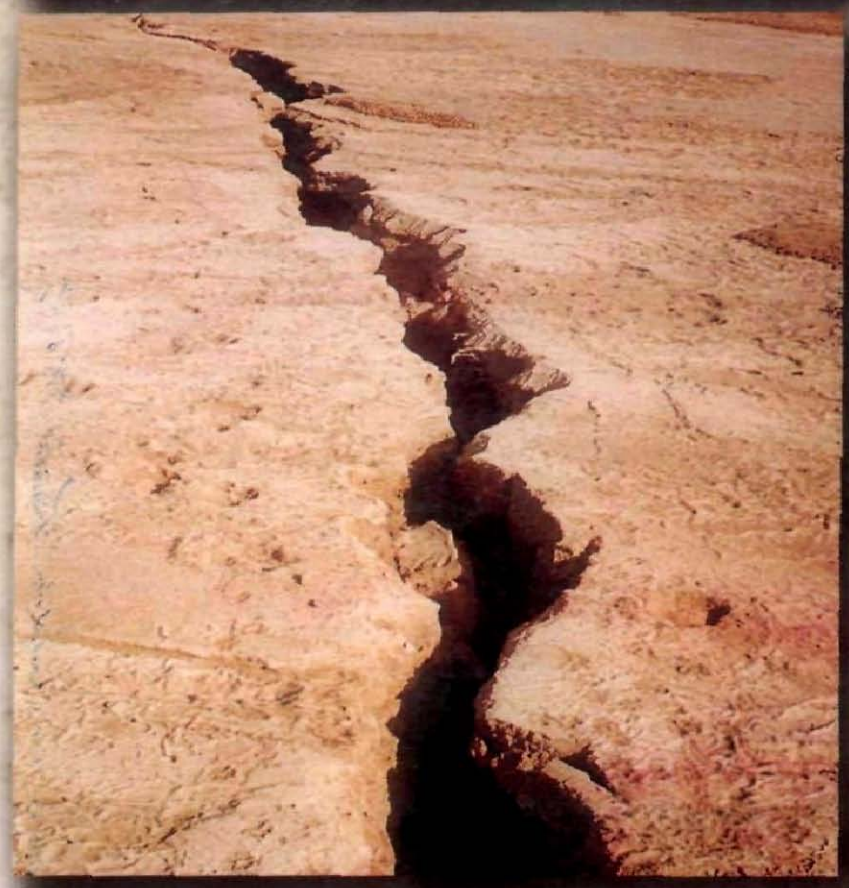
IMPACT OF EARTHQUAKE
ON NATURAL RESOURCES IN KACHCHH REGION



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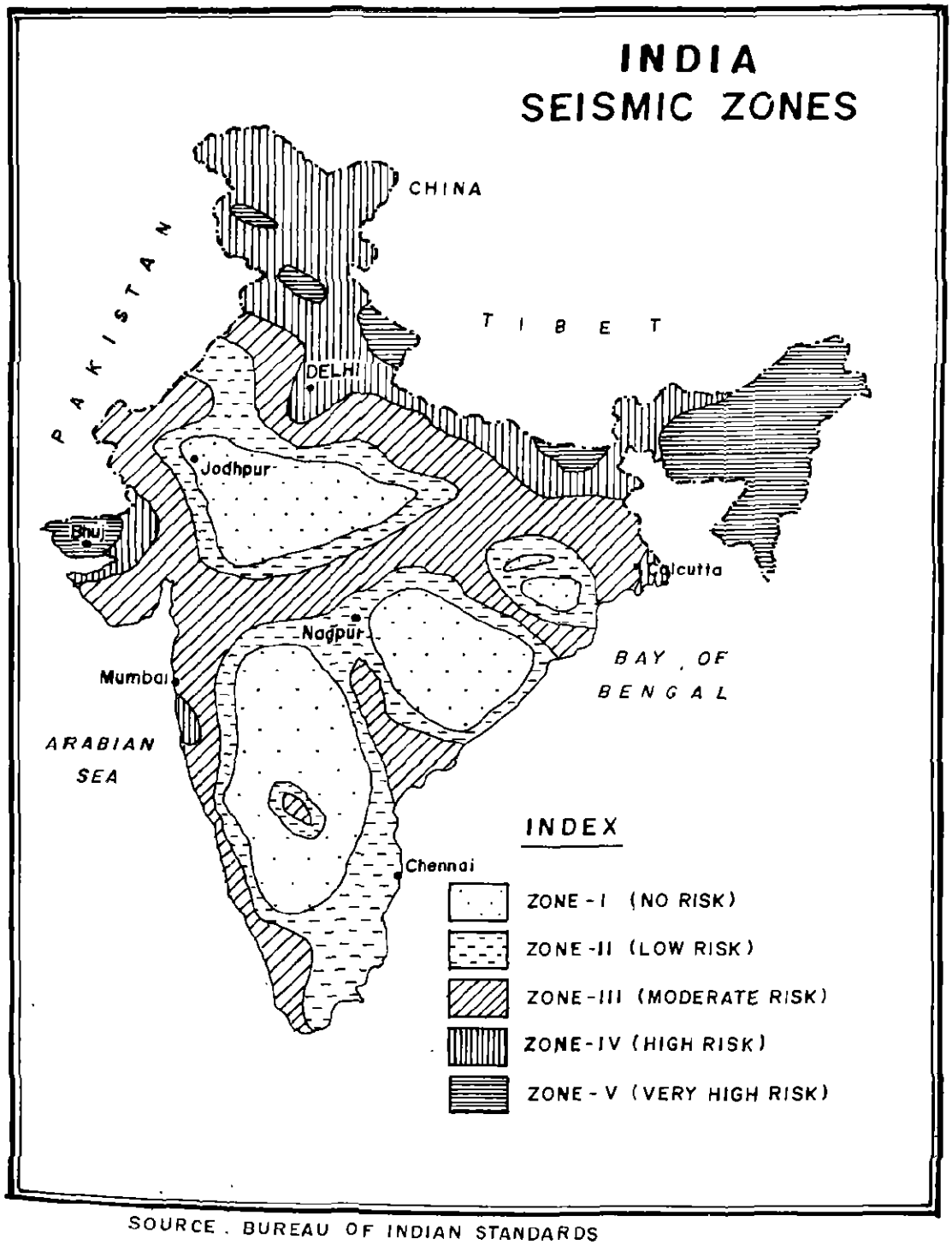

SOURCE . BUREAU OF INDIAN STANDARDS

Fig. 1

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2002

Foreword

Earthquake is one of the most disastrous natural calamities allowing no time to think for any preventive measures. Predictions and forecasts of earthquakes are not so accurate in time and space. Regions of ancient civilization in the world with rich natural resource base are falling under seismic zone and prone to earthquake disaster. The western coastal desert of India frequented by drought and cyclonic storms, had suffered several times by earthquakes. But the recent earthquake of 26th January 2001 in Gujarat with high magnitude and wide destructive range has caused widespread loss of human life and property in the state of Gujarat particularly in Kachchh district. The other severely affected sectors were transport network, water supply, power supply, hospitals, schools and colleges, dams and bridges. The disaster also severely affected natural resources of Kachchh region, livestock wealth, water harvesting and conveyance system, irrigation wells and crops on arable and non-arable lands.

Soon after this tragic event, the scientists of the Central Arid Zone Research Institute (CAZRI), Jodhpur conducted a survey of worst affected district of Kachchh. This has brought out some significant findings and challenging issues by an in depth study of the region. Some measures have been suggested to formulate post earthquake management strategies and sustainable development of natural resources in the region.

The resilient people of Gujarat have endured the jolt of this disaster and are in process of rehabilitation by joining hands with Government, NGO's and several donor agencies. Exactly after a year, a bulletin on ***"Impact of Earthquake on Natural Resources in Kachchh Region"*** is being brought out by the CAZRI, which would be utilized to complement efforts of decision makers and policy planners in formulating strategies of disaster management and development of natural resources in the region in long-term. I congratulate the CAZRI scientists in this endeavor.

New Delhi
January 26, 2002

Panjab Singh
Director General ICAR & Secretary, DARE

Preface

Earthquake by tectonic movements is a natural process causing world wide losses to human life and property. About 20% area of our country is falling under high and very high seismic risk zone but very little efforts have been made to minimize losses and put timely and effective relief measures on one hand and protect natural resources on the other. Looking into the increased frequency of earthquakes and severity of damages, it is high time to think for long term planning to deal with such natural disasters. The widespread and most destructive Gujarat earthquake of fateful morning of 26th January, 2001 has put a question mark on efficiency and management capability of our system. A team of scientists from Central Arid Zone Research Institute made efforts to assess the impact of earthquake and severity of damages on landforms, soils, settlements/ built up area, agriculture and irrigation, transport network and infrastructures in Kachchh region through extensive field surveys and interpretation of IRS LISS-III remotely sensed data. Valuable data on the above aspects have been generated and maps have been prepared. Besides, measures are suggested for immediate relief measures, long-term future strategies, and development of infrastructure and support system for both rural and urban areas and amelioration and management of natural resources.

It is hoped that outcome of the present study as well as issues addressed, will be of immense help to planners and managers in formulating rational post earthquake relief, resettlement and development plans for Kachchh region.

Authors

Acknowledgements

The authors are highly grateful to Dr. Punjab Singh, Director General, Indian Council of Agricultural Research and Secretary, DARE, Govt. of India for his keen interest in this study. Dr. J.S. Samra, Deputy Director General (NRM), ICAR has been a constant source of inspiration and deriving force to accomplish this task. His valuable suggestions and advices regarding fodder relief and other help to farming community and management of agricultural resources are praise worthy. Thanks are due to the officials of Zila Panchayat, Bhuj for providing information on land use and various aspects of earthquake losses. Thanks are due to Dr. S.P. Vyas, Head and Shri M.L. Swami, Farm Manager, Regional Research Station (CAZRI) Kukma, Bhuj for providing all short of help and information during the course of survey. Authors are thankful to Dr. I.C. Gupta, ex Head and Dr. M.A. Khan, present Head of Natural Resources and Environment Division, CAZRI, Jodhpur for providing facilities for this endeavor. The assistance provided by Shri J.S.Chauhan, Sr. Technical Officer and other technical and supporting staff of Cartography and Land Use Section is gratefully acknowledged.

Contents

Impact of Earthquake on Natural Resources in Kachchh Region

INTRODUCTION

Indian peninsula has been in the process of bonding with Asian continent for centuries, thus creating tectonic disturbances and earthquakes. One such catastrophic earthquake event happened on the 26th January, 2001 at 8:46 AM with a magnitude of 7.9 Mw on the Richter scale. The earthquake caused widespread loss to human life, public and private properties in the state of Gujarat particularly in Kachchh district. The killer earthquake reportly took away 13,805 invaluable lives. Not only, the major towns of Bhuj, Bhachau, Anjar, Rapar and Gandhi Dham in Kachchh district were devastated but numerous villages, huts and dwellings of poor were razed to dust in matter of 110 second turning as many as 12,05,198 houses in to rubble leaving people in crackling psyche and uncertain vacuum. It is reported that about 7,633 villages were affected in the state of Gujarat. The initial estimation of losses reported by the Directorate of Information Publicity, Govt. of Gujarat was to the tune of $ 4.5 billion. This included losses to housing $ 2.100 million, GDP $ 1.200 million, public property $ 100 million, infrastructure $ 150 million and livelihood $ 550 million. About one lakh people were feared dead, two lakhs injured, over 3.50 lakhs houses completely destroyed and nearly 10 lakhs damaged or cracked due to vigorous shake. Other severely affected sectors were power, health, water supply, education, irrigation, road, bridges, transport network, public

buildings, religious places and monuments, civil administration and agriculture at large. The more realistic figures reported by the government after a year reveal that a total loss by damage to public and private property is worth Rs. 15,000 crores. There may be some variations in reports because of rumours, different surveys, deaths reported in more than one places, temporary movement of people and role of media to mobilize awareness, public opinion and support. Now more precise information, wherever available, has been supplemented. Yet this report may be viewed in its essence and concepts rather then on quantum of damage, which was immeasurable by any scale.

Looking in to the gravity of the calamity, a team of scientists from Central Arid Zone Research Institute, surveyed the entire earthquake affected area of Kachchh district to assess the impact of earthquake on the natural resources, which include landforms, soils, surface water, ground water, land use and agriculture, infrastructure, human and livestock. Sites where ruptures/cracks developed and saline water with sediments oozed out through craters were located through GPS, sediments and water samples examined, collected and analysed. Relational data on different aspects viz. landforms, soils, land use, agriculture, irrigation, human and livestock were collected and discussed. Based on the integrated impact analysis of various attributes, the areas with very severe, severe, moderate and slight categories of impact have been delineated and mapped. The management of natural resources is to be viewed on long-term basis. Because of a social angle involved and many uncertainties, the report can be supplemented at any stage. However, salient findings based on the first hand study and strategies to manage such calamity are highlighted in this report

ENVIRONMENT

Location

The Seismic Zonation Map of India prepared by Bureau of Indian Standard, delineates Seismic Zone I to V (Fig. 1). Kachchh district, which is rocked by most devastating earthquake on 26th January 2001, lies in Zone V which is Seismically more active.

Kachchh district with a geographical area of 45652 sq km lies in hot arid region of north- western India (Fig. 1a). The crescent i.e. tortoise shaped Kachchh district stretches from 22° 44' 11" to 24° 41' 25" north latitudes and 68° 09' 46" to 71° 54' 47" east longitudes. It is bounded by Thar Parkar district of Pakistan towards north and west; Banaskantha district in the east and Gulf of Kachchh and Arabian Sea in the south. The

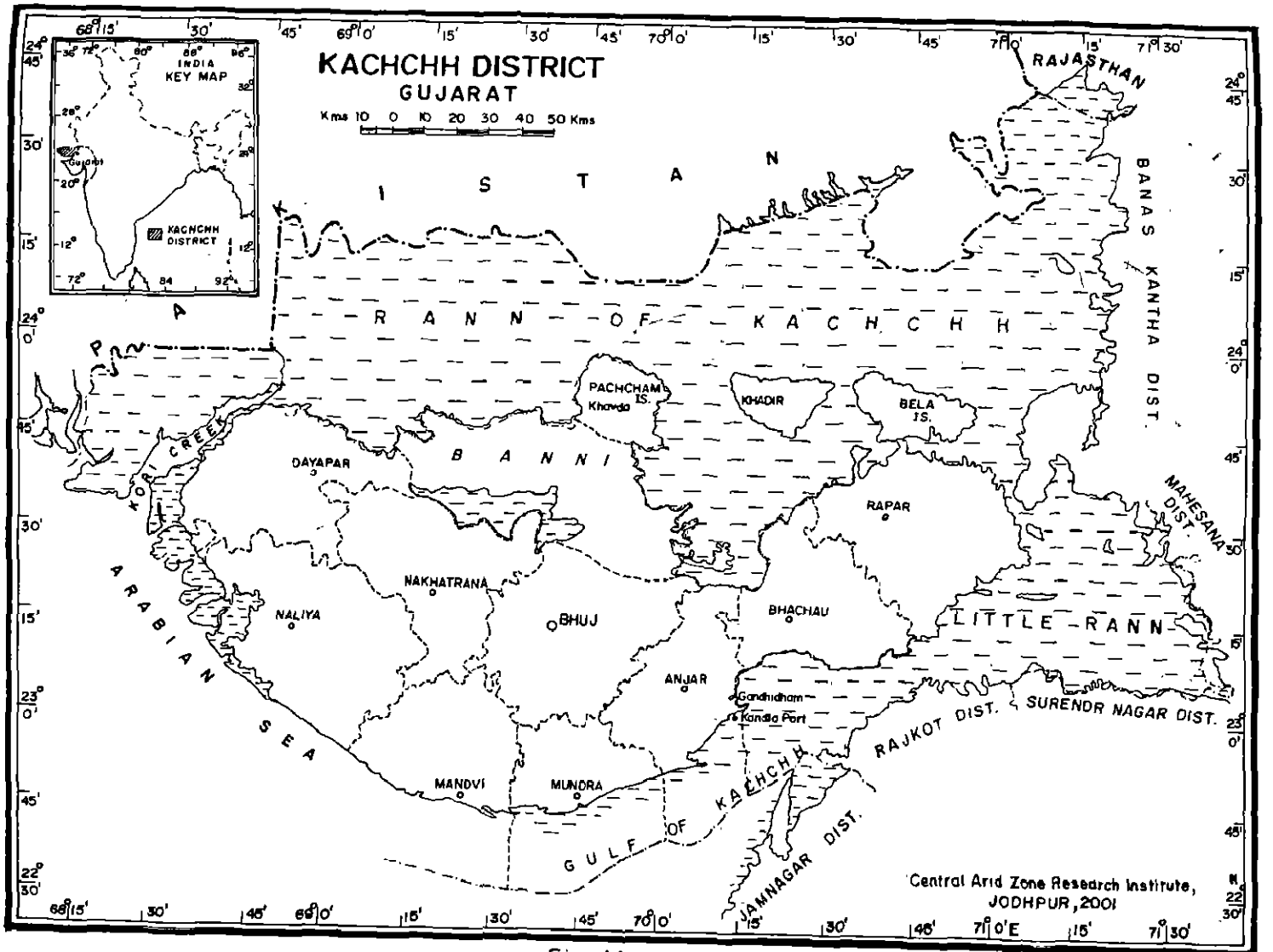

KACHCHH DISTRICT
GUJARAT
Kms 10 0 10 20 30 40 50 Kms
INDIA
KEY MAP
KACHCHH DISTRICT
RAJASTHAN
BANAS KANTHA DIST.
MAHESANA DIST.
RANN OF KACHCHH
PACHCHAM IS.
Khavda
KHADIR
BELA IS.
PAKISTAN
KORI CREEK
DAYAPAR
BANNI
RAPAR
ARABIAN SEA
NAKHATRANA
NALIYA
BHUJ
BHACHAU
LITTLE RANN
ANJAR
Gandhidham
Kandla Port
RAJKOT DIST.
SURENDR NAGAR DIST.
MANDVI
MUNDRA
GULF OF KACHCHH
JAMNAGAR DIST.
Central Arid Zone Research Institute,
JODHPUR, 2001

Fig. 1A

district has a long coastal line of 352 km with nine ports namely Kandla, Tuna, Jangi, Kharirohar, Mundra, Mandvi, Jakhau, Koteshwar and Lakhpat, which support livelihood of people in addition to agriculture.

Climate

Endowing a very fragile ecosystem, Kachchh district receives an annual rainfall of 358.4 mm varying from 286 to 440 mm, with erratic and skewed distribution. Taluk wise rainfall distribution of past decade (Table 1), revealed that coefficient of variation was as high as 80.7% in Nalia and 52.4 % at Kandla over 12 to 22 rainy days in a year. Early or late onset and abrupt withdrawal of rains are quite common. Winter rains account for only 8 to 9 per cent of the annual rainfall. The mean maximum and minimum temperatures are 38.3°C in May and 11.2°C in January. Sometimes it may touch to 47.8° C and drop to 1.1°C. Potential evapotranspiration (PE) varies from 1750 mm/year in coastal region to 1900 mm in Bhuj and Anjar. The mean moisture index is always (-)79. Besides earthquakes, frequent droughts compound the problems of the region. The district has experienced 40 droughts since 1901. Therefore strategies have to be evolved for combating catastrophies like earthquakes as well as droughts for ensuring *sustainability in the Kachchh region.*

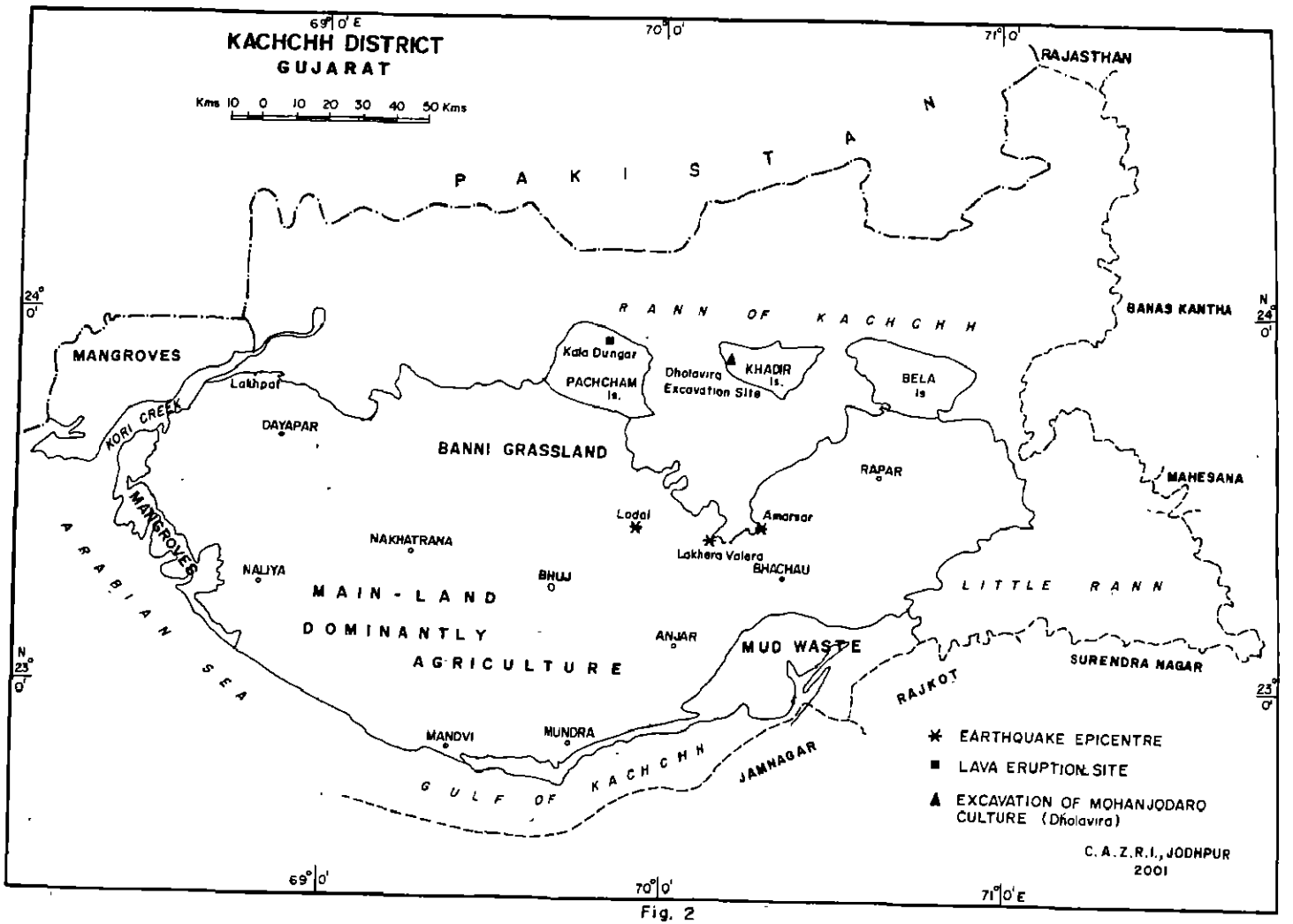

KACHCHH DISTRICT
GUJARAT
Kms 10 0 10 20 30 40 50 Kms
69° 0' E
70° 0'
71° 0'
RAJASTHAN
P A K I S T A N
24° 0'
RANN OF KACHCHH
BANAS KANTHA
MANGROVES
Lakhpat
KORI CREEK
DAYAPAR
Kala Dungar
PACHCHAM Is.
Dholavira Excavation Site
KHADIR Is.
BELA Is
BANNI GRASSLAND
RAPAR
MAHESANA
MANGROVES
Lodai
Amarsar
NAKHATRANA
Lakhera Valera
BHACHAU
NALIYA
BHUJ
LITTLE RANN
ARABIAN SEA
MAIN-LAND
DOMINANTLY
AGRICULTURE
ANJAR
MUD WASTE
SURENDRA NAGAR
RAJKOT
23° 0'
MANDVI
MUNDRA
GULF OF KACHCHH
JAMNAGAR
EARTHQUAKE EPICENTRE
LAVA ERUPTION SITE
EXCAVATION OF MOHANJODARO CULTURE (Dholavira)
C.A.Z.R.I., JODHPUR
2001

Fig. 2

Table 1. Taluk-wise Rainfall distribution in Kachchh District (1990 to 1999)

(Rainfall in mm)

Years	Bhuj	Mandvi	Mundra	Anjar	Bhachau	Rapar	Nakhtrana	Abdasa	Lakhpat	Average
1990	281	191	273	324	306	273	271	182	138	249
1991	82	64	148	118	203	174	40	37	18	98
1992	*508*	*750*	*842*	*459*	*366*	*390*	*886*	*720*	*943*	*651*
1993	79	30	46	174	121	268	71	69	189	116
1994	800	1040	1195	981	1055	701	1070	633	1262	971
1995	172	168	285	242	245	228	108	367	308	236
1996	87	135	135	108	277	382	80	149	29	195
1997	314	511	861	668	659	828	440	271	233	532
1998	416	453	491	366	375	486	461	346	230	403
1999	123	84	120	86	273	189	100	187	65	133
Average	**286.2**	**342.16**	**439.6**	**352.6**	**388.0**	**391.9**	**359.4**	**296.1**	**341.5**	**358.4**
C V (%)	**81.9**	**98.8**	**89.7**	**81.1**	**70.7**	**56.4**	**103.5**	**76.9**	**122.6**	**79.1**

Source: Zila Panchayat, Bhuj

Physiography

Out of the total geographical area of the district, reporting area (mainland) is 19576 sq km (42.81%) and remainder 57.19 per cent un-reporting area is occupied by dry salt ranns, mud flats, creeks and mangroves (Fig. 2). The physiography of the mainland is characterised by hills and uplands (16.4% of the geographical area) running east-west in the central part and comprising of Jurassic sandstone, coral limestone, gypseous shales and Cretaceous ferruginous sandstone and basalt flows with intrusive of dolerite dykes. Other formations are Eocene laterite and conglomerate. Remaining large part of the northern region is dominated with recent to sub-recent alluvium, blown sand and colluvial plains. Colluvial plains, coastal plains, tidal mud flats and raised mud flats constitute13.0, 5.3, 4.6 and 5.5 per cent of the district respectively.

Soils

Nearly 63 per cent of the reporting area is represented by miscellaneous soils of hills, ranns and mud flats. Of the remainder, fine textured clay to silty clay loam soils constitute 9.2 per cent, moderately fine textured clay loam to sandy clay loam 8.9%, medium textured loam to silt loam 8.9% and coarse to medium textured loamy sand to sandy loam 10.0%. The soils are generally coarse textured with gravels up to 49%. Deeper layers of few soil series contain 30 to 50 per cent clay. The surface soil pH varies from neutral to alkaline, salinity up to 40 dSm^{-1}, and calcium carbonate (up to 43 %) at some depth is also quite common. Soils are in general poor in organic carbon (0.278-0.615%) and available P_2O_5 (4-8 kg/ha), however, the available K_2O is usually high (300-850 kg/ha). The land capability cum land use scenario reveals that the district has only 20 percent arable lands and major area is 80 percent non-arable (Class VI and VII land) having severe limitations of either salinity, depth or texture.

Land Capability cum Land Use of Kachchh district

Land Capability Class	*Land Use*	*% distribution*
Class II	Fit for single/double cropping with irrigation	< 1
Class III	Fit for single crop rainfed farming	13.2
Class IV	Occasionally suitable for agriculture	6.2
Class VI	Unsuitable for agriculture	74.6
Class VII	Unsuitable for agriculture	1.3

Water resources

Both surface and ground water resources are scarce and limited both in quantity and quality, which affect livelihood in the region. Out of 27 major ephemeral streams, run off of 20 streams is being harvested, stored and utilized. About 1483mcm runoff is harvested in the district, of which Ca.42% is utilized through 18 medium and 160 minor irrigation schemes. Though there are no major irrigation projects but more than 68 per cent of minor irrigation projects of the State are located in Kachchh district. As per 1994-95 statistics 14,600 and 13,300 ha in the district is irrigated by medium and minor irrigation projects respectively. Irrigation through well is quite common in Kachchh. The district had 219 tube wells, 28,306 open wells for agriculture and 1918 wells for domestic use. Out of the total 1,52,296 ha gross-irrigated area during 1999-2000, 85 % is served by wells and 15 % through medium and minor irrigation canals originating from check dams and tanks (Table 2). Out of 1,09,000 ha of ultimate ground water irrigation potential, 94,000 ha is utilized up to 1997 leaving a meagre unutilized balance of 15,000 ha. Fresh ground water resources are very limited. The Mesozoic Umia and Bhuj formations are the most promising aquifers. Depth to water varies from 19 to 80 metres. The excessive groundwater exploitation, deepening of wells and frequent droughts had caused lowering of water table causing intrusion of saline ground water in the wells resulting in their abandonment. District has potential to harness 58% runoff through dams and ponds to utilize it more efficiently.

The rocky terrain around Bhuj, region is gifted with rocky or a subsurface impermeable hard strata of *murram* comprising of silt impregnated dolomite making it feasible to store runoff water with negligible seepage losses. It is also evident by the traditional water-harvesting tank created by erstwhile rulers. Hence there is good scope of runoff harvesting and utilization for sustainable agriculture from sloping rocky terrain. Run off management through *khadins*, water harvesting structures, skimming wells and tapping of sweet water floating on saline water by improved *douru* system are a few limited choices of water availability in the district. Quality of water resources is equally an important issue concerned with human and animal health. About 120 villages of Kachchh are affected by high fluorides, which may lead to fluorosis. Whereas runoff water is free from such maladies. Efficient methods of water application like drip and sprinklers for maximizing irrigation and cropping system economize on water use and higher water use efficiency is required to be promoted in Kachchh district.

Table 2. Irrigation potential in Kachchh district (1998-99)

Name of Taluka	Tank No.	Small tanks No.	Check dams No.	Medium irrigation scheme			Small irrigation scheme			Wells		Small /dug wells		Oil engines No.	Electric motors No.	Total irrigated land (ha)
				No.	Canal length (km)	Command (ha)	No	Canal length (km)	Command (ha)	No.	Command (ha)	No.	Command (ha)			
Abdasa	24	29	–	4	64.49	1100	24	102.53	950	–	–	2245	7021	310	1019	9071
Anjar	11	18	7	–	–	–	11	50.45	616	25	268	3368	11148	1293	1940	12032
Bhachau	16	32	1	–	–	–	16	35.55	845	28	143	2851	14272	1250	1730	15260
Bhuj	34	79	13	3	41.93	2281	32	62.58	1095	81	327	4097	34381	2000	4221	38084
Lakhpat	15	34	–	3	39.07	1686	15	54.14	175	–	–	395	907	162	1007	2768
Mandvi	21	17	2	1	7.00	98	21	117.33	3625	10	35	3328	18279	274	4232	22037
Mundra	10	9	–	2	26.89	1443	10	54.80	2209	14	160	3066	7969	1031	2196	11781
Nakhtrana	15	56	–	3	45.73	2987	15	35.76	471	61	567	3541	22463	1650	2183	26488
Rapar	16	48	1	2	39.59	1548	16	56.70	1779	–	–	5415	11448	2530	2436	14775
Total	162	322	24	18	264.70	11143	160	569.84	11765	219	1500	28306	127888	10500	20964	152296

Source : Zila Panchayat, Bhuj

Land use and agriculture

According to 1991 census population of Kachchh district [1] residing in 8 towns and 893 villages touched 1.26 million recording 18.7% decennial growth with 27 person sq km. The district is composed of 70 per cent rural and 30 per cent urban population. The livestock population of the district was 1.40 million as per 1998 livestock census. The ratio of human: livestock population is 1:1.2, which is more than twice to the rest of the country. Evidently livestock plays important role in supporting livelihood of people in Kachchh region.

Out of the total reporting area of the district (1997-98), forests constitute 14.74%, barren and uncultivable land 21.98%, land put to non- agricultural uses 3.73% while permanent pastures are only 3.58 per cent. Culturable waste, fallow lands and net sown area constitute 17.78, 2.70 and 35.48 per cent respectively. Taluk wise net and gross irrigated areas (Table 3) constitute 7.56 % and 7.78 per cent mainly in Mandvi, Nakhtrana and Bhuj taluks. Forests dominate in Abdasa (23.9%), Bhuj (19.8%), Lakhpat (19.2%) and Nakhtrana (15.2%) taluks. The barren and uncultivable lands concentrate in Rapar (19.4 %), Lakhpat (17.5 %) and Nakhtrana (16.9 %). Bhuj taluk has maximum 61 % culturable wastelands in the district. The land use scenario in the past decade reveals about 22 % increase in forest area and 4% increase in barren and uncultivable land and land put to non agricultural uses, while there is about 4% decline in net sown area. Irrigated area has shown 160 % in 1997-98 against 1984-85. Despite increase in irrigated area there is no perceptible rise in double crop area.

Kharif crops occupy 85.8%, rabi crops 7.56% and summer crops 6.7 per cent of the cropped with 103 per cent average cropping intensity. On 1995 to 1999 basis, Bajra, jowar and wheat occupy 14.54, 12.91 and 2.95 per cent of cropped area respectively. Moong, moth and guar occupy 8.85, 3.91 and 13.42 per cent area while groundnut, sesamum, mustard, castor, cotton, isabgol and cumin 16.25, 4.96, 1.41, 8.13, 7.15, 2.21 and 0.66 per cent area respectively. Cowpea, sunflower, coriander, onion, potato, sugarcane, gram, vegetables and fodder crops occupy insignificant area. Trend in cropping pattern (1990-91 to 1999-2000) is shown in fig 3.

Table 3. Taluk wise Land Use pattern in Kachchh district (1997-98)

(Area in ha)

Taluk	Total Reporting area	Revenue Village (Nos.)	Forest	Barren and uncultivable land	Land put to non-agrl. uses	Pasture land	Culturable waste land	Fallow land	Net sown area	Net Irrigated area
Abdasa	240544	137	69078	28985	3470	13023	47597	6555	71836	6187
Anjar	135298	75	3935	16589	14842	6607	21044	5089	67192	12032
Bhachau	202214	71	17005	55062	2399	5730	6870	3263	111885	15260
Bhuj	458123	142	57178	56347	21782	9535	212069	8323	92889	38084
Lakhpat	188606	94	55455	75447	1640	2450	13400	12214	28000	2768
Mandvi	142538	87	6768	35377	5468	10900	9477	7148	67400	22037
Mundra	88805	61	8202	6621	9713	6130	5498	3799	48842	11781
Nakhtrana	198732	129	43980	72622	6620	10961	4162	1447	58940	26488
Rapar	302769	97	26978	83287	7039	4722	28062	4979	147702	13402
Total (1997-98)	1957629	893	288579	430337	72973	70058	348179	52817	694686	148039
Total (1984-85)	1957629	887	237299	414035	70054	69958	398726	42466	725091	56860
± Change (%)	-	-	+21.61	+3.94	+4.17	+0.14	-12.68	+24.37	-4.19	+160.35

Source: Zila Panchayat, Bhuj

Shift in Cropping System

Since 1950 a shift in cropping system in the region is evident due to persistent drought on the one hand and increase in acreage of castor and sesame cash crops on the other due to increase in irrigated area (Table 4). During 1983-84 to 1997-98, there has been 26.2, 42.8, 47.4 and 23.7 per cent decrease in the acreage of jowar, bajra, groundnut and cotton respectively on account of continuous droughts. The acreage of castor, guar and sesame on the other hand has increased by 104.4, 57.3 and 40.1 per cent. The trend in acreage of principal crops during the past decade suggests that (Table 5) despite intermittent drought acreage of cash crops like castor, sesame, mustard, isabgol and cumin is on continuous rise. There is also increase in acreage of wheat while the coarse cereals showed a declining trend.

The productivity of wheat, castor and sesame has substantially increased while negative trend has been observed in cotton and groundnut. The shift in cropping pattern from 1950-51 to 1999-2000 is shown in Fig. 4. The yield of major crops (1990-91 to 1999-2000) is shown in fig 4A. The yields of wheat, groundnut and mustard being partly irrigated remained stable while that of rainfed crops fluctuated due to rainfall. The variability in cotton production is associated with management of insect pest and diseases.

MAGNITUDE AND NATURE OF EARTHQUAKE

Table 6 shows major earthquakes occurred in India. Seismically active Kachchh district has experienced 19 earthquakes during past 200 years. But the earthquake of 26th January 2001 was strongest in last 40 years, the tremors of which were felt throughout the country. The tremor lasted for 72 seconds with a magnitude of 7.9 Mw on Richter scale in Kachchh district. The magnitude of greater than 5.9 Mw was concentrated along the major fault line and that of 3 to 5 Mw near Lakhpat, Nalia, Mandvi, Mundra and Khadir Island. The tremor was felt by upward jolt with thunder and cloud of dust and then vigorous shaking like the sieve movements, which collapsed and compressed the houses and other buildings. Those who were inside and trying to escape were trapped and many of them died. Some of them lost life due to suffocation, fear and want of rescue in time. As of now 13,806 innumerable lives have been lost in the Gujarat state. More than 50 % of the death toll is in the district of Kachchh, where 7,394 people died and 24,765 injured. Highest reported calamity was 4,340 in Bhachau, 1070 in Anjar, 508 in Rapar and 675 in Bhuj talukas (Fig. 5).

Table 4. Trend in area and productivity of principal crops in Kachchh district (1951 to 1999)

Area (ha); Production kgha^{-1} in parenthesis

Years	Wheat	Jowar	Bajra	Groundnut	Cotton	Castor	Sesame	Moong
1950-51	7300 (411)	61500 (97)	110100 (16349)	1000 (1100)	8900 (449)	400 (N)	4400 (114)	N
1960-61	7900 (1089)	90200 (23)	110500 (367)	26000 (258)	77200 (453)	6500 (354)	8600 (140)	N
1965-66	9600 (833)	102200 (127)	146900 (363)	50700 (424)	74600 (773)	6300 (254)	11800 (212)	N
1980-81	13000 (2246)	87600 (273)	129000 (605)	77000 (673)	68000 (740)	24100 (456)	17800 (191)	177061 (N)
1983-84	18800 (2590)	83100 (333)	131100 (1144)	91000 (857)	64475 (N)	19000 (368)	15000 (266)	110082 (N)
1990-91	14000 (2568)	129241 (291)	35282 (795)	25551 (1610)	67138 (457)	68014 (882)	24577 (397)	48724 (404)
1994-95	14870 (3100)	102490 (100)	111410 (1000)	66950 (1000)	59340 (200)	58970 (1200)	33200 (400)	91450 (500)
1999-2000	18102 (3251)	25332 (00)	37163 (258)	45951 (950)	17458 (466)	19101 (1970)	19955 (54)	21427 (34)

Source: Zila Panchayat, Bhuj

Table 5. Trend in acreage of principal crops in Kachchh district (1990-91 to 1999-2000)

Area (ha)

Crop	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-2000
Bajra	35282	81421	113520	77748	111410	81620	79090	103720	78220	37163
Groundnut	46299	57412	96368	58972	96440	101150	102750	129340	104974	56330
Cotton	67138	48754	61670	26945	59340	65930	48100	5002	50325	17458
Castor	68014	30495	48400	24546	58970	62600	40070	39186	51475	19101
Sesame	24577	15960	26210	14902	33200	25350	22210	34750	27240	19955
Moong	48837	58176	90732	39371	91900	8010	57150	80341	66144	21518
Moth	12822	14355	18300	15587	26520	24800	23740	27670	19540	6460
Guar	51201	62901	97180	50338	95660	82740	64030	85558	72499	48539
Jowar	129241	76463	121050	42158	102490	86270	64840	89531	71225	25332
Cowpea	4966	665	2870	000	3290	2310	000	3750	1180	000
Wheat	14000	9600	12995	10717	14870	9190	14920	16719	18102	18102
Sunflower	448	3615	6345	932	250	490	480	640	113	217
Mustard	6500	6800	7538	7178	7200	4440	4310	7020	10370	10739
Isabgol	6600	4900	12274	6658	11540	7720	9640	16910	14804	8690
Cumin	1000	1200	3205	5874	2130	830	2070	4130	6305	3945
Total Area	516925	472717	718657	381926	715210	563450	533400	544949	590516	293549

Source: Zila Panchayat, Bhuj

Table 6. Major Earthquakes in India

Year	Place	Toll	Richter Scale
1905 (April 4)	Kangra, Himachal Pradesh	Major	8.0
1934 (Jan 15)	Bihar-Nepal border	Extensive	8.3
1941 (June 26)	Andman Islands	Heavy	8.1
1950 (Aug 15)	Assam	Major	8.5
1975 (Jan 19)	Kinnaur and Lahul Spiti Himalayas	Extensive	6.2
1988 (Aug 21)	Bihar-Nepal border	900	6.5
1991 (Oct 20)	Uttarkashi, Uttar Pradesh	1,600	6.6
1993 (Sep 30)	Latur, Maharashtra	10,000	6.3
1997 (May 22)	Jabalpur, Madhya Pradesh	40	6.0
1999 (March 29)	Chamoli, Uttar Pradesh	Extensive	6.8
2001 (Jan 26)	Indian sub continent in general, Gujrat in particular	20,000	6.9-7.9

Source : Manorama Yearbook 2002

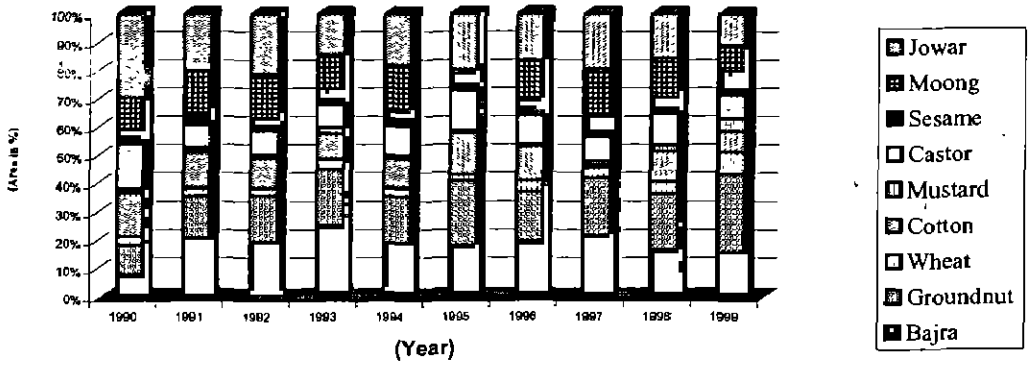


Fig. 3 Trend in Cropping Pattern in Kachchh district (1990-91 to 1999-2000)

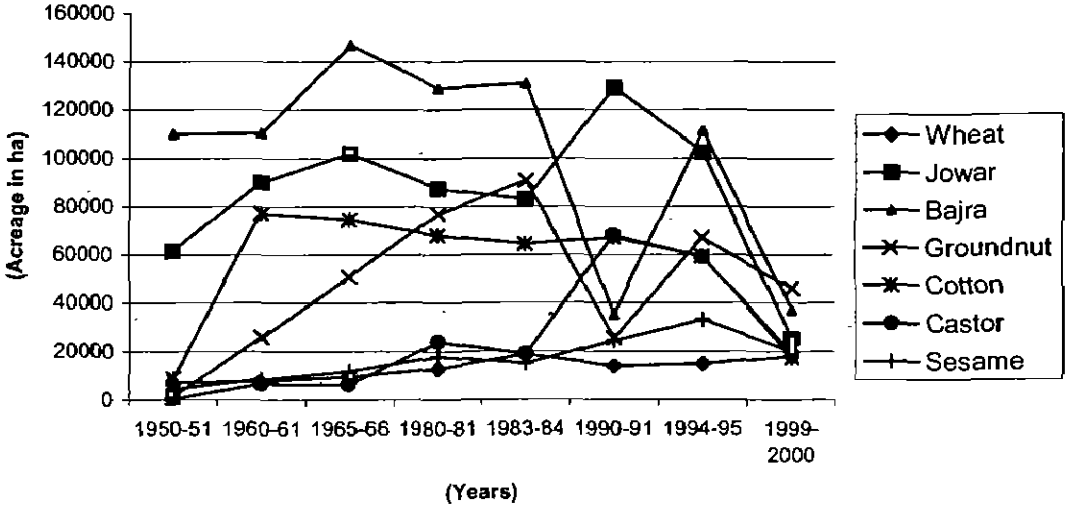


Fig. 4 Area and Productivity of Principal Crops in Kachchh district (1951 to 1999)

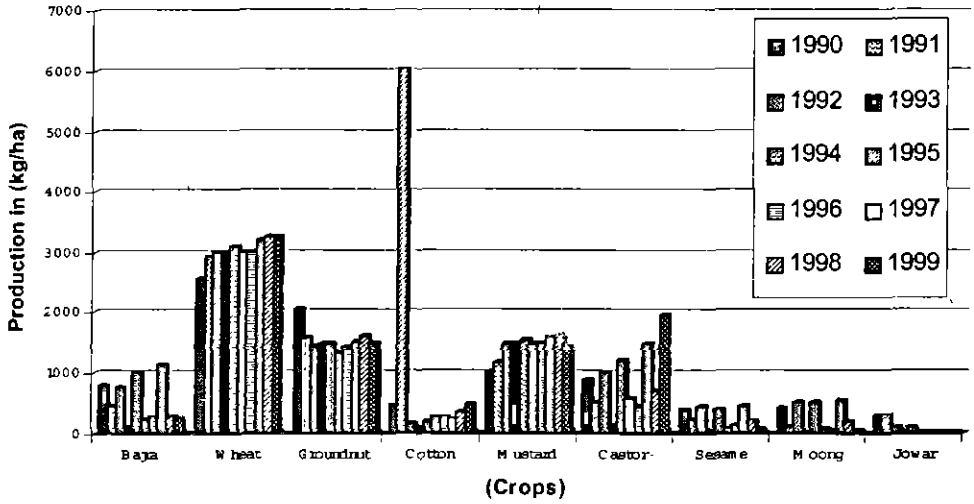


Fig. 4A Yield of major Crops in Kachchh district (1990-91 to 1999-2000)

Unofficial reports are that about one lakh people feared dead, thousands injured and many lost their senses due to the shock of loss of their near and dear ones and losses to their property. Plates 6 to 9 depict some of the horrendous scenes of this calamity. Up to 20th March 580 tremors were recorded of which 32 were found to have above 4.0 Mw magnitudes between January 26 and February 8, 2001. About 55,802 pukka houses and 72,908 kacha house were completely damaged, while 78,362 pukka houses and 47,098 kacha houses were partially damaged. Highest numbers of houses got damaged in Rapar, Bhachau, Bhuj and Anjar talukas (Fig. 6). After the survey of entire Gujarat state about 12,05,198 houses are reported to be destroyed and damaged. The earthquake also caused death to animal life. About 4301 animals are reportedly died in Bhachau, 806 in Bhuj and 513 in Anjar taluk. Details of losses to human and animal life and damage to property are given in table 7. Except in Bhuj and Anjar talukas maximum damage was observed in kacha houses, which were totally damaged followed by pukka houses, which were partially damaged.

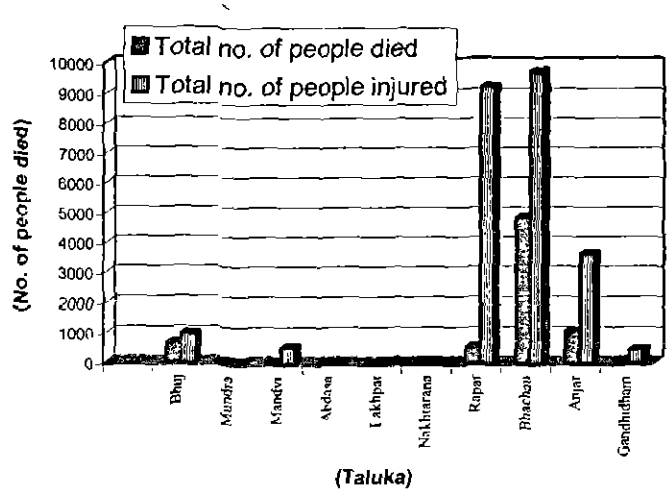


Fig.5 Loss to human life in Kachchh district

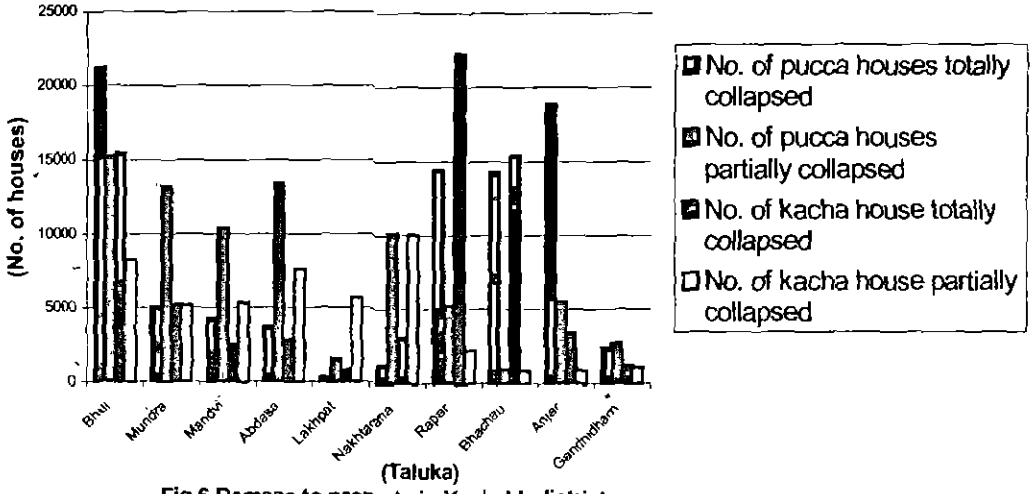


Fig 6 Damage to property in Kachchh district

Epicentre of Earthquake

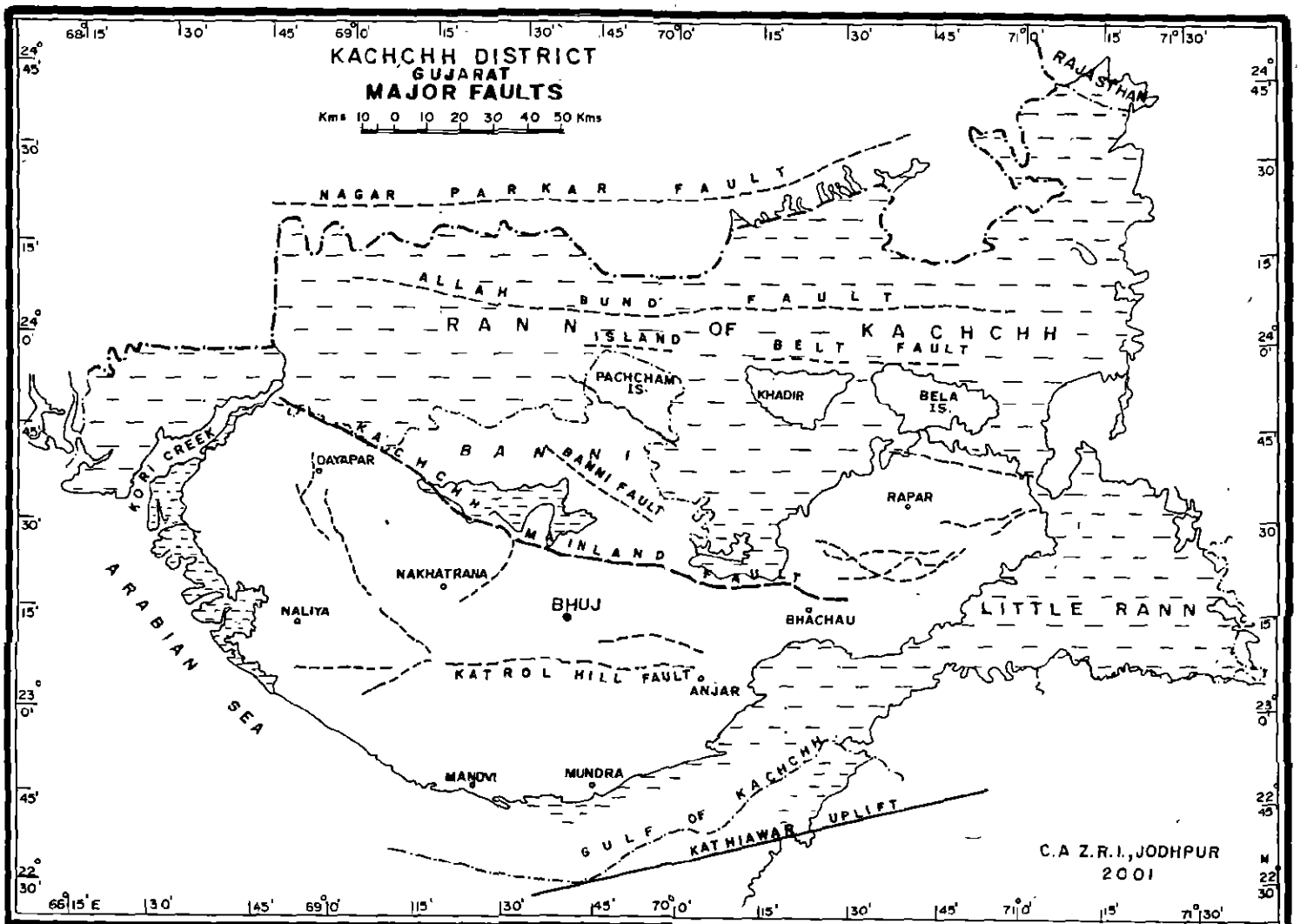
The epicenter of the earthquake became controversial issue. It was first reported north of Bhuj at 23° 36' latitude and 69° 48' longitude and then Lodai and thereafter

Amarsar (Fig. 2). According to United States Geological Survey the epicenter was at 23° 24' north latitude and 70° 19' east longitudes near Amarsar in Bhachau taluk. Hypothesis of Experts from M.S.University, Vadodara suggest that the entire region of Kachchh district is criss-crossed with faults in a seismic belt of 250 km long (east west) and 150 km wide (north-south). This is flanked by several east-west trending faults viz. Nagar Parkar fault towards north, and Kathiawar fault in south. In between lies Allah bund fault, island belt fault, Banni fault, Kachchh mainland fault and Katrol fault (Fig. 7). The earthquake of January 26 occurred along the Kachchh Mainland Fault. According to Jan Sangharsa Manch (JSM) of Gujarat, the epicenter was at 23° 28' north and 70° 22' east.

Manifestations on Earth Surface

CAZRI team traversed rigorously along the Kachchh mainland fault. A series of ruptures and oozing of salty water from craters of high magnitude covering large area was observed 5 km west of Manfara, near Amarsar and Lakhera Valera villages, which are closely located. It substantiate that the epicenter may be near Amarsar at 23° 24'32" north latitude and 70° 17' 22" east longitudes at 9 m above MSL and 17.5 km north west of Bhachau town (Fig. 2). The size of longitudinal ruptures varied from few centimeters to 60 cm wide, 5 to 33 metres long and 10 to 110 cm deep. The diameter of craters varied from 2 to 40 cm. Such phenomenon were observed by the team 3 km north west of Wang (Plate 1), 4 km north of Loria, 4.5 km east of Lodai, 1.5 km north of Lakhara Valera, 1.0 km west of Kunjisar and Amarsar and 5 km west of Manfara villages. Oozing of saline water through a series of craters (Plate 2) also formed cracks on the ground. This phenomenon has also been observed in riverbed around Bhachau, along the southern coast on the saline flats and northern side of Bela, Khadir and Pachham islands. Such water was still coming out towards north of Kala Dugar when the team visited three weak after the earthquake on 18th March 2001. A perennial water flow like a springlet was also observed in the Kaila riverbed south of Sodha camp at 23° 24' 06"N and 69° 36' 20"E (Plate 3).

At places landslides have taken place and cracks are developed on roads and adjacent land (Plate 4). Bhachau, Anjar, Bhuj and Rapar were the worst affected taluks of the district. Such saline water formed salt layer up to 4 cm thick on large scale in Great Rann of Kachchh (Plate 5). These are some of the examples of manifestations of earthquake in Kachchh, which may be of wide spread in number close to the epicenter.



SOURCE :- Times of India 20th Feb. 2001

Fig. 7

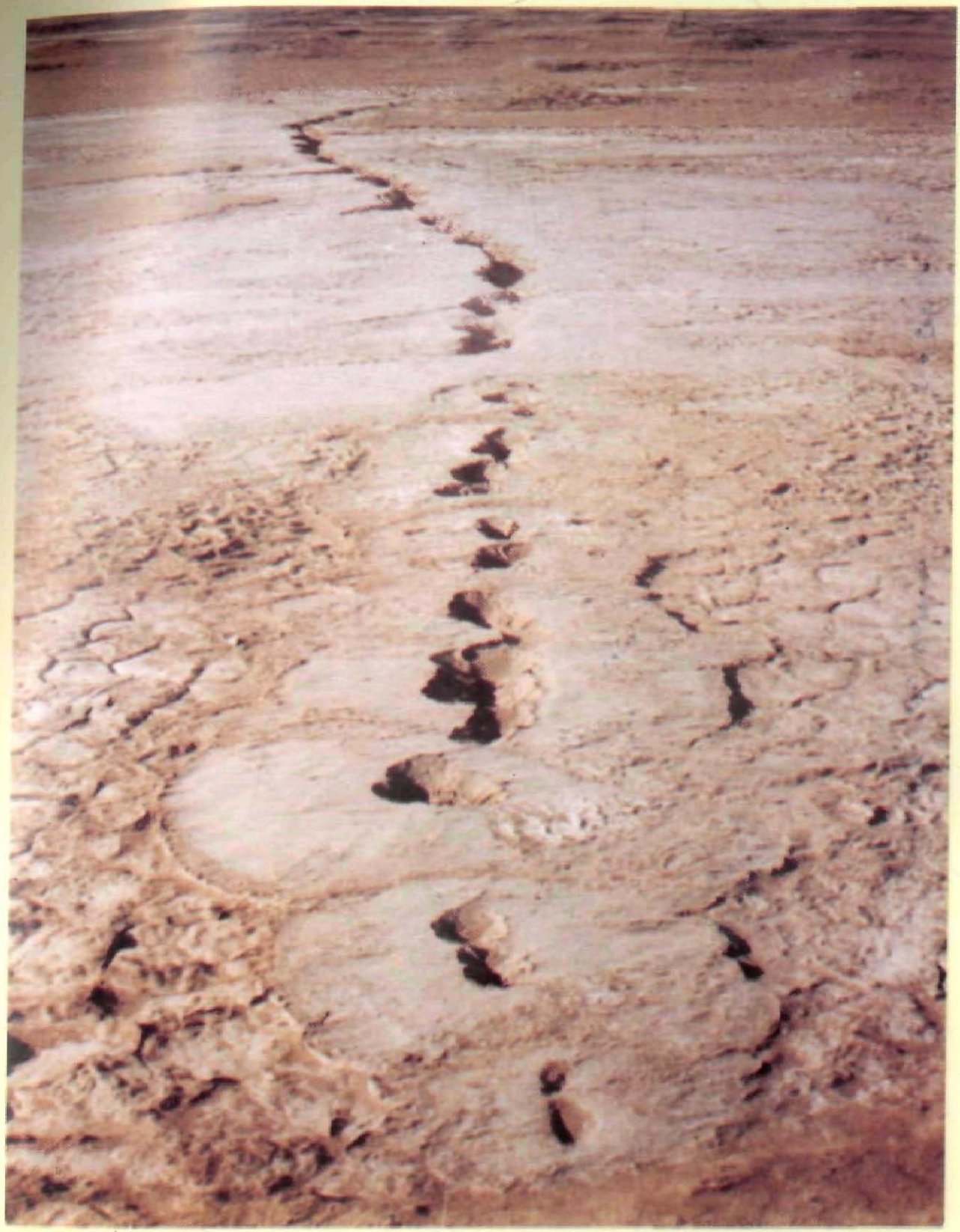


Plate 1. Series of craters developed in alluvial zone near Wang village

Plate 2. Oozing of saline water from crater near Lodai village

Plate 3. Temporary water spring formed by earthquake in the Kaila river bed

Plate 4. Long cracks developed along Bhuj - Bhachau road near Sikra village

Kind of damages

Apart from heavy loss to human and animal life following are the major kind of damages caused by the earthquake.

- Razing of million houses to rubble and dust, which included public buildings, educational institutes, hospitals, religious places, monuments, industrial, commercial, recreationa, and government buildings and all kinds of pucka, kacha structures and farmers dwellings in country side
- Tilting of multistory buildings crushing with each other, development of cracks in buildings particularly around foundation
- Caving in of roads/railway bridges, culverts and development of horizontally and diagonal cracks on roads
- Breaking of water supply lines and irrigation channels
- Development of horizontal and vertical cracks on check dams, anicuts and other water harvesting structures
- Damage to power and communication lines
- Collapse and burying of engines and pumps of irrigation wells
- Damage to cropland through a serics of ruptures and formation of salty silt crust through craters and subsidence of farmlands
- Formation of widespread salt crust in ranns
- Landslides, rock- deformation and fragmentations etc.

Table 7. Loss of human and animal life and damage to property

Taluka	No. of people died	No. of people injured	No. of animal died	No. of pucca houses		No. of kacha house	
				Totally collapsed	Partially collapsed	Totally collapsed	Partially collapsed
Bhuj	675	970	806	21232	15254	15452	8271
Mundra	64	35	19	5061	13228	5224	5163
Mandvi	45	551	652	4283	10422	2517	5340
Abdasa	18	–	NA	3686	13413	2840	7628
Lakhpat	2	15	NA	296	1532	783	5680
Nakhtarana	12	90	31	1232	10161	3057	10043
Rapar	569	9271	619	14437	5230	22265	2224
Bhachau	4857	9752	1662	14312	952	15458	838
Anjar	1070	3640	513	18861	5535	3450	868
Gandhidham	82	462	NA	2412	2735	1210	1049
Total	7394	24786	4302	85812	78562	72056	47099

Source: Zila Panchayat, Bhuj

IMPACT ON NATURAL RESOURCES

Landforms

Alluvial plains and salt ranns are major landforms affected by the earthquake. Alluvial plains are ideal region for settlements and agriculture, which are damaged and disfigured badly by series of ruptures, formation of silty salt layer of greater size and at places subsidence. Buried pumps of irrigation wells and collapse of water delivery channels and farmhouses are largely located on this landform. Similarly the terrain outlook of Great Rann of Kachchh has disfigured by formation of widespread white salty layer of 2 to 4 cm thickness (Plate 5) through oozing of saline ground water from craters. This phenomenon was still occurring towards north of Kala Dundar in Pachham Island and east of Khadir Island after about 3 weeks of event. This may cause environmental degradation in the years to come (Table 8).

Soils:

Medium to fine textured moderately deep soils in the region got series of ruptures, more than1 m vertically deep and 5 to 50 meters long. Development of craters and oozing of saline ground water has taken place in fine textured (saline) Moti Chirai series soils, fine coarse to medium textured younger alluvial soils, fine textured highly saline soils of Great and Little Rann and fine textured soils of mud flats along the southern coast. At places along with the ruptures, subsidence on land surface has also taken place. From some craters along with the saline ground water, fine sandy to silt loam sediment pinkish in colour has come up and deposited in patches in large areas. In Great Rann, a very bright white colour salt crust 2 to 20 cm thick deposited in the similar fashion. This large-scale deposition of salt crust might be due to rise of water table in rann area. Before the earthquake, the surface of rann was reportedly looking light yellowish brown to light gray brown in colour. In the region of coarse to medium textured alluvial soils between Amarsar and Chobari, grayish colour fine sandy as well as pinkish colour silt loam laterite sediment came up along the ground water through the craters. EC of water samples collected from craters between Lodai and Jawahar Nagar was 32 to 60 dS/m^{-1} and pH 8.0 to 8.1. In fine sandy highly saturated sediment EC (1:2) ranged from 22 to 200.0 dS/m^{-1} and pH from 7.6 to 8.9. The EC value varied from place to place due to nearness of rann and textural variability. The EC value of water sample collected from.

Table 8. Spatial variability and surface morphology of the deformities

Location	Co-ordinates	landforms	Surface morphology
Amrapar lakha, North-west of Bhachau	23° 23' 36 "N 70° 07' 38"E	Saline depressions/ Great Ranns	*Big cracks* (100-200m long, 30-40cm subsidence, 40-60cm wide, 10 to 20cm deep, meandering pattern, *small cracks*: (5-15m long, narrow, 10-15cm wide,80-140cm deep and 10 to 20m apart, circular, linear and radiating patterns Craters on the surface, cracks along the craters from few centimeters to half a meter radii
Chobari-Manfara (10kms north of Bhachau)	23° 30' 35"N 70° 17' 32"E	Alluvial flats (agricultural lands)	*Big cracks* in the form of vast ruptures extended up to 1.5 to 2 km, very long(500-700m), parallel formations, 20-50cm wide, 60-120cm deep, subsidence by 1 to 2m at places, distance between two immediate cracks varies from 30 to 50cm, coarse alluvium and roughly terrace pattern *Major cracks* are intercepted by some vertical cracks in a small pocket around the major crack area being short (2-3cm wide, 1-3m long), linear and shallow formed along the path of small craters. The sediments erupted are lateritic, yellow in color and forms polygonal desiccated cracks
Lodai	23° 24' 15"N 69° 53' 20"E	Alluvial flats/Ranns	*Small craters* numerous (0.5 to 10cm radii), forming linear pattern of cracks, some are ruptured during pressure release with small pockets of sediment deposits
Kunjisar	23° 22' 32"N 70° 20' 20"E	Alluvial flats(Agricultural lands)	100-200m *long cracks*, linear as well as circular, 4-5m wide local subsidence, cracks formed in elliptical pattern in more than 600m area, lateritic eruptions at the site as well as in nearby plains and riverbed
Near Mundra fort	22° 47' 44"N 69° 42' 25"E	Saline mudflats	*Craters* (0.5m to 1m radii, 40-60cm deep and spread area of the sediment in more than 500m area, thickness of sediment varying from 2-10cm, fine sand deposits associated with more than 100ft high eruption during the earthquake, causing 1 feet soil detachment from nearby fish ponds

Plate 5. Formation of thick salt crust and oozing of saline water on Rann near Wandh village

Plate 6. Collapsed PHED building near Manfara village

Table 9. Sediment characteristics at rapture sites

Location	Depth (cm)	PH 1 : 2	EC dsm^{-1}	Characteristics
Lodai	0-2	8.5	20.50	Fine sandy sediment oozing with water
	2-15	8.9	13.59	
	15-27	8.8	6.30	
Lakhera Valera	0-5	8.4	42.50	Fine sandy sediment flowing out along with water
	5-20	8.2	36.70	Silty clay loam soils
Lordi	0-10	8.1	32.40	Fine sandy sediment
	10-20	7.9	36.40	Clay loam alluvial plain
Kunjisar	0-2	8.5	30.00	Silt loam material deposited over normal cultivated loamy sand soil
	2-25	8.2	2.810	Normal loamy sand contaminated soils
Chaubari	0-40	8.0	6.21	Sink soil profile
	40-100	8.1	5.07	
	100-200	8.4	1.32	
Haji Pir	0-2	7.9	27.70	Fine sand deposited on surface
	2-20	8.08	16.90	Original clay loam soils of Rann
Between Wand and Gadhada	Thick salt crust	7.0	200.00	Crystal of salt developed on surface

the springlet erupted due to earthquake towards south of Sodha Camp in Kaila riverbed ranged from 4.0 to 5.0 dS/m^{-1} In cultivated areas comprising fine texture soils of Kukma series and redish colour sandy loam soils of Ghad series cracks measuring up to 2 cm wide and 50 meter long were developed. Another striking salt deposition was observed in Great Rann between Balasar and Khadir Island. Here very bright and extra ordinary 25 to 50 cm pure sodium Chloride salt depositions occurred by eruption of saline ground water (Table 9).

Land use

The settlements (rural and urban) and constructions were first victim of the earthquake causing large scale human casualties. Bhachau, Anjar, Bhuj and Rapar taluks were very severely affected. The magnitude of damage was very severe in walled city Bhuj having old and congested houses. Official reports are that houses in 178 villages collapsed 100% and in 165 villages more than 70%. In Bhachau, Anjar, Bhuj and Rapar taluks 69, 63, 97 and 31 villages have been very severely and severely affected. The villages with more than 70% house collapse in other taluks account for 29 in Abdasa, 22 in Mandvi, 6 in Nakhtarana, 14 in Mundra and 12 in Lakhpat (Table 10). Generally old buildings/houses made up of mud and stone or with substandard materials or with faulty designs (Plate 6) collapsed totally. In the very severely affected Bhachau (Plate 7) town the entire settlement collapsed and turned into rubble. Similar damages to houses were also observed in Lakhadiya and Ratnal (Plate 8). Even 2 feet height water delivery channel of irrigation wells collapsed badly. In towns, multistory buildings were crumbled and some buildings withstanding earthquake, developed wide cracks, tilted from the base and developed cracks along the foundation becoming unfit for living. In severely affected zone 40 to 80 per cent, houses collapsed or partially damaged or became unworthy for living. In rest of the houses multi dimensional cracks developed. In moderately affected areas, 20 to 40 per cent houses collapsed completely and rest got cracks or tilts. In slightly affected region, up to 10 per cent houses (very old) collapsed while cracks developed in 20 to 30 per cent of the houses. Bhuj town was severely affected. The official reports state that 178 villages of Anjar town were 100% damaged and in 165 villages more than 70% houses were damaged. The survey and traversing across the district revealed that in every village cracks developed in the houses and old ones collapsed. Along with the residential areas, commercial complexes,

Plate 7. A scene of very severely affected Bhachau town

Plate 8. View of very severely affected Ratnal village

Table 10. Villages affected by earthquake in Kachchh district

Taluka	100% houses collapsed	>70% houses collapsed	Total
Bhuj	12	19	31
Abdasa	0	29	29
Mandvi	5	17	22
Nakhtarana	3	3	6
Rapar	79	18	97
Bhachau	59	10	69
Anjar	10	51	61
Mundra	5	9	14
Lakhpat	5	7	12
Gandhidham	0	2	2
Total	178	165	343

educational, industrial, health, religious, recreational, public and other government buildings were equally affected. Almost all the old temples (Plate 9) and mosques collapsed, even if they are located in slightly affected area.

Apart from the settlements and buildings, other affected systems were transport network, water-harvesting structures (Plate 10) and water supply lines. In the severely affected zone, almost in all bridges and culverts cracks were developed (Plate 11) and many above the ground structures collapsed. A very severely affected zone has been identified between Kumbhardi and Sikra villages on Bhachau- Bhuj road, where every culvert was badly damaged and horizontal and diagonal cracks developed on the roads and adjacent area. Similar impact was also observed on the road bridges to Rudra Mata dam and to Simarkhia, Bhachau and Gabdhidham on the National Highway to Ahmedabad.

Agricultural lands

In agricultural lands, specific damages were recorded on irrigated cropland located in alluvial region. Here 90% irrigation wells were damaged, wherein pipes were broken and pump sets and engines buried or dislodged (Plate 12). The water delivery channels and pipelines were also destroyed. This phenomenon was specifically observed between Kharoi, Bandhadi, Ner. Kadol, Wand, Amarsar, Manfara, Chobari, Bhrudiya and Ekal villages. About 4 km west of Manfara, number of isabgol fields were damaged by formation of a series of longitudinal ruptures measuring 2 cm to 2.0 m wide, 5 to 30 m long and 5 to 120 cm deep (Plates 13 and 14). Due to this phenomenon subsidence has also taken place. Besides, such fields are also affected by formation of 2 to 4 cm thick yellowish and grayish crust of fine sandy and silt loam lateritic sediment, which oozed out with saline ground water through a series of craters of varying diameters (Plate 15). Similar phenomenon was noticed in the castor fields around Loria, Jhura and Sumrasar villages. Such conditions might impose obstacles to field operations on arable lands. It may also adversely affect the soil fertility on long-term basis. The findings need confirmation in subsequent croppings. There seems to no specific perceptible impact of the earthquake on the pastures and rocky/stony wastelands. But formation of salt crust on the large area of Great Rann of Kachchh, fringes of Banni area and rise of surface might degrade the eco-system and hamper the regenerating capability of the region in the years to come. The Banni grasslands did not notice perceptible damage due to earthquake. The damage was relatively lesser on western side of Kachchh main land fault.

Plate 9. A severely damaged temple near Gundala village (Mandvi taluk)

Plate 10. Large cracks developed on the Kesawati river dam

Plate 11. A badly damaged culvert near Sikra village

Plate 12. Damaged irrigation well near Manfara village

Plate 13. Series of cracks developed and subsidence taken place in cropland

Plate 14. A view of series of cracks developed in agricultural field

Plate 15. Thick crust of sediments deposited on cropland through craters near Chobari village

ASSESSMENT THROUGH REMOTE SENSING

Visual interpretation of IRS LISS-III FCC of Jan. 29 and Feb. 1st 2001 on 1:50,000 scales were carried out to identify and map the areas affected by the earthquake in form of the development of cracks and ruptures, deposition of silty salt crust, magnitude and direction of the flow of saline water, landslides and subsidence. These phenomenon are not widespread on Kachchh mainlands and generally occur in small and isolated pockets and hence were not mappable due to limitation of spatial resolution, association of varied land use systems and vegetation cover. However in the Great Rann of Kachchh such phenomenon was clearly visible on the satellite imagery. Except the Banni area, the entire Great Rann of Kachchh was subject to deformations/manifestations of varying degrees by craters, ruptures and deposition of white salt crust of saline sediment. At several places in Great Rann of Kachchh 25 to 50 cm thick bright and pure sodium chloride salt depositions took place. Detailed mapping of such deformations has been done in three selected areas. Their location, landforms and soil characteristics, image characteristics as well as their spatial distribution are presented in Table 11.

1. Lodai area (41E/15)

The area is located north of Lodai village, which is about 22 km northeast from Bhuj town. Deformations in form of deposition of fine sandy to silt loam sediments (2.0 cm to 20.0 cm thick) through the series of craters erupted with saline ooze and development of 2.0 to 20.0 cm wide, 5.0 to 20.0 m long and 15 to 60 cm deep cracks running southwest to northeast direction (Plate 16). The EC of water ranged from 32 to 60 dS/m^{-1} and pH from 7.6 to 8.9. The size of such deformed areas varies from 1.5 to 2.3 sq km. In the fine sandy and highly saturated sediment EC was 22.0 to 200.0 dS/m^{-1} and pH from 7.6 to 8.9. About 21.0 sq km area has been affected through these degradation processes. The salt encrustation clearly appear in dull white to milky white color and flowing accumulation of erupted water in medium blue to deep blue color on imagery (Fig. 8). However a number of isolated and small patches could not be mapped.

2. North of Chobari (41I/6)

Towards north and northwest of Chobari village an area of 38.0 sq km in Great Rann of Kachchh has been identified and mapped, which has been affected by the above referred deformations. This region occupies largest area affected by the deposition of highly saline fine sandy to silty clay sediments. Two big channels of saline ground water laden with sediments have been formed in the region by earthquake impact (Plate 17).

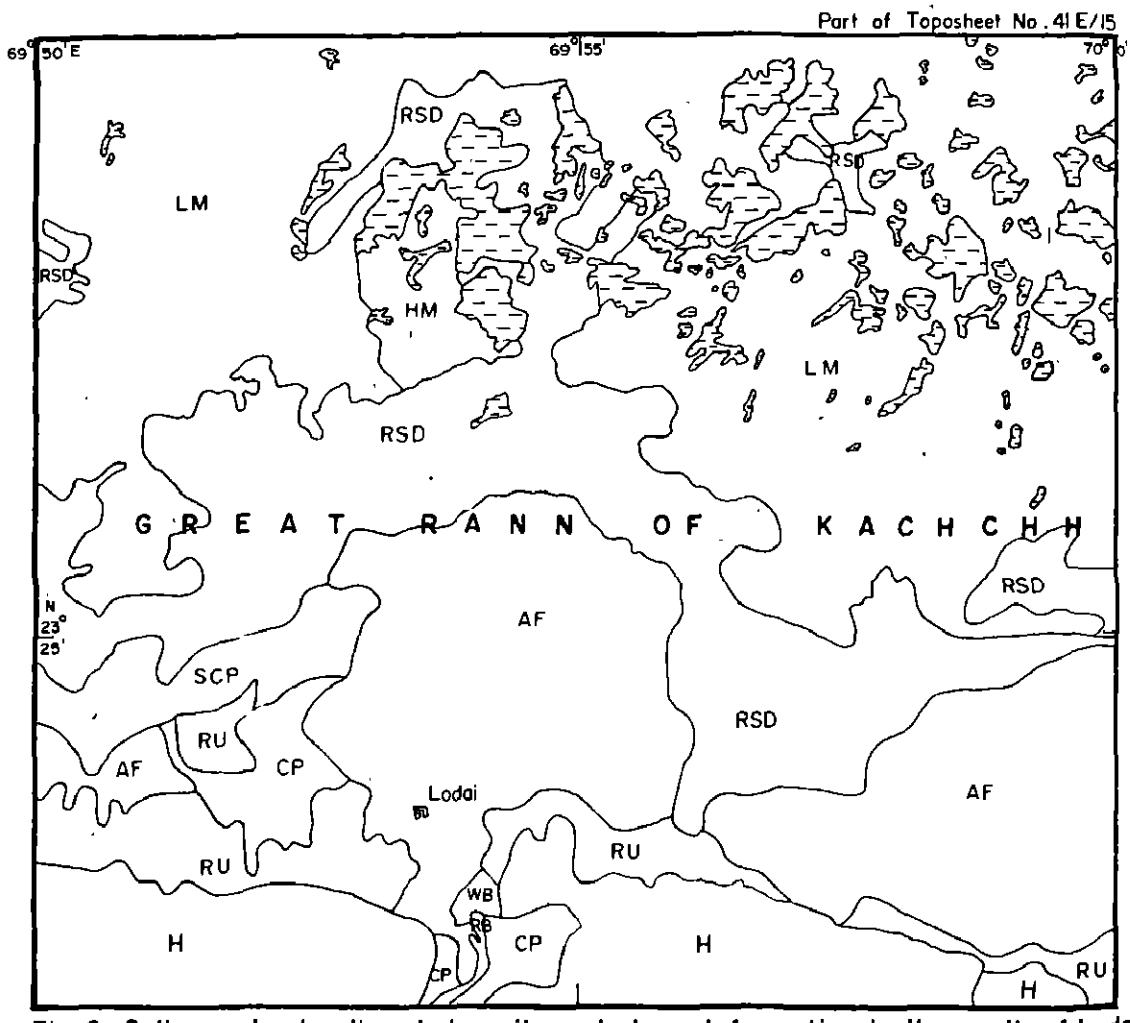


Fig. 8 Saline water / sediment deposits and channel formation in the north of Lodai

H Hills	RU Rocky upland	CP Colluvial plain	SCP Saline colluvial plain
RSD Residual saline depressions		LM Low mud flats	WB Water body
Saline water/sediment deposit		AF Alluvial fan	HM High mud flat

SOURCE : IRS 1D LISS III IMAGE, DATED 29th JANUARY, 2001

C.A.Z.R.I., JODHPUR
2001

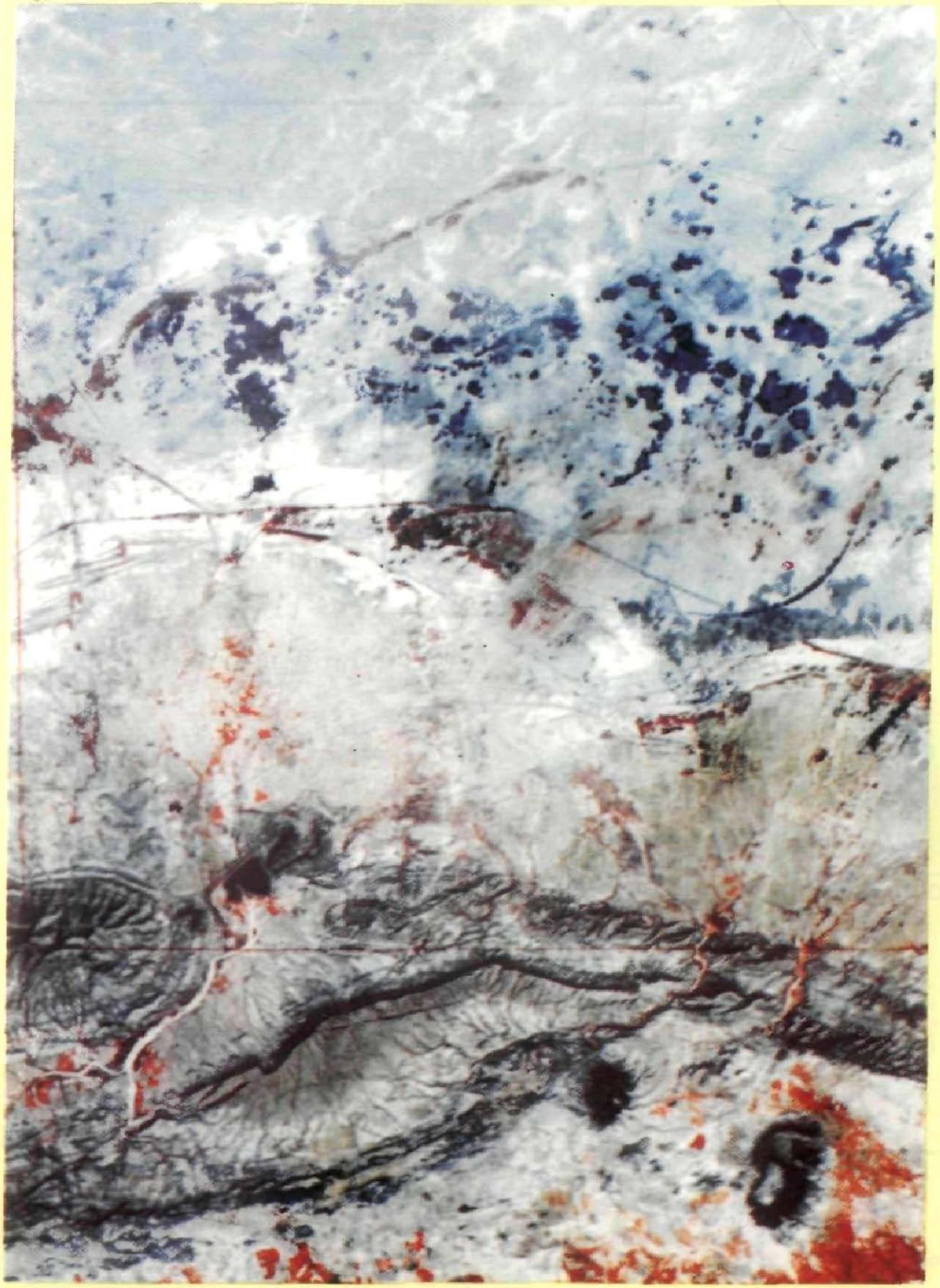


Plate 16. Segment of IRS LISS-III image (45E/15) north of Lodai village showing deformation in Rann of Kachchh

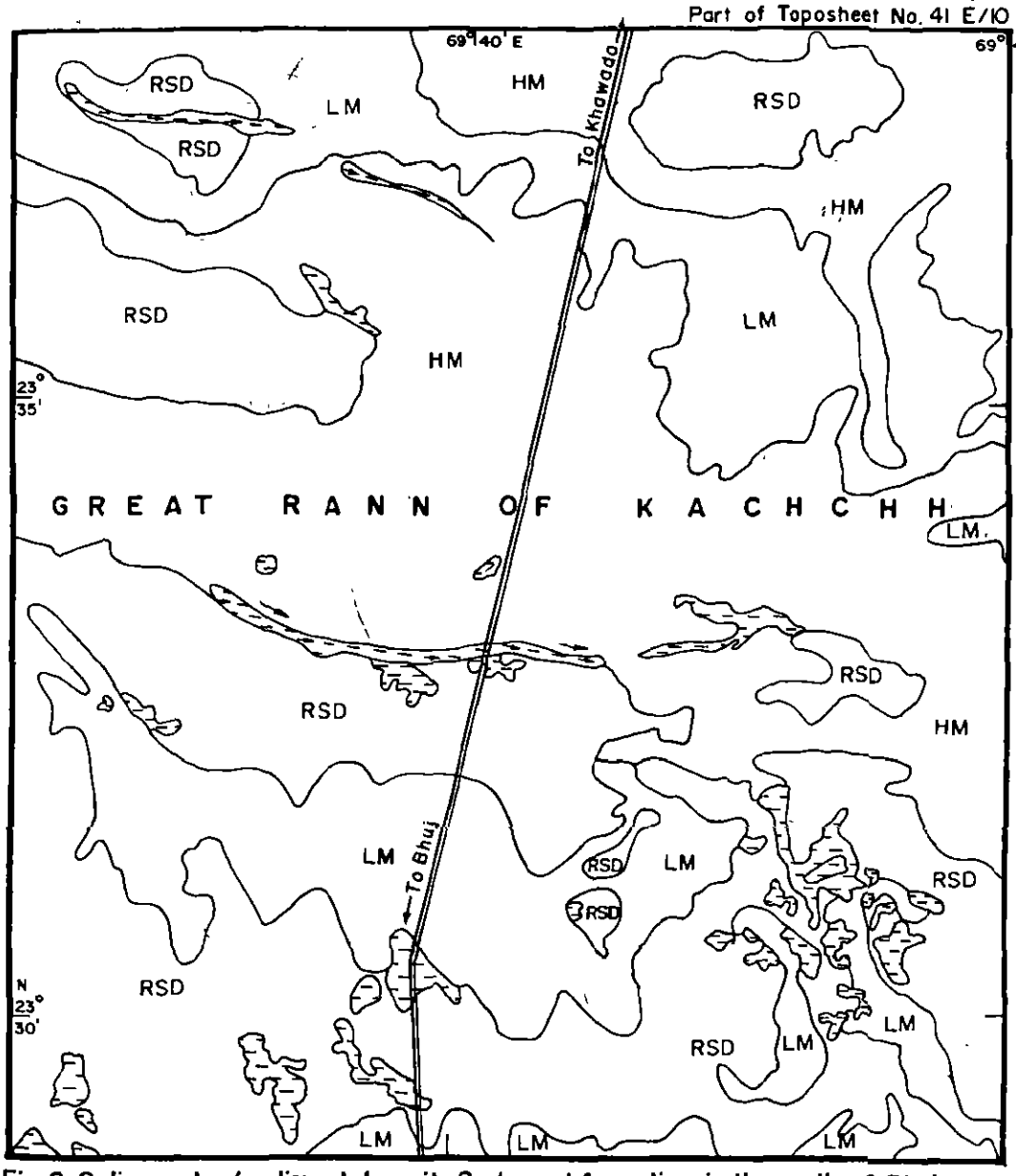


Fig.9 Saline water/sediment deposits & channel formation in the north of Bhuj

SOURCE: IRS 1D, LISS III IMAGE DATED 1st FEB. 2001

Saline water/sediment flow

Sediment deposits

RSD Residnal saline depressions

LM Low mud flats

C.A.Z.R.I., JODHPUR 2001

First one is identified in the extreme north, which is 16.8 km long and 7.0 km wide (at places it narrowed down). Second narrow channel has been identified towards southern part of region with SSW to NNE trend and eastward flow direction. It is about a km long and 400-600 m wide (Fig. 9). It is evident from field checks that the direction of ruptures and cracks is generally from southwest to northeast direction while the flow direction of oozed water follows the local slope.

3. North of Loriya (41E/10)

This area is located 37 km north of Bhuj town and about 6 km north of Loriya village along Bhuj-Khawada State Highway and adjacent to Banni land. Major deformations in this region have taken place in dry salt rann area. An area of 14 sq km has been identified and mapped with above cited deformations. Two prominent channels in linear form have been formed in this region. These are 100-150 m long and 20-30 m wide with west to eastward direction. These are located towards northwestern part of the region. Another long channel with similar direction has been identified in central part of the region running across the State Highway (Fig. 10). The pH value of sediments being 7.7 to 8.8 and EC 27.7 to 42.3 dS/m^{-1} on the surface and 16.9 to 19.5 dS/m^{-1} in sub surface (2-10 cm depth). In this region fine sand is deposited on surface, although original soil texture is clay loam.

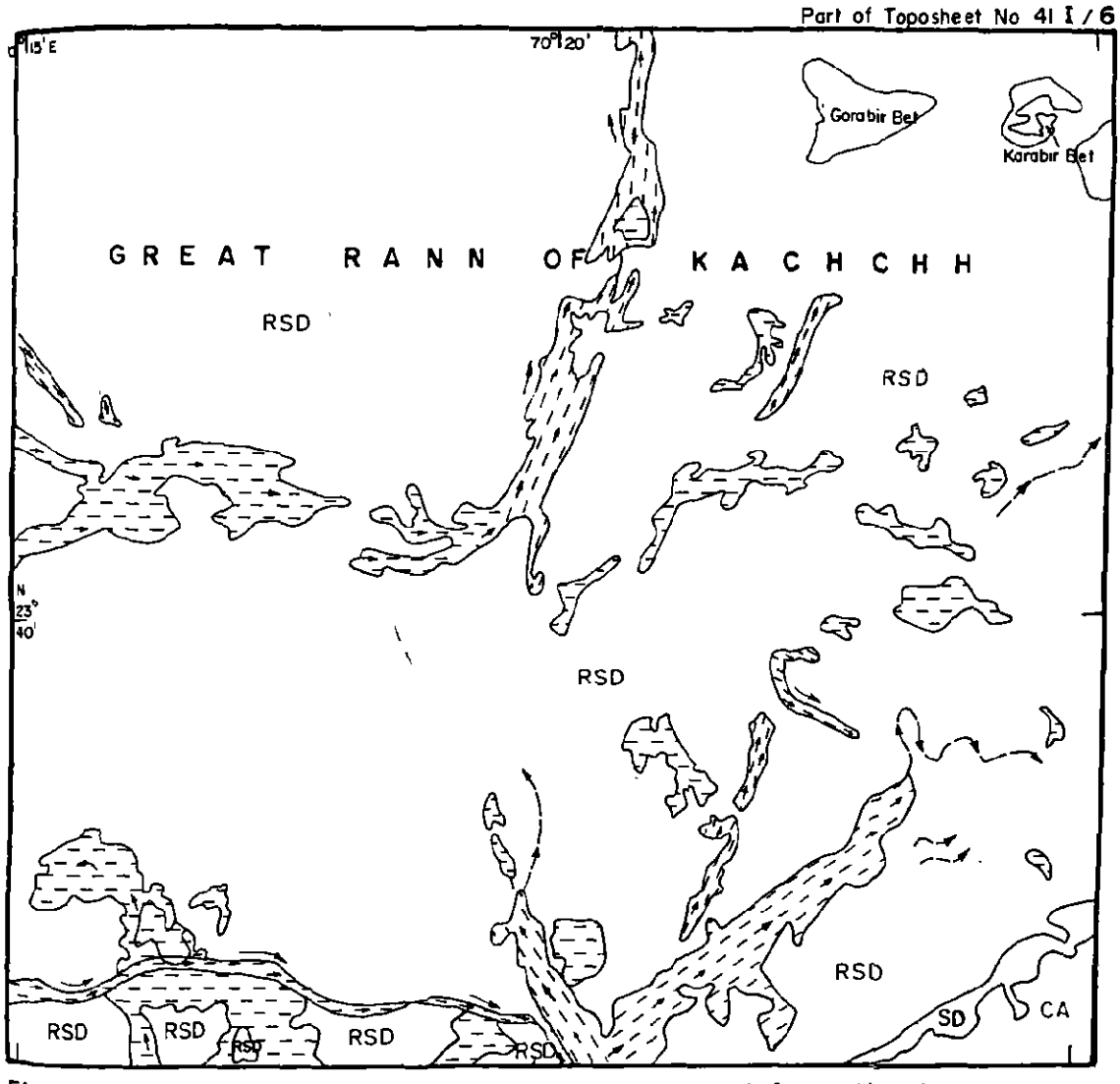


Fig. 10. Saline water / sediment deposits and channel formation in the north of Chobari .

Source : IRS 1D LISS III IMAGE, DATED 29th JANUARY, 2001

RSD Residual saline depression or ranns

SD Sand dunes

Sediment deposits

CA Coastal alluvium

Saline water and sediment flow in channels

C.A.Z.R.I., JODHPUR
2001

Table 11. Image characteristics of surface deformities in some specific sites of earthquake affected area

Site	Land surface characteristics	Surface deformities and their dimensions	Image characteristics of the affected surface		
			Tone	Shape	Association
Toposheet no. **41 E/15** North of **Lodai** epicenter about 27 kms N-E of **Bhuj** town	*Dominantly* raised mudflat – (a part of Banni grassland area), surrounded by saline depressions or Ranns in the south	*Small but prominent* depressions **(average size, 1.5-2.3 sq km)** **Total affected area 21 sq km**	*Dark and* light blue tone indicating deep and shallow sediment deposits	*Irregular* and disturbed	*Ranns (dull* white tone) in the fringes of raised mudflats (light gray tone) with degraded grass cover (light brown tone)
Toposheet no. **41 I/6** North of **Chobari** epicenter, about 25 km north of **Bhachau** town	Dominantly residual saline depressions (RSD) or great Rann	Deformations on ranns with cracks, channels (linear and disintegrated, **9 km long, 400-600m wide),** length of longest channel being **16.8 km** in the extreme north and irregular depressions **Total affected area 38 sq km**	Dominantly light blue for sediment flow in the channels and dark blue for deposits in the depressions	Channels (linear and curved) depression (irregular)	Ranns (dull white tone) with scattered vegetation (light brown tone)
Toposheet no. **41 E/10** 40 kms north of **Bhuj** town	Dominantly mudflat (MF) with scattered saline depressions and narrow belt of degraded grassland	Few narrow channels **(100-150m long and 20-30m wide)** and small saline depressions dotted with a number of small depressions filled with water and sediments. **Total Affected area 14 sq km**	Light blue (water) surrounded by white tone (saline sediments)	Irregular	Ranns (dull white) and grassland (light brown tone)

Sources: IRS-ID LISS III Satellite data of 29th January and Ist Februry, 2001

Plate 17. Segment of IRS LISS-III image (41 I/6) north of Chobari village showing deformation in Rann of Kachchh

Plate 18. Establishment of Indraprastha - a model village

IMPACT ASSESSMENT OF SEVERETY OF EARTHQUAKE

Based on the nature, quantum and kind of damages and their direct and indirect impact in respect to losses as well as mortality of human beings, the entire Kachchh district has been delineated in to very severe, severe, moderate and slight categories of damages out of the total reporting area (Fig. 11).

- **Very severely damaged zone:** Constitute about 8.80 per cent of reporting area, identified around Bhachau town and extending from Lakhara Valera to Chobari towards north and Padana and Simarkhiya towards south. The affected area extends up to coastal line.

- **Severely affected zone:** Constitutes nearly 26.96 per cent of the area covering Bhuj, Anjar and Rapar taluks. Its southern boundary extends from Mankuva, 15-km west and 8 km south of Bhuj town to 3 km south of Anjar town near Viri village. It covers eastern part of Bhachau and Western part of Rapar taluk, Khadir, Pachham and part of Bela islands and of course eastern part of Banni area. Towards northwest it extends up to Jhura village.

- **Moderately affected zone:** Nearly 29.23 per cent district area has been delineated under this category. It mainly covers eastern part of Rapar, southern part of Anjar and Bhuj and major part of Nakhtrana taluks as well as western part of Banni area. Moderately affected areas also occur in patches in Ramaniya, Bhadeshwar, Gundala, Nani Tumbadi and Vadala villages of Mundra taluk; Umarsar, Suger, Naredi, Jalurai and Saran villages of Lakhpat taluk; Kotri, Nagrecha, Bhadai Nani, Bhadai Moti and Dhokda villages of Mandvi taluk and Bandi, Bhimsar and Jesarbandh of Nakhatrana taluk.

- **Slightly affected zone:** Constitutes nearly 35.01% of district area and occurs mainly in Lakhpat, Abdasa and Mandvi and Mundra taluks. Near Kandla Port too slight damage has taken place. Slightly affected area is also occuring in eastern fringes of Rapar taluk towards east of Adesar.

REHABILITATION MANAGEMENT STRATEGIES

Immediate relief measures

1. Restoration of communication with outside world ensuring availability of fleet of heavy machinery for the clearance of rubble, extraction of people, functioning of routes, roads and communication system, infrastructure facilities for easy and safe transportation of goods from out side.

2. Immediate relief measures to be undertaken are evacuation of injured and dead; provide temporary shelters, medical aid, food and water; restoration of transport, communication, power, fuel, medicines; fodder and other items of daily needs and ensure their proper distribution. Maintenance of law and order and safety of human lives, private and public property is another top priority.

3. Removal, transport and dumping of debris at proper site; inventory and assessment of damages, restoration of areas fit for human dwelling, selection of alternate sites, reallocation of space according to their immovable property lost and family compensation. provisions of subsidy, waiving/deferring the repayment of taxes/loans and other financial obligations are essential to maintain the faith and confidence among the affected people.

4. Coordination of relief work of different volunteers and Govt. agencies. International agencies and logistic support for stocking and storage of relief material and warehouse management.

5. Establishment of appropriate structures to better respond to the needs of affected communities, and provision of drinking water food and alternate housing. Gearing up of public distribution system.

6. Creation of community based health programmes for treatment with an emphasis of the most vulnerable issues such as maternal and child health in the affected region, to reduce the infant mortality rate and maternal mortality rate so also to provide relief to aged and invalids.

7. Reconstruction of anganwadis with minimum of 100 Red Cross rooms, sub-health centers and primary health centers.

8. Establish of operational mobile units to facilitate disaster coordination and information management.

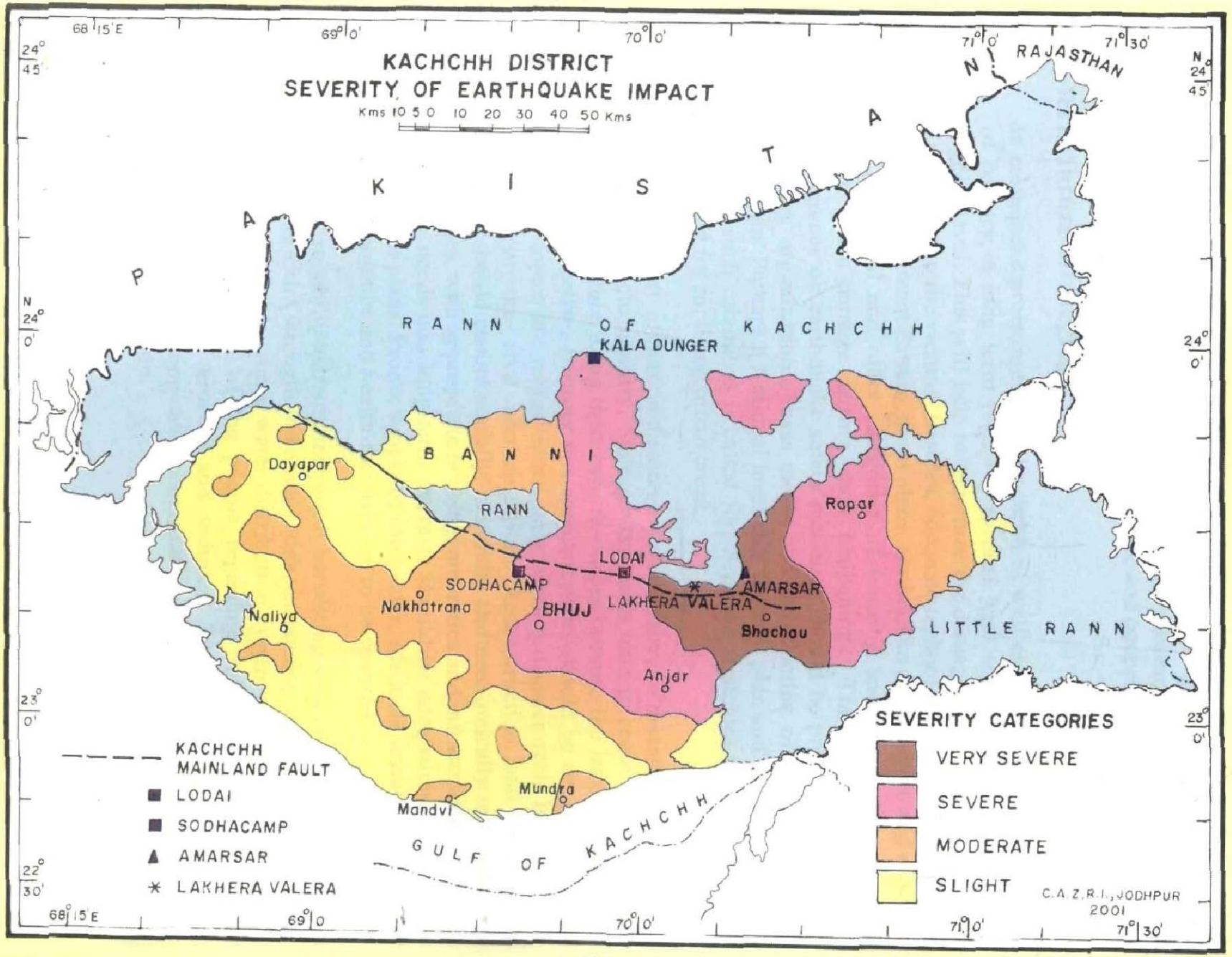

KACHCHH DISTRICT
SEVERITY OF EARTHQUAKE IMPACT
Kms 10 5 0 10 20 30 40 50 Kms
68°15'E
69°0'
70°0'
71°0'
71°30'
24°45'N
24°0'N
23°0'N
22°30'N
RAJASTHAN
PAKISTAN
RANN OF KACHCHH
KALA DUNGER
BANNI
RANN
Dayapar
Rapar
LODAI
SODHACAMP
Nakhatrana
BHUJ
LAKHERA VALERA
AMARSAR
Bhachau
Naliya
Anjar
LITTLE RANN
Mandvi
Mundra
GULF OF KACHCHH
KACHCHH MAINLAND FAULT
LODAI
SODHACAMP
AMARSAR
LAKHERA VALERA
SEVERITY CATEGORIES
VERY SEVERE
SEVERE
MODERATE
SLIGHT
C.A.Z.R.I., JODHPUR
2001

Fig. 11

9. Voluntary organizations should be given full government support for providing relief measures. The rehabilitation measures need be undertaken in rational manner with people's confidence and cooperation.

Long-term future strategies

1. In earthquake prone areas like Kachchh as well as other seismic prone zones of country, a long term planning to deal with such disaster is realized at highest level. This will help to minimize the damages, casualties and provide timely help to the victims. Besides, adequate technology is needed to develop suitable settlement pattern, town plans, earthquake proof design and materials for residential and other categories of housing and infrastructures which suffers least damage during such happenings. Training and awareness programmes on earthquake safety measures should be promulgated through voluntary organizations, mass media and introduction of chapter in school curriculum. Perhaps a National level task force to plan and develop strategies to tackle such calamities is called for. Separate strategies are required to be formulated for rural and urban areas.

2. Despite a history of natural disasters, the efficiency of disaster management is a handicap in our country. State governments tend to requisition the armed forces even before using their own resources because the latter's response is quick and effective. Disaster management plans should be structured so that the armed forces are requisitioned only when a disaster scale is beyond the capacities of the civil administration. Reconstruction and resettlement objectives should ensure socially, culturally and economically self-sustaining communities, with appropriate housing, amenities and infrastructure. People's short term needs and long-term interests should be adequately addressed in management plans. Proper supply of safe water, adequate sewage facilities for local communities and health facilities are to be ensured.

3. In order to rehabilitate traditional water harvesting structures; improvement in design with extra strength in seismic zone, increasing water storage capacity, providing a reliable sturdy water distribution system through piped network; improving awareness of the people regarding safe water, sanitation and health; reducing soil erosion and sediment load to the water harvesting structures from adjoining catchments and emphasis on ground water recharge needs due consideration.

4. The seriously damaged small-scale industry sector should be a priority in the process of rehabilitation as it employs mainly rural population. Efforts should be made to market product, allow continued production and job opportunity. Although industrial development in the region is not very high, and direct impact of calamity is relatively low, the industrialization process has halted and the indirect impact will be staggering. Therefore, rehabilitation of the industrials sector needs attention.

5. The Gujarat earthquake has challenged India's information system. While damage from such disasters can only be reduced by implementing structural and non-structural measures, disaster response mechanisms will be more effective by using GIS based tools, a strong database and time series analysis of the data with other modern tools to improve prediction of such happenings.

6. There is a need to developed comprehensive database in respect of economic, social and demographic information by credible independent bodies. This will be invaluable for planning and monitoring of relief and rehabilitation measures. Information should be integrated with suitable GIS-based system for use by local administration, social workers and policy planners.

7. There is a need for damage assessment tools for emergency operations centers, preparation of multi-hazard micro zoning maps and emergency and back-up communication systems.

8. The recovery and reconstruction process should emphasize appropriate understanding and awareness of risk among the stakeholders, sufficient advance training and confidence building among professionals, engineers and masons; and appropriate planning is required.

9. Established a functional disaster management network in each of the India's four most disaster-prone zones. There is need to launch a national earthquake combating strategies that should incorporate :

   - A building retrofitting program with finance and demonstration process.
   - Enforcement of land use restriction
   - Formulation of buildings codes for different seismic zones and
   - Strengthening of the country's search and rescue capability

LESSONS LEARNT

Urban areas

Town planning with modern state of art is perhaps the most serious task. In Ahmedabad town out of 79 buildings collapsed, plans for 32 have been submitted for approval and only 7 have been approved so far. So also is the case of four badly devastated towns namely Bhuj, Bhachau, Anjar and Rapar of Kachchh. Due to stringent bylaws of earthquake proofing, many builders are not coming forward. Rome was not built in a day. Neither would be Bhuj, nor Bhachau, nor Anjar, nor Rapar. Neither will be Kachchh nor Gujarat. Various kinds of survey with people's participation and least legal complications are a herculean task. The Government of Gujarat launched "Public-Private" partnership programme (PPPP) with involvement of NGO's is perhaps remedies to stand with.

Proper survey, inventory and assessment of damages and loss to human lives should be carried out promptly. Demolition and clearance of debris should be done in phased manner. The debris must be dumped out side the municipal limits at appropriate sites. Procedure for assessment and disbursement of compensation should be made simplified to minimize hardship to the victims. Standard norms should be followed in repair works and then only the premises should be declared fit for use. Safety norms should be strictly enforced in schools and multistory buildings. Limits of horizontal and vertical expansion for different city zones should be fixed and judiciously enforced. For urban livelihood programme, basic support is required for industrial sector including financial/material assistance to salt workers, small entrepreneurs and handloom weavers.

Rural areas

Caste, social custom and economic status play an important role in rural settlement. Theses factors as well as basic needs of the local communities should be taken into consideration during rehabilitation strategy. For selecting alternate sites also these factors are very important. Establishment of Indraprasth is one of such example (Plate I8). Rocky/stony and saline areas are not suitable for rural settlements. People's views should also be considered before allotting any site for such purposes. These sites should also not be far away from their agricultural fields and water points. There should be sufficient space for keeping animals and farm produce. Social

security of the weaker sections should also be ensured. Other important activities to be undertaken are :

1. Distribution of farming inputs to all the eligible farmers before ensuing sowing season.

2. Distribution of farm structures, irrigation routs and restoring power etc.

3. Emergency repair of irrigation structures, dams and strengthening of structures vulnerable to seismic activities.

4. Due to obvious emphasis on human, the animal sector is ignored during any such event. Provisions for cattle field, fodder from adjoining states, medical arrangements for animals and their look after is equally important in the hour of such crises.

Development of Infrastructure and Support System

After the immediate relief measures, it is necessary to prevent out migration of people and livestock by restoring their confidence in livelihood through natural resources of the region. Provision of fodder and vaccination of animals should be given high priority since livestock contribute significantly towards livelihood of *Maldharis*. Standing rabi crops of wheat (18,102 ha), mustard (10,739 ha), castor (8,690), isabgol, cumin (3,945 ha), coriander (455 ha), cotton (386 ha) and others (235 ha) were nearing maturity. Harvesting and threshing facilities of the farmers were damaged basically or destroyed. It is very essential to arrange combine-harvesting machines. Many private operators are available around in the states Haryana and Punjab could render their help. Storage and marketing of the harvested produce may also be planned.

Sowing of summer and kharif crop is a second highest priority. Since bullock power, existing machinery, pump houses, farm houses, storage bins etc. were severely damaged, it is incumbent to arrange tractors, seed drills and other farm machineries of the Govt. and NGO's. Machines can be purchased or hired and should be managed by Self Help Groups as envisaged in the guidelines of watershed management. Similarly other agricultural inputs like seed, fertilizers etc. may also be managed.

Repairs of dams, wells and water-conveyance system should be given top priority to make the irrigation system functional. There is no major irrigation scheme in the Kachchh district and most of the ground water resources are already exploited. There is a great potential to harness rainfall producing 58% runoff by way of water harvesting,

storing and recycling. Construction of embankment type water storage structures, *khadin* and in situ conservation of rain is called upon. Simultaneously water saving methods of irrigation like drips and sprinklers need to be promoted. Improved *Douru* technology is quite successful for skimming fresh water floating on saline ground water in sandy coastal belt, which can be utilized effectively.

AMELIORATION AND MANAGEMENT OF NATURAL RESOURCES

Amelioration and management of natural resources of the region degraded through this earthquake, human activities is simultaneously required to save these precious natural assets from further degradation and putting them in to sustainable production systems by adopting area proven technologies. This will supplement efforts of people in post earthquake hour of need.

Agricultural Land

Irrigated Land

Scraping of saline sediment, filling of cracks with good soil from adjoining fields, soil amendment and leveling of fields are required in the irrigated fields damaged due to earthquake. Growing of salt tolerant crops, crop rotation, judicious use of ground water, minimizing transmission losses and suitable irrigation methods are to be undertaken to prevent secondary salinisation and fertility loss.

Rainfed Land

In-situ water conservation practices together with agro- forestry and agro-horticultural systems should be adopted to ensure adequate fodder production as well as alternate source of income. Wherever saline sediments and cracks are developed due to earthquake, scraping of such saline sediment and filling of cracks with good soils are to be undertaken before the ensuing kharif season. Field bunding and raising of suitable tree/shrub species or grasses on them and use of vegetative barriers for erosion control on mild slopes may prove beneficial. Crops of economic/industrial value like '*senna*' and *menhadi* can be introduced to provide additional income.

Non-Agricultural Land

1. Barren rocky/stony waste

Adoption of soil conservation measures viz. contour furrowing, contour trenching and contour terracing are required to rehabilitate such vulnerable areas. These will improve the soil moisture conservation and erosion control. The suitable species for plantation are *Acacia senegal, Anogeissus pendula, Grewia tenax, Acacia leucophloea, Maytenus emarginatus, Commiphora wightii and Euphorbia caducifolia.* The ground flora can be enriched by growing grass species like *Sehima nervosum, Cenchrus setigerus and Cymbopogon jwarancusa* between tree/shrub rows (3 to 5 m spacing) by dibbling the pelleted seeds or planting rooted slips. Protection of plantation is required at least in first year. A live hedge of *Acacia senegal* and/or *Euphorbia caducifolia* can also be developed. At suitable sites 'tanka' or other water harvesting structures should be constructed to store water for the establishment of plantation. Uneconomic quarrying of stones should be prohibited. Stone quarrying should be scientifically done in planned manner and simultaneously land shaping, rehabilitation and plantation of mine spoiled areas be taken up. In all development activities people's participation and their cooperation should be ensured to get social security of the area and success of the development works.

2. Rocky/gravelly upland

Degraded rocky/stony and gravelly upland and shallow hard pan soil areas with very scanty and poor distribution of unpalatable shrubs and grasses as well as very low production potential, are recommended for development of silvi-pasture. Improved soil and water conservation measures to minimize soil loss, spread the rainwater evenly and allow it to penetrate at lower depth and harvesting of rainwater should be planned for such areas. Construction of contour furrow and trenching at an interval of 3.5 m on moderately sloping land, vegetative barriers as per topographic needs and terracing on steep sloping land should be practiced. Suitable moisture conservation techniques viz. half-moon terraces, ridge and furrow and microcatchment should be undertaken.

Cleaning of area from the unwanted weeds/plants, proper soil working by mixing moist sandy soil three to four times the volume of suitable grass species like *Cenchrus ciliaris, Dichanthium annulatum, Sehima nervosum* and *Cenchrus setigerus.* Their seeds should be drilled uniformly in line 50 cm, apart in 8-10 cm deep furrow at depth of not more than 2-3 cm under the soil. For ensured and continuous supply of quality fodder

suitable tree and shrub species viz. *Prosopis cineraria, Acacia tortilis, Acacia senegal, Colophospermum mopane, Hardwickia binata, Cordia gharaf, Grewia tenax* and *Ziziphus spinacristii* should be raised. Their seedlings should be planted at 20 m row-to-row distance and 5 m tree-to-tree spacing in contour furrows. In hard pan soil areas such trees can be grown by breaking hard concretionary strata by crow-bar. For areas having 10-20 cm soil depth with calcareous (murrum) layer, plantation in pits (60cm x 40 cm) at 5 m x 5 m spacing of *Acacia tortilis, Acacia nilotica* and *Tecomella undulata* is recommended. Economic plants like senna (*Cassia angustifolia*) can also be grown in wasteland. In order to protect the areas from biotic interference at the initial stage, live hedge is required to be grown with *Ziziphus rotundifolia* (Bordi) and *Euphorbia caducifolia* (Danda Thor). Nursery may be developed near water points i.e. 'nadi' for providing seedlings. Mining stones for domestic purpose is a common phenomenon on such lands, which needs properly regulated and simultaneously after the land shaping rehabilitation should be done and suitable tree and shrub species be planted. Open grazing over such lands needs regulated in a faced manner. In all such developmental activities participation of local people should be ensured to provide social security and success of developmental work.

3. Salt affected land

Saline depressions in desert areas are called 'Ranns'. In these low lying areas water along with sodium salts accumulate from surrounding uplands. Continuous accumulation of salt forms white encrustation preventing any vegetation to grow except few halophytic species on its periphery. In order to increase the production potential of these lands plant species should be selected according to the salinity level. For soils having EC (dSm^{-1}) 8-16 *Acacia leucocephala, Dichrostachya nutans* and *Acacia nilotica* can be grown. For areas having EC more than 16 the suitable tree/shrub species are *Tamarix aphylla* (Jhau), *Salvadora* sp., *Haloxylon salicornicum, Salsola baryosma* (Jerio Lana), *Suaeda fruticosa* and *Atriplex* sp. Suitable salt tolerant grasses are *Sporobolus marginata (Khari ghas), Dichanthium annulatum, Chloris virgata* and *Cenchrus setigerus*. For establishment of above trees saplings pits are dug and the saline soil wherever is replaced by good soil. Grasses are grown through pelleted seeds or rooted slips on ridges of 0.8 to 1.0 m height made east-west direction at a regular interval of 5-6 m apart in between the tree rows. Few top feed species like *Salvadora oleoides* and *Dichrostachya nutans* may be grown on bunds or along the margin of saline depression. Application of gypsum @ 50% soil gypsum requirement is essential. For planting trees the compact subsoil layer should be broken and gypsum mixed with the soil should be refilled in the pit. This will progressively increase the infiltration rate over the years.

4. Reseeding and development of degraded pasture/grazing land

All the open grazing lands are in highly deteriorated condition. Continuous heavy grazing modifies the botanical composition of the grasslands. Palatable grass species have been over exploited. These perennials with high forage potential like *Cenchrus ciliaris, C.setigerus, Lasiurus sindicus, Dichanthium annulatum, Panicum antidotale*, etc. are the first victim of overgrazing. Continuous grazing of these species and frequent droughts and famines lead their complete extermination. At present almost all grazing lands especially village commons; "Orans & Beers" do not support these productive species. Pioneer species like *Aristida funiculata, A.mutabilis; C.biflorus, Eragrostis poaoides and Indigofera cordifolia* may be hardly seen. Loss of ground cover has a bearing on runoff and moisture status. Higher soil bulk density lead to lower infiltration rate causing low moisture storage in soil profile. Village common grazing lands need priority for rehabilitation. It can be achieved only with the active co-operation of local people. The main objective is to provide a palatable vegetation cover on these lands and regeneration of the degraded vegetation cover by providing suitable soil and moisture conservation measures and the protection. The approach should be ecologically suitable and acceptable to local people. Being in the vicinity of the village it becomes essential to check the movement of grazing animals. Several methods to be adopted are :

(a) Barbed wire fencing with 4 strings and different posts like angle iron, stone slabs, wooden posts may be tried.

(b) Ditch digging and bund formation is another method. It is labour intensive and needs continuous maintenance. Live fencing of desirable species should be raised along the bunds, which will become effective in 5-7 years. *Euphorbia, Parkinsonia, A.senegal, P.juliflora, A.tortilis* are preferred species.

(c) Contour furrows, 60 cm wide and 25 cm deep are constructed in grasslands at a distance of 10-15 m apart, across the slope of the land. In another technique of inter-row water harvesting (IRWH) system in which 30 cm wide ditch alternate with 70 cm wide raised beds are made. The grasses/legumes/shrubs are grown on the edge of the ditch. The grass seeds are pelleted by mixing grass seed, clay, FYM and sand in 1 : 30 : 5 : 5 ratio in a pellet making device. Pellets of 0.5 cm diameter are prepared and sown in line either in contour furrows or in IRWH system. The seed rate varies from 2.5 to 7.5 kg/ha for direct sowing of different types of grasses. For planting trees in the grazing/ *oran* lands piting-discing

techniques should be followed. This involves making shallow pits by the disc-mounted tractor.

(d) Planting of multipurpose leguminous species of top feed value should be selected for plantation in the grassland area.

(e) The area in question for rehabilitation should be divided into four to six compartments and one part may be taken up for grazing each year.

(f) Forage cutting should be preferred over grazing. It will allow sustainable forage production from the rehabilitated sites.

(g) The reseeding is needed to enhance the annual forage production because under natural conditions the progress of succession is quite slow. High yielding species like *C.ciliaris, C.setigerus, D.annulatum, P.antidotale* and *Lasiurus sindicus* depending on the soil type may be sown through 1-2 years old seeds or rooted slips or dibbled along the rows in the furrow at 10 mm depth.

(h) Introduction of (30-50 trees/ha) top feed species like *A.tortilis, A.nilotica, Prosopis cineraria, Salvadora oleoides, A.senegal, Dichrostachys nutans, Ziziphus nummularia, Calligonum polygonoides, Capparis decidua* may be transplanted. The sapling should be raised in polyethylene bags and must be 6-9 months age at planting.

(i) *Prosopis juliflora* was introduced in the saline Rann ecosystem by forest department in 1960-61. Later on some plantations of *Prosopis juliflora* were also raised in coastal saline belt. This species has now invaded even pastures or grassland of Banni and *Maldharis* feel upset with the loss of biodiversity. It is difficult to eradicate this prolific coppice. The best alternative would be to exploit it for fuel-wood, charcoal and furniture making to generate productive employment. The pods can be feed to the cattle.

5. Regeneration and gap filling of forestland

In Kachchh district degraded forest areas mostly occur on hills and their foothill zone. Due to high runoff and moderate to severe water erosion, these areas require rehabilitation to check erosion of skeletal soil. In this case soil conservation measures like contour furrowing at 8-10 m interval with 20-30 cm deep furrow, 60 cm wide contour

trenching and bunding are required to be developed for improving the soil moisture status. Contour trenching consists of excavated trenches and forming bunds at trenches along a uniform level or at a particular contour across the slope of uncultivated wastelands. The main objectives of contour trenches are to reduce the amount and intensity of runoff, conserve moisture in soil and helping the establishment and accelerating the growth of trees in afforestation programme. The runoff collected in trenches which ultimately percolated through the soil and travel down and benefits the sloppy lands in middle and lower parts of the catchment.

Contour trenches are excavated at suitable vertical interval depending on the slope of land. Their cross sections are designed to collect and convey the runoff expected from inter-space between the successive trenches. The side slopes of the trenches are 1:1 or ½:1 according to the nature of soil. Trenches are continuous or staggered type. Normally continuous trenches are 15 m long with cross section rarely exceeding 0.3 x 0.3 m. A common practice is to have 4 m long trench at an interval of 4 m along the contour line. The staggered trenches are shorter lengths and occur in a row along the contour with interspacing between them. In the alternate row, the trenches will be located directly below one another. The trenches in successive rows will be staggered with the trenches in upper row and the inter-space in the lower row being directly below each other. The length of the trench and inter-space between the trenches in the same row may be suitably arrived at so that there will not be long unprotected sloping lands. In arid areas, trenches of 1.5 m x 45 cm x 45 cm are dug at 3 m space staggered on contour. The excavated soil is piled up on the down hill slope along the trench length. The seeds are either sown on berm of the trenches on in diagonally half filled trenches. Tree species like *Acacia senegal, Anogeissus pendula, Grewia tenax* and *Maytenus emarginata* can be grown to enrich the forest area by transplanting poly bags raised seedlings. Ground flora may be enriched by *Sehima nervosum, Cenchrus setigerus* and *Cymbopogon jwarancusa*. Even with plantation the existing germules of annual species shall be first to colonize along the trenches with significant forage production. The species of ground flora may be sown between the tree/shrubs rows (3 to 5 m spacing) by dibbling the pelleted seeds or rooted slips transplantation. Live hedge of *Acacia senegal* and *Euphorbia caducifolia* may be developed. The afforestation and gap filling activities should be carried out at appropriate time i.e. within first fortnight of the occurrence of first monsoon good soaking shower. Initial watering and seedling mortality should be timely monitored and quickly replaced. Planting operation should be completed within the shortest period. The seedlings should be of 45-60 cm high with long and well developed tape roots. Coiled roots should be straightened at the time of planting and collar zone of the plants should be completely covered by the soils. The depth of pit should be more than the root portion of the

seedling. The species should be able to produce coppice shoots and viable seeds for further propagation. After planting a saucer shaped depression around the plant having 15 cm deep and 1 m diameter in plain areas and a crescent shaped ridge of 15 cm high may be provided on sloppy areas to collect and store rain water.

6. Rehabilitation and development of mined spoil areas

The rehabilitation of mined wasteland can be achieved through an optimum combination of rainwater harvesting, soil profile modification and appropriate plant species. The surface of the mine spoils shaped into terraces and slopes for providing a catchment for harvesting precipitation and a terrace for transplanting saplings. The rainwater harvesting techniques are micro-catchment, half moon terraces and ridge and furrow. To modify soil profile planting should be done in auger holes of 15 cm diameter and 1 m depth. The auger holes be filled up with necessary growing medium consisting of a mixture of fine sand, farmyard manure and top soil in equal proportions. Plantation of a mixture of top feed tree, shrub and grass species is to be done at 5 m x 5 m spacing in order to enhance soil fertility and stability, nitrogen fixation and provide fodder for animal browsing. These are *Acacia nubica, Acacia tortilis, Azadirachta indica, Cercidium floridum, Dichrostachys nutans, Prosopis cineraria, Salvadora oleoides, Salvadora persica* and *Tamarix aphylla.*

For reclamation of mined spoil areas the first requirement is land shaping and construction of bench terraces or half moon terraces as per requirement for rainwater harvesting. This is followed by covering of surface with 45 to 60 cm layer of find sand and *murram* to neutralize H_2SO_4, soil profile modification by digging pits and filling them with fine sand, pond silt or clay and FYM and plantation of suitable tree, shrub and grass species.

Animal husbandry

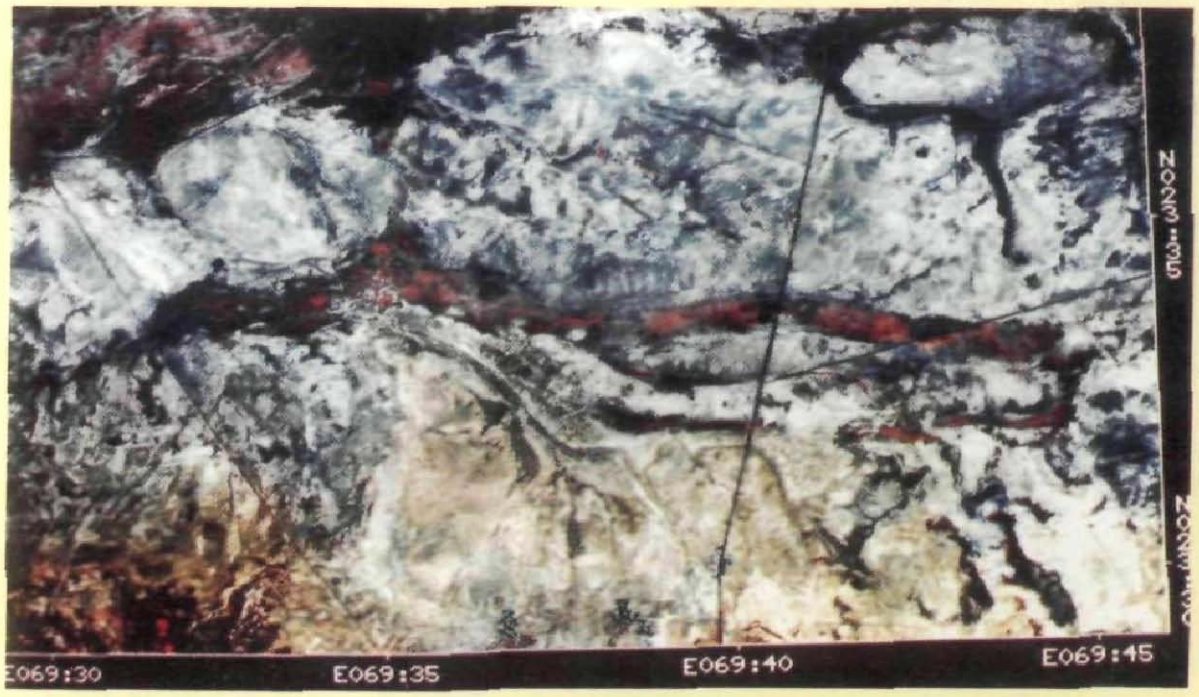
Animal husbandry being one of the important sectors in Kachchh district needs proper recognition and priority. In order to prevent out migration and starvation deaths of animals during drought, which is a common phenomenon, creation of fodder bank, construction of drinking water tanks and regulating their proper supply are to be undertaken. Palatability and nutritive value of feeds can be improved by supplementations of fermentable energy based feeds. CAZRI has tested in developed some of these feeds viz. liquid feeds, compact multi-nutrient feed block, roughage based multi-nutrient feed blocks and roughed based complete feed blocks. In order to improved nutritive value of crop residues as well as palatability and digestibility, ammonification

(urea treatment) can be undertaken. *Tumba,* ground nut seed cake, groundnut shell, tree leaves and pods of *Prosopis juliflora* are some of the non conventional feeding stuffs. Adequate and properly distributed veterinary hospitals should be made available. Awareness programme for treatment of common ailments of animals and preventive measures are risk prone diseases should be launched with the involvement of social workers and NGO's.

CONCLUSIONS

The unique and highly devastated earthquake of 26th January 2001 has caused heavy loss to human being and an extensive damage to private and public assets worth Rs. 15,000 crore. Bhachau, Anjar, Bhuj and Rapar are the worst affected taluks in Kachchh where apart from towns 343 villages have been very severely damaged and rendering lakhs of peoples homeless. Other severely affected sectors are public buildings, transport network, water supply system, religious places and monuments. Out of the total reporting area of the district, assessment through remote sensing reveal 8.8% very severe, 27% severe, 29% moderate and 35% slightly affected. It had also changed the terrain condition of Great Rann of Kachchh inducing further degradation. The Asian Development Bank and World Bank have estimated cost of rehabilitation amounting Rs. 10,600 crore. This is challenging and uphill task and can only be accomplished through perspective vision, viable and eco-friendly technologies and their realistic and judicious implementation in an integrated fashion through people's cooperation. In order to feed and sustain the population of the disturbed region, there is need for sustainable use and management of natural resources. This calls for appropriate land use planning and utilization of resources on sustained basis.

Different size of craters formed by earthquake oozing saline water with sediment



Segment of IRS LISS-III image north of Loriya village showing deformation in Rann of Kachchh

Badly damaged building in Lakadiya village

Isabgol field damaged by saline sediment oozed from craters

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