PLANNING FOR INFRASTRUCTURE FOR EARTHQUAKE PRONE AREAS

A DISSERTATION

Submitted in partial fulfilment of the requirements for the award of the degree

of

MASTER OF URBAN AND RURAL PLANNING

By :

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CANDIDATE'S DECLARATION

I, hereby, certify that the work which is being presented in this Dissertation entitled **`PLANNING FOR INFRASTRUCTURE FOR EARTHQUAKE PRONE AREAS'** in partial fulfilment of the requirements for the award of the degree of **MASTER OF URBAN AND RURAL PLANNING,** submitted in the Department of ARCHITECTURE AND PLANNING, UNIVERSITY OF ROORKEE, ROORKEE, is an authentic record of my own work carried out during a period of eight months from August 1993 to March 1994 under the guidance of **Ms. Pushplata.** The matter embodied in this dissertation has not been submitted by me for the award of any other degree.

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CERTIFICATE

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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INTRODUCTION

1.1 GENERAL

Earthquake is a natural disaster, but unlike for other natural disasters like floods, cyclones, draughts etc., it is not yet scientifically possible to predict the exact location, time and magnitude of a possible earthquake. The state of the science today can locate critical areas, can keep all the parameters closely watched and give a fair indication of what could happen if earthquake comes, but in our country even the estimation of probable damage is not possible till now.

India is a developing country undergoing population growth at an alarming rate. Due to better facilities and more opportunities for earning, more and more people are being attracted from rural areas to urban areas and from smaller to bigger urban centres. In the wake of urbanization most of the cities are expanding rapidly in an uncontrolled manner and it is getting even more difficult to guide the development in a planned way.

At the same time, since last few years the seismic activity in India has also gone up resulting, despite a number of small tremors, in devastating earthquakes of Uttarkashi in October 1991 and the recent one in Maharashtra on September 30, 1993 which claimed thousands of lives and was the worst in Indian history of earthquakes. According to scientists some more earthquakes are expected in near future in the lower himalayan region. In other highly seismically active countries like Japan, U.S.A. etc. seismic considerations have gained considerable importance in the planning of settlements as the negligence of these factors has resulted in severe losses in the past.

Now the need to take into account the seismic considerations in town planning is being felt in India also. Actually the planning for such areas depends largely on the geologic - both surface and sub-surface features of that area.

1.2 NEED OF THE STUDY

Though scientific research in the field of seismicity has made it possible to make the structures like dams, bridges, important buildings like hospitals, schools etc. earthquake resistant for a specified maximum magnitude of earthquake, but still geologic features of the area are not considered for the location of such structures due to lack of availability of such data and inability of town planners to incorporate these features into the planning process. If these factors are taken into consideration for the locational planning of various structures and facilities, the risk can be reduced by a great extent.

Modern cities usually rely heavily on utility systems for their day to day activities. Various utilities and services like transportation and energy transmission facilities, communication and water supply facilities etc. which are essential to support the normal life and whose functioning is of crucial importance not only during the earthquake but also after the erthquake in providing post-disaster relief to the affected people are termed as 'Lifelines'.

Earthquakes are a potential threat to the continuous functioning of a city's lifelines; however, untill recently seismic considerations have not been an integral part of the planning, design, construction and operational phases of lifeline ststems. The need for such criteria has been demonstrated by the damage and loss of lifeline systems during recent earthquakes. Destruction of transportation and energy transmission facilities and disruption of communication and water supply will lead to extreme disorder in a city, which in turn increases the potential for various secondary disasters like fire, epidemics etc. In this sense the earthquake problems of utility systems become increasingly more important in proportion with the level of urbanization and the porpose of the study into these problems is not only to minimize the direct financial loss but also to minimize the period of suspension of human activities due to earthquake effects.

Earthquake damage to utilities is different from that to other structures in that the former is less directly related to the loss of human life. Utilities being network systems spread over a large extent of area, damage to certain locations in a utility network often affects significant portions of the system. Post disaster functioning of water supply and transportation systems is of enhanced importance for mitigating possible fire hazards and evacuation of the affected people and providing essential commodities and relief work to the affected community. At present the role of planning is confined mostly to post-disaster phases like rehabilitation.

1.3 SCOPE AND LIMITATIONS

Town planning can play enormous role in all the three phases or responses viz. Prevention, Mitigation and Post-disaster aid; to earthquakes. But due to paucity of town planners involved with disaster-related studies, the other earthquake related fields (structural engineering, geological science, and disaster relief) are unaware of the transformations within the town planning field and vice-versa. As a result of this, at the present state of affairs the role of town-planning is more or less limited to post-disaster relief works only.

Taking into consideration the recent transformations and research in other earthquake related fields, town planning can play a very significant role in the mitigation of the damages due to earthquakes. The necessity for 'looking below the surface' as a part of planning process must be appreciated from the very earliest stages of site considerations. Hazards due to natural disasters like earthquakes can be prevented or reduced greatly if the geology of the site is known.

Town planning, in itself, being a very wide field the present study is limited to planning for a few selected infrastructures in earthquake prone areas.

1.4 OBJECTIVES

Following are the objectives of this study:

i. Formulation of guidelines for the infrastructure planning in earthquake prone areas.

ii. To study the infrastructure provision in a selected city as a case study.

iii. To suggest policy guidelines for the infrastructure planning for the selected city.

1.5 METHODOLOGY

The methodology will consist of the following sequential steps:

i. Collection of relevent information from books, journals and similar case studies.

ii. Analysis of the literature and information gathered.

iii. Formulation of guidelines for the planning of physical infrastructure for earthquake prone areas. Specifically the infrastructures included are-

a) Road Netwrok

b) Water Supply Network

c) Sewerage Network

iv. Policy guidelines and proposals for the above mentioned infrastructures for Haridwar town, according to the formulated guidelines.

CHAPTER : TWO

LITERATURE REVIEW

CHAPTER - 2

LITERATURE REVIEW

2.1 INFRASTRUCTURE IN PLANNING CONTEXT

a) It is defined as the basic services on which urban development depends.

b) It is a term widely used in planning field denoting the services and facilities which are integral part of the life of a community. Such an infrastructure is geared to expanding economic and social life.

TYPES OF INFRASTRUCTURE

Infrastructure can be divided into two types according to the nature of their need and function:

i) Utility Infrastructure/Physical Infrastructure

This includes the basic urban services which are required for the physical development of an area. These are -

a) Transport network

b) Water supply system

c) Sewerage system

d) Drainage system

e) Electricity and Communication networks

ii) Social Infrastructure

It is defined as the infrastructure needed for the overall social development of an area; e.g. schools, shopping, health centre, recreation, banks and post office etc.

Therefore, the basic urban services which are essential part of the life of community are known as infrastructure services in the planning field. These are so important for the smooth going of life in the present world that these are termed as 'lifelines'.

2.2 EARTHQUAKE AND ITS IMPACTS

WHAT IS AN EARTHQUAKE ?

An earthquake is a sudden, transient motion or a series of motions of the ground which originate in a limited region. Earthquakes occur due to sudden release of the stored strain energy through the zones of structural weakness in the form of faults, fissures and thrust areas in rocks forming the earth's crust, when it exceeds their elastic limit.

An earthquake produces elastic waves called seismic waves which travel through the earth in every direction from the centre of the distrubance' called Focus.

IMPACTS OF EARTHQUAKE

An earthquake occurs in the form of seismic waves travelling through the earth which impart vibrations to the earth mass. Sometimes these ground vibrations result in movement of the earth or rocks along fault lines making them active, rupturing or breaking of previous continuous rock mass, land sliding and various phenomenon related with soil, for example, liquefaction, densification, settlement etc. These have hazardous impacts on various structures lying on, above or below the ground surface.

Structures lying below the ground surface are affected mostly by fault movements and liquefaction of soil.

Ground vibrations are imparted to the structures lying on the surface of the ground. When the frequency of vibration of superstructure and the part of structures in surpension like bridges matches with the natural frequency of vibration of the ground, the damage is maximum.

Earthquakes have great impact on massive structures like dams, high rise buildings, bridges, over head storage tanks etc. The failure of these due to ground shaking results in the loss of a number of lives. The impact of earthquakes on the infrastructure services is never the less as the suspension of these services has very adverse effects on the welfare of the community. Facilities lying below the surface of ground are most badly affected by the liquefaction of soil.

2.3 APPROACH TO HAZARD ASSESSMENT

The potential of an area for the seismic hazard and the response of the systems in that area can be assessed. This will help in a big way in establishing and maintaining various facilities in that area. The risk or potential for damage can be assessed by following steps-

i. Investigate the geology of the area where the lifeline system is located: locate faults and thrusts, zones of landsliding, lateral spreading and liquefaction.

ii. Survey the lifeline system in order to identify critical elements in relation to geologic hazards.

iii. Investigate the performance of critical elements in past earthquakes, including malfunction under normal operating conditions.

iv. Establish priorities for maintaining or restoring key elements of the system.

Siting in loose soils, rigid connections and corrosion lessens the ability of pipelines to withstand ground shaking and differential ground movements. Pressure surges add to the stresses induced directly in pipes by ground shaking.

2.4 PLANNING FOR SEISMIC HAZARDS

Land use planning has been used only recently as a method to mitigate losses due to earthquake hazards. The urban growth in highly seismically active countries like Japan, California and Alaska, for example, in recent decades has moved ahead with little regard to seismic hazards. Following are some possible land uses and building policies for mitigating earthquake hazards resulting from surface faulting, ground shaking and ground failure:

a) Surface Faulting

i. Faults are major breaks in the continuity of solid rock strata. These may be surface faults or concealed ie. sub-surface faults and in some cases may be potential causes of distrubance at ground level. In all cases faults should be avoided for sites upon which permanent structures are to be erected.

ii. Recommend land uses that would be compatible with ground displacement for future development, for example-undeveloped open space, recreational areas, parking lots etc.

iii. Establishment of a fault hazard easement, requiring varying setbacks from active faults.

iv. For any development to be within or immediately adjacent to an active fault, detailed geologic studies should demonstrate that the construction would conform to the standards of community safety and that an undue hazard to life and property would not ensue.

v. For already existing development, non-conforming building ordinances would require the eventual removal of structures in the greatest danger, starting with those that endanger the greatest number of lives - schools, hospitals, auditoriums, offices followed by commercial buildings and perhaps eventually by single family residences.

b) Ground Shaking

i. Low density land-uses for future development.

ii. Ordinances requiring detailed geologic, soil and engineering analyses for structures having high occupancies in areas suspected to have strong ground shaking.

iii. Hazardous buildings and parapet abatement programmes sould be initiated.

c) Ground Failure

i. In areas of expected instability, open space or other non-occupancy uses sould be proposed.

ii. For occupancy use site can be prepared to eliminate hazardous condition or special engineering design sould be adopted.

Town Planning as a Response to Earthquakes

There are mainly three responses to earthquakes which may assign roles to town planning. These are :-

i. Post disaster aid : largest role due to lack of preparedness.

ii. Prevention : minimum role as it is largely an engineering fallacy.

iii. Mitigation : considerable role is expected. If communication and services are considered as part of town planning, prediction will help especially with respect to locational planning for relief and rehabilitation.

2.5 PLANNING FOR TRANSPORTATION SYSTEMS

Though roadways, railways, airways and waterways are all modes of transportation but roadways and railways are the prime and most widely used modes. Both roadways and railways have their own place of importance. But in the context of the present study roadways are more significant than railways because these provide access to the interiors of a community and moreover these have a smaller grid network.

2.5.1 Importance of Transportation Systems

The primary function of a transportation system is safe and economical movement of people and goods. The importance of proper functioning of these is enhanced in case of seismic hazards for the evacuation of the affected area and providing relief work to the affected people.

The primary tasks or functions of a transportation system following a major earthquake are:

1. Serve as routes of travel for people escaping fires and other life threatening dangers like flood, tsunami etc.
2. Allow movement of medical teams and civilian assistance personnel to stricken areas for removal of the injured to functioning hospitals.
3. Permit access to the emergency areas, of mobile fire fighting equipment and other machinery for clearing routes and the debris of collapsed buildings.
4. Provide adequate ways for disaster relief agencies to bring in food and water to the devastated areas, thus preventing casualities due to shortage of these.

2.5.2 Earthquake damage to Transportation lifelines

Earthquake damage to transportation lifelines occurs from one or more of the follwing earthquake related activities:

1. Ground shaking, with structural damage caused by the vibratory nature of the earthquake.
2. Crustal alterations caused by tectonic movements,

which produce uplift, subsidence and relative movement across faults.

3. Ground alterations by local settlement, slope failure at embankments, landslides, liquefaction and surface rupture.
4. Consequential damage caused by tsunamis, fire and other earthquake related effects.

HIGHWAYS

Most of the damage reported on highways is on 'bridges'. Damage to a bridge may occur in the superstructure, the substructure or supports or to the approaches to the bridge deck. Elements of highways besides bridges, which may suffer earthquake damage include tunnels, embankments and retaining walls. Damage to embankment may occur due to permanent ground movements such as subsidence or slope failure. This sometimes occurs in combination with liquefaction or failure of retaining walls.

RAILWAYS

Damage occuring to this lifeline is in-general similar to that to highway lifelines and arises from the same causes. However railroad bridges are less vulnerable to earthquake damage than highway bridges because of the followings:

i. Due to absense of deck slab, the superstructure is lighter.

ii. The beneficial effects of the rails tying adjacent spans together.

iii. Larger seat widths for girders providing stronger connections.

iv. Design for other transverse and longitudinal loads (e.g. centrifugal and braking forces) provides horizontal load resistance even with no special design provisions for earthquake forces.

Permanent ground displacements either vertically or horizontally have a more severe effect on railways than on highways.

AIRPORTS

These involving very large capital investments are constructed after detailed site investigations and therefore are the least vulnerable transportation system. Control towers and other buildings are subjected to the effects of vibratory ground motion in the same manner as other types of buildings. The runways are susceptible to cracking, subsidence and dislocation due to tectonic movements, soil liquefaction or the effects of sea waves if these are in close proximity of sea shores.

2.6 PLANNING FOR WATER AND SEWAGE LIFELINES

Water and sewage lifelines are comprised of intersecting gridworks of pipelines, storage facilities, pumping plants, treatment plants and the sources; whose continued operation following an earthquake is essential to public health and safety. All of these components are quite susceptible to damage due to earthquakes but the storage tanks, transmission and distribution or collection pipelines are the most vulnerable. The loss of storage facilities (surface, buried or elevated tanks) can drastically impair the functioning of a water supply system resulting in its inability to provide sufficient water even for fire fighting and emergency facilities such as for hospitals. In addition, the collapse of a tank can cause injuries to persons and damage to property both from the fallen structure and the rapid release of water! An evaluation should be made of the path of discharge of water through the surrounding area in case of failure of a storage facility.

Different components of a water supply system have different susceptibility to failure during an earthquake depending upon the cause of failure. Here, failure means inability of the component to perform its function during the days or hours immediately following an earthquake. The ratings as shown in the table 2.1 have the following rather crude meanings:

Very High: Moderate earthquake quite likely to cause failure.

High: Major earthquake likely to cause failure and moderate earthquake might well cause failure.

Moderate: Major earthquake might well cause failure, while failure is unlikely during a moderate earthquake.

Low: Unlikely that a major earthquake would cause a failure.

Very Low: Almost certain that no failure will occur.

A moderate earthquake might involve upto several feet of fault displacement or repeated peak accelerations in the range of 0.1 g to 0.2 g. A major

TABLE 2·1

SUSCEPTIBILITY OF COMPONENTS TO FAILURE
DURING AN EARTHQUAKE

COMPONENT	AGENT			
	FAULTING if fault crosses site	FAILURE OF SITE if soil is poor	LANDSLIDE from steep adjacent terrain	GROUND SHAKING
DAMS	L to M	VH	L	L to H
DEEP TUNNELS	H	VH	VL	VL
SHALLOW PIPES	VH	VH	L	L to M*
OPEN CANALS	H	VH	H	L
ELEVATED PIPES	H	VH	H	M
TREATMENT PLANTS	H	VH	H	M
PUMPING STATIONS	H	VH	M	M
STANDPIPES, TANKS	H	VH	M	M

VH = very high
H = high
M = moderate

L = low
VL = very low

*For firm and soft soil, respectively

earthquake might involve five or more feet of fault displacement and repeated peak accelerations of 0.3 g to 0.4 g or higher.

In protecting any water supply system the need for uninterrupted power supply is an important consideration. All water treatment plants and pumping stations should be furnished with auxilliary power source.

The state of the art for the design of sewers must take into account the following potential kinds of damage:

i. Pipe crushing and cracking by shearing and compression,
ii. Joint breaking because of excessive deflection or compression,
iii. Joint pulling open due to tension, and
iv. Changes in sewer grade causing reduced flow capacity.

To minimize public health hazards following an earthquake, safe water must be available throughout the emergency. This requires keeping sewage out of the water supply. Water systems are generally vulnerable to sewage contamination in one or both ways: (i) Sewage entering a water source, (ii) Sewage seepage into water mains with little pressure.

Preventing sewage seepage into water mains is an important problem even under nonearthquake conditions. During an earthquake the potential for such seepage is amplified by massive structural damage to both the water and the sewage systems and the concomitant loss of water pressure and sewage leakage. The best defence is to keep water mains and sanitary sewers properly separated. Therefore, in designing a water system that should be safe during and after an earthquake, the importance of adhering to good practices in separating water mains and sewers must not be overlooked.

The key to protective design is flexibility, in the system as a whole and in the details of facilities. Multiple sources of supply and the capability to reroute service should be high on the list of desirable objectives.

Local geology and soil conditions are found to play a major role in performance of these lifelines. An important step in the planning and design of these lifelines to resist earthquake effects is to determine the potential for ground failure, due to faulting, lateral spreading, landsliding, liquefaction or other causes along the routes of pipelines and beneath other facilities. The geologic portion of the investigation will likely require a reconnaissance near the site, as well as of the site itself.

Water and sewage pipelines are laid generally below the ground surface and are called buried pipelines, but in some cases these may be provided above the ground also. However, the seismic behaviour of the underground or buried pipelines is quite different from that of above ground pipelines.

2.6.1 Response of Buried Pipelines to Earthquakes

Seismic damage to buried pipelines is mainly caused by movement due to fault, liquefaction of sandy soil, or difference in dynamic properties of two horizontally adjacemt soil layers. Seismic ground shaking alone generally can not be expected to cuase any major rupture and/or buckling failure of properly designed, manufactured and laid out pipeline. So the response of buried pipelines to Permanent Ground

Movement is an important part of the lifeline earthquake engineering.

Permanent Ground Deformation (PGD) refer to nonrecoverable soil movement due to landslides, surface faulting, or liquefaction induced lateral spreading. The response of a buried pipeline to PGD is a function of the pipeline orientation with respect to the direction of ground movement. In most cases it is found that longitudinal PGD (ground movement parallel to the pipe axis) was more likely to result in failure than transverse PGD (ground movement perpendicular to the pipe axis) for both continuous and segmented buried pipelines.

Since the buried pipelines have practically the same displacement and accelerations as the surrounding soil, inertia forces have little role to play in causing damage to buried pipelines.

Further, the earthquake damage to buried pipelines can be described in terms of the following-

i. Pipe material: Pipes with 1 to 2% ductility have much better resistance than brittle pipes.

ii. Join type: Flexible or slip joints permit necessary axial deformation to resist damage far more than rigid welded or bolted joints.

iii. Size: The more the diameter, the more the resistance against rupture.

iv. Nature of the ground: pipelines fare worse in loose soil than in dense native, or compacted soil. Difference in dynamic properties of horzontally adjacent layers is one of the main causes of shaking damage. Even with large displacements in softer soils, the displacements can be much smaller than the relative displacements that occur at the junction between stiffer and softer soils resulting in damage in the junction area.

v. Direction of pipeline with respect to the incident seismic waves : Other parameters remaining same the stresses induced in the pipe due to seismic waves parallel to the axis of the pipeline are approximately twice those due to waves at right angles to the axis.

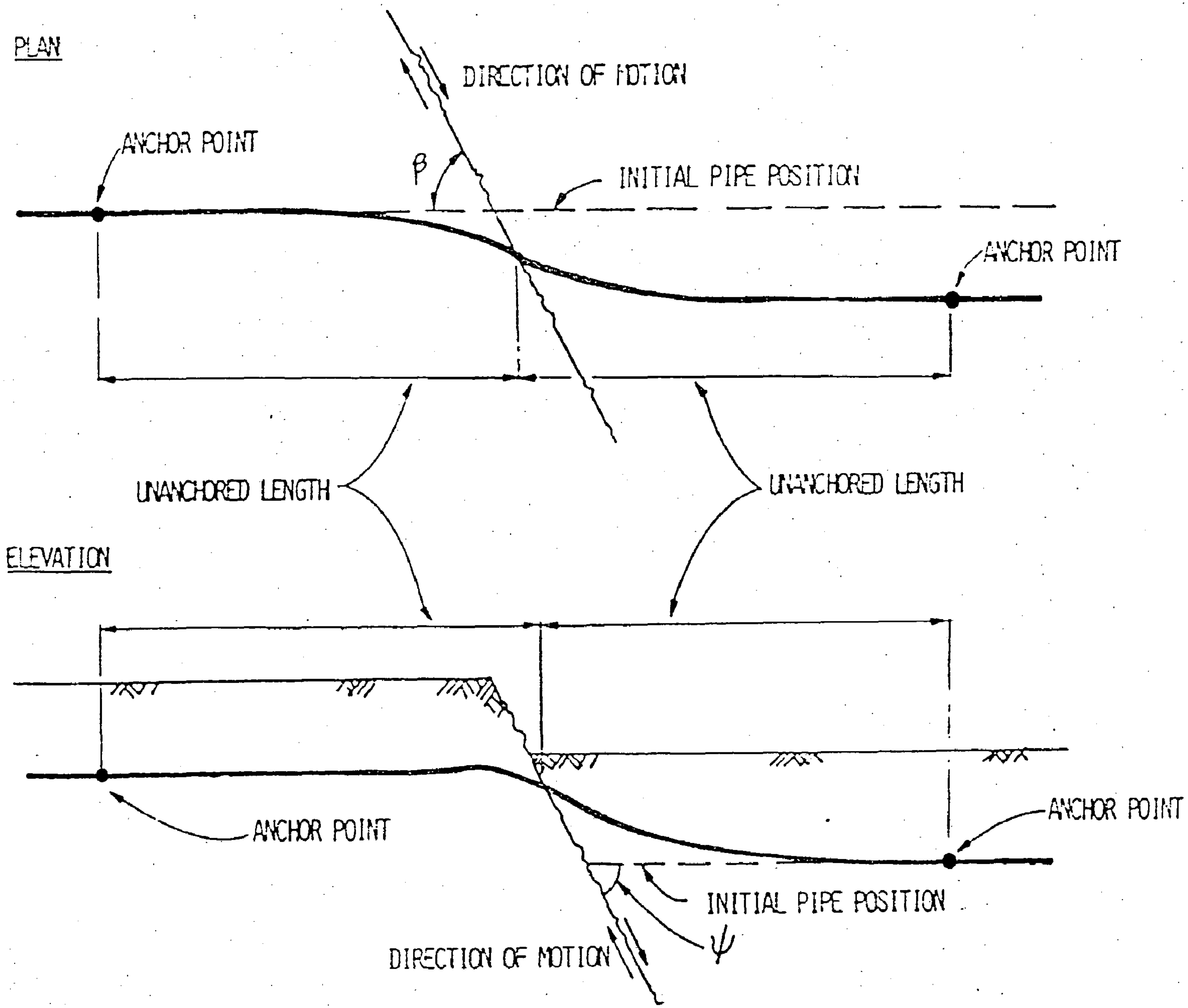
2.6.2 Pipelines Subjected to Ground Distortion

A major class of problems involves pipelines crossing a zone of differential ground displacement. It should be emphasised that the plane of abrupt or differential ground displacement need not always be fault, but may be any rupture surface associated with lateral spreading, landslides and subsidence caused by earthquakes. However, large scale ground displacements are often the result of faulting. Pipelines placed across such faults should consider, in addition to the potential for storng ground shaking, the potential for surface faulting and ground deformation.

The geologic and historic record of fault activity demonstrates that the location of future surface faulting will most likely occur on or near the most recently active fault - trace.

For any project or structure located across or in the vicinity of a fault, the primary consideration is location and amount of fault displacement and the possiblity of recurrent movement on that fault with a time period which is considered significant to that project or structure.

As an example, consider a buried pipeline crossing a fault. The pipeline can be subjected to either or both the dip and the strike - slip movements. The lateral



PIPELINE SUBJECTED TO BOTH NORMAL AND STRIKE-SLIP MOVEMENT AT A FAULT CROSSING motion causes the pipe to displace laterally with respect to the soil resulting in a lateral soil pressure load on the pipe, imparting tensile strains and curvature in the pipe in the vicinity of the fault. On the other hand, for shallow burial, the uplift resistance of the soil is small and normally is much lower than the downward bearing resistance. Thus the pipeline can be laid and designed such that the pipe can lift upward with relative freedom to accomodate the vertical fault movement and it is for this reason that the relative motion between the pipe and the soil occurs predominantly on the downward moving side of the fault.

The axial elongation or contraction is resisted by frictional forces at the pipe - soil interface. Hence, the frictional resistance offered by pipe - soil interaction governs the length of the pipe required to accomodate fault - generated strains.

2.6.3 Response of Above Ground Pipelines to Earthquakes

The basic cause of damage to above ground pipelines is ground shaking but these sometimes get damaged due to falling of soil mass during landsliding or of structures on them. The repair and maintenance of these pipelines is easy.

The failure to these pipelines during past earthquakes has principally been attributed to excessive stresses at joints between pipeline segments because of differential displacements at these joints. This type of joint failure has been attributed to two causes : spatial variation of ground motion along the length of the pipeline, and flexibility of the foundation soil - medium.

Following are the conclusions from studies conducted in the recent past:

i. Softer joints attract less differential response, and are therefore safer.

ii. Joint distress is found to be greater for pipelines running through softer soils or having longer spans.

iii. Joint distress in pipelines supported at higher elevation is less due to isolation of the spatial variation in ground motion.

iv. Higher soil damping does not necessarily reduce differential pipeline joint response, especially for axial motions.

2.7 EMERGENCY PLANNING AND RESPONSE PROGRAM

In order to minimize loss of life, spread of diseases and destruction of property following an earthquake, an `Emergency Planning and Response' program should be instituted as part of an overall plan, which may include response to flooding, fire and storm emergencies.

The first step in the planning is to analyse system vulnerability; weak links can be identified and critical ones can be strengthened.

Emergency stockpiles of equipments and materials should be maintained in areas with easy access and away form faults and areas with unstable ground. A reliable communications network is critical, particularly if the telephone system is inoperable.

Response to an earthquake can be divided into three phases - immediate; sustained; and repair.

Immediate phase lasts untill the threat of flood and fire are passed. Then starts the sustained phase. Restoring life support services, such as providing potable water and sanitary disposal system should begin.

Once the extent of damage is known, the repair phase begins. Repair priorities should be based on the number of people affected and required to make the repairs.

CHAPTER : THREE

CASE STUDY - HARIDWAR TOWN

CHAPTER - 3

CASE STUDY - HARIDWAR TOWN

3.1 INTRODUCTION

Haridwar is a famous religious place besides being the district headquarter of Haridwar District. Being situated on the important road and rail routes the town is undergoing rapid development of various economic activities. In the recent past a few small scale industries have set up in this town. It is directly connected with the important towns of Meerut, Saharanpur, Dehradun and Rishikesh of North India. On the basis of population distribution the town can be divided into four parts :-

1. Haridwar
2. Jwalapur
3. Kankhal, and
4. Bharat Heavy Electricals Limited (B.H.E.L.)

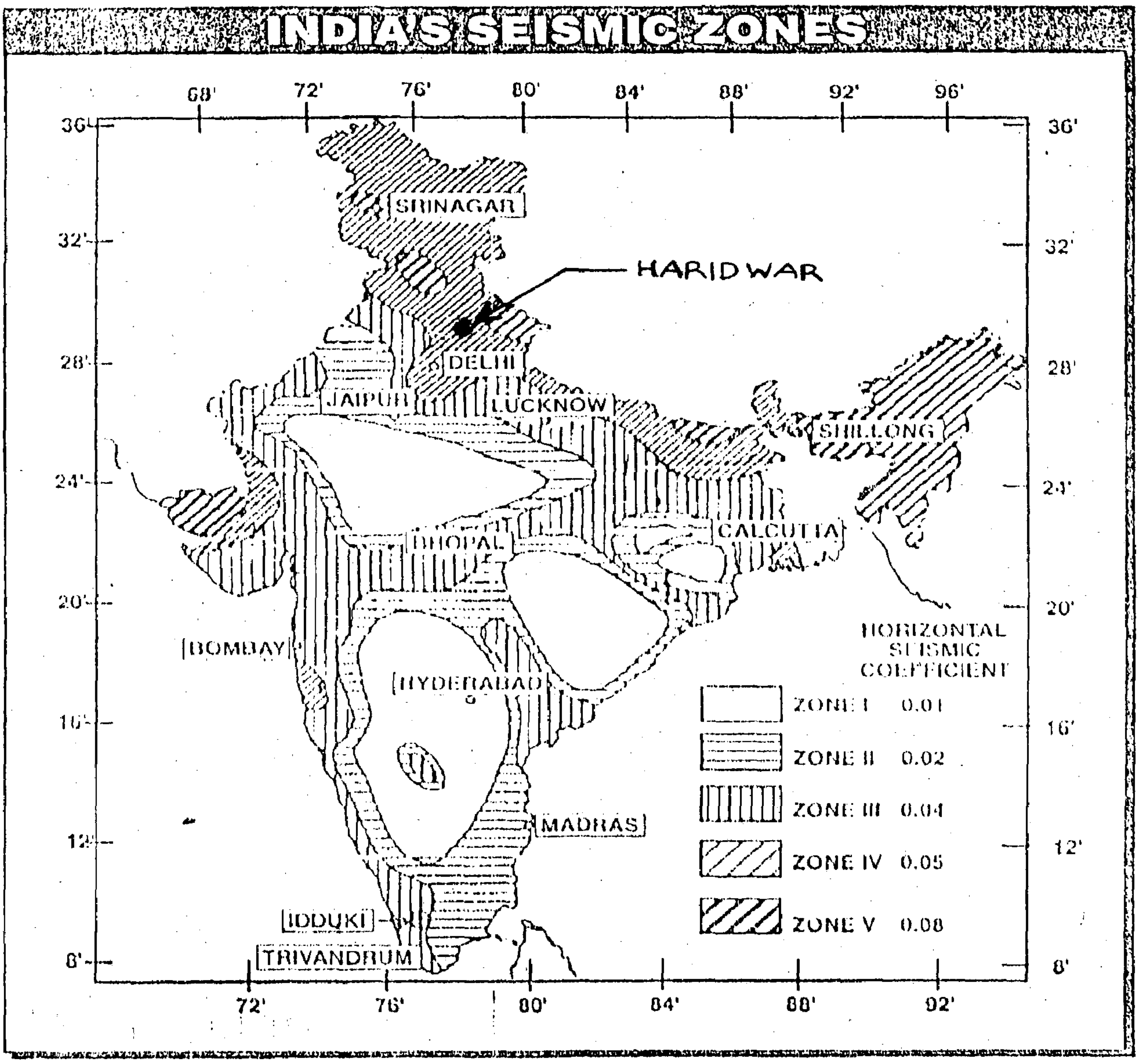
Haridwar is an important market (mandi) of the forest wood in western U.P.. It is situated on state Highway no.45. This state highway starting from Delhi, running through Meerut, Muzaffarnagar, Roorkee, Haridwar and Rishikesh goes upto Niti Pass on Indo - Tibetan border.

3.2 IMPORTANCE OF THE CITY

Haridwar is the nodal point connecting Delhi - Meerut, Saharanpur, Najibabad, Dehradun to the various small towns of the hills of western U.P. through state highway no. 45. The town is the business centre for the entire Haridwar district and provides regional services to the adjoining areas.

The town has greater importance from the point of view of National security because it is the terminal railway station linking the plains of U.P. and Delhi to the various defence Stations along Indo - Tibetan border. From here, the other towns of western U.P. hills are connected only through road viz. State Highway 45. Therefore from security point of view the importance of the town can not be overlooked.

The country has been classified into five Seismic Zones; zone I, zone II, zone III, zone IV and zone V, based on their vulnerability to earthquakes. Zone V includes some parts of Jammu and Kashmir, Himachal Pradesh and the entire North - Eastern India.



- SEISMIC ZONING MAP OF INDIA -

Zone IV being the second most potential zone includes rest of J & K , H. P. and parts of Punjab, Uttar Pradesh and Delhi. Haridwar falls under zone IV, as shown in the seismic zoning map of India.

The importance of the town is significant from religious point of view also. It is the place for the famous Kumbh Fair. People come from all over the country ~~and from foreign countries also to take holy dip at Har~~ - Ki - Pauri, one of the most sacred bathing ghat of India.

3.3 GEOGRAPHICAL LOCATION

Haridwar is situated on the right bank of River Ganga at the foot of Shiwalik hills at 29 deg. 58 minutes North longitude and 78 deg. 10 minutes East latitude, and from this vary town start the plains of U.P. in the Ganga River Valley. It is an important railway station of Northern Railway and is connected from all sides by rail and road routes.

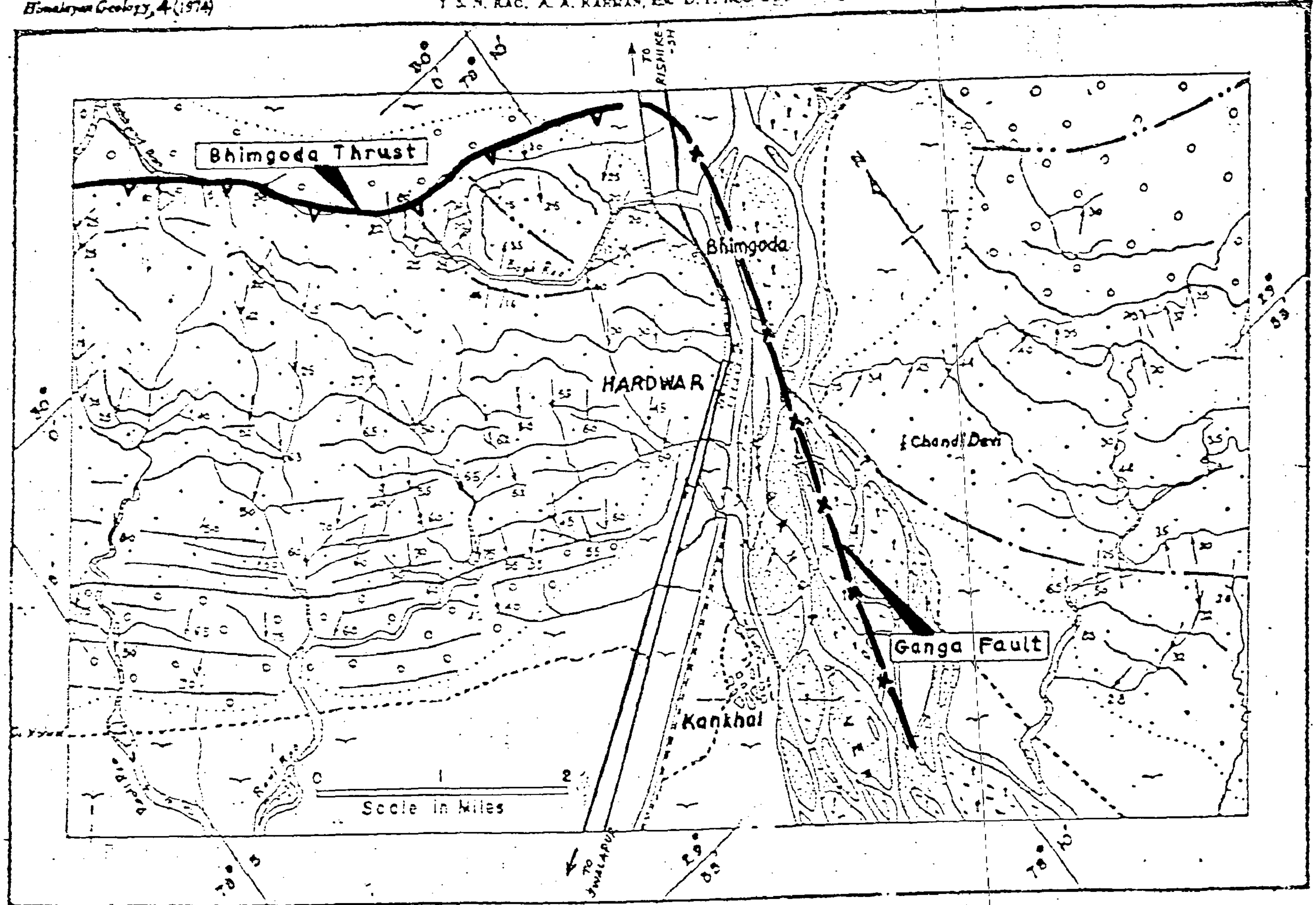
On the Geo-physical basis Haridwar is situated between River Ganga in the South and the Shiwalik hill range in the North and North- West. The climate of the town is same as that of plains of U.P. The average temperature varies from 1.3 deg. C. to 41.1 deg. C.. Average annual rainfall is of the order of 46.67 inches i.e. 118 cm. The average depth of water table is 25.35 feet.

3.4 GEOLOGY

North India is subjected to earthquake hazards because the Himalayas are the site of collision between the Indian and the Eurasion plate. Indian plate is moving towads North - North East at the rate of about five centimeters a year.

An uderground ridge of the Aravali and Vindhyan basement is extending and moving below the Garhwal Himalayas. Slope failure at Mansa Devi in Haridwar, straight course of Ganga along tear fault at haridwar, subsidence and landslides of other Garhwal Himalayan valleys, enhanced activity of minor and major earthquakes in Lower Himalayan range, all point towards this movement of basement.

Haridwar is situated on the North - North East ride, the Delhi - Haridwar - Harsil (DHH) ridge due to which Ganga takes up an easterly course near



LEGEND

Recent Alluvial Deposits	Limit of Recent Alluvial Deposits
Upper Siwalik	Dip of Strata
Middle Siwalik	Thrust
Stratigraphic Boundary	Thrust (Position Approximate)
Horizon Traced on Aerial Photographs	Fault
Wrench Fault (Position Approximate)	Anticlinal Axis
Anticlinal Axis (Position Approximate)	Synclinal Axis

… Geological map of Hardwar area …

Muzaffarnagar. This ridge is about 2 to 3 km below ground surface at Haridwar while it gradually descends further on going towards north. Adjustments below the surface have led to wide ranging changes in the landscape above Delhi - Haridwar - Harsil ridge in a narrow linear strip of 10 to 12 km width treading North - North East : South - South West.

The middle shiwalik rocks are comprising of thickly bedded sandstones with minor bands of clayey stone and silt stone. Beds dip into the hillock on both the banks of River Ganga forming a sort of an anticline, so there is no problem of landsliding in this area. (personal communication: Dr. R. Anabalagan, Dept. of Earth Sciences, U.O.R.).

Haridwar is situated on the bank of river Ganga and lies in the uppermost part of the plains of Ganga River basin. The soil in this region is coarse sand mixed with gravels, so there is almost no potential of liquefaction of soil during dynamic loading resulting form an earthquake. (Personal communication: Prof. Ramesh Chandra, Dept. of Earth Sciences, U.O.R.).

The whole town lies very close to the Ganga fault which runs along the Ganga river bed in the Haridwar reach and taking westerly turn towards north passes through the town near Bhimgoda to meet the Bhimgoda Thrust which lies in the Shiwalik hills. This is a sub - surface fault. Studies have yet not revealed whether it is an active fault or not.

Dr. K.N. Khattri, a seismic expert at Roorkee University, in a recent scientific study published in current science, a journal of the Indian Academy of Sciences, Banglore, predicted that the region between Haridwar and Delhi were among the most likely site for the next major earthquake.

3.5 DEMOGRAPHIC PROFILE

Like most other Indian towns Haridwar too has undergone rapid increase in populaion and urbanization. Till 1986 when 'Haridwar Development Area' was not declared the development of the town took place in an unorganised manner. Being religious place situated at the bank of river Ganga and surrounded by natural beauty, the floating population which the town attracts in the form of tourists and pilgrims has also gone up, besides increase in the native population of the town.

On any festival the town sees a large influx of devotees, so the town faces problems somewhat different from those with other cities.

Haridwar is the fifth most populated city of Meerut region. Since last three decades the twon has seen tremendous increase in the population growth. The comparative figures of the other important towns of Meeurt region are shown in table 3.1.

The percentage rate of increase during 1971-81 was 45.71 % and the population of the town increased by over 36,000 during this decade. In 1981 the population of the town was over one lakh and in 1991 it crossed the mark of 1.5 lakh.

The reason for extraordinary increase in population during 1941-51 may be the division of India during which many refugees might have settled here. But since 1961 the town has undergone rapid population growth basically due to development of economic activities in the town. The decadal increase in population is shown in table 3.2.

considering the rate of urbanization and the growth of population in rural areas falling under the Haridwar Development Area and the growth potential of the town, the projected population of the town for the year 2001 is:

Year	Population of the town	Population of Haridwar Development Area
1981	1,15,513	1,71,479
1991	1,58,182	2,38,360
2001	2,13,704	3,06,514

It is clear from the table that the population of the town will exceed Two Lakh mark by 2001.

Table 3.1

RATE OF POPULATION GROWTH OF MAJOR TOWNS OF MEERUT REGION (1951 - 81)

S. NO.	TOWN	POPULATION	% GROWTH RATE 1951-61	1961-71	1971-81
1.	Meerut	5,38,461	23.14	29.49	46.42
2.	Saharanpur	2,94,361	-24.78	21.70	-30.61
3.	Gaziabad	2,91,955	60.00	81.29	128.62
4.	Muzaffarnagar	1,72,435	36.52	30.94	33.43
5.	Haridwar	1,15,513	4.57	32.22	45.71
6.	Bulandshahar	1,03,666	17.80	37.70	74.21
7.	Hapur	1,03,466	12.16	28.99	45.18
8.	Roorkee	79,145	72.25	36.36	26.72

Source : Census, 1981

Table 3.2

RATE OF POPULATION GROWTH OF HARIDWAR TOWN

YEAR	POPULATION	DECADAL INCREASE	% INCREASE
1941	40,823	-	-
1951	57,338	16,515	40.46
1961	59,960	2,622	4.57
1971	79,277	19,317	32.22
1981	1,15,513	36,236	45.71

Source : Town Directory, 1981.

3.6 IMPACT OF FLOATING POPULATION

Due to large floating population, the planning strategies for various infrastructure facilities to be provided in the town are modified. The city is the centre for Kumbh Fair. Hence for such a large event when tens of thousands of people come and stay here for a couple of days, temporary provision for various infrastructure services viz - bridges over the river, temporary water supply and temporary sewerage system; has to be made. This should be considered as an integral part of the planning process for these utility services for the general conditions, because at that time the temporary provsions will depend heavily upon the already existing facilities.

At the time of fair to facilitate smooth movement of people across the river a number of temporary bridges are made. These temporary bridges should be so designed as to resist earthquake forces of certain maginitude. This is must in view of the possibility of a large number of casualities, in case an earthquake occurs during the fair, and the bridges collapse.

Water storage and treatment facilities have to be designed accordingly to provide enough water during these days also. Similarly sewage treatment plants are designed for such capacity as to take the load of the increased flow. These should be made earthquake resistant and should be located in such a way that if these get damaged during an earthquake, the flow of water or sewage is not towards the inhabited area because during fair the population density is very high and even small damage can result in great secondary losses.

To accomodate this vast floating population considerable area has to be kept open within and around the town to provide temporary shelter camps for this population. These areas should be away from the hazard zones like faults, zones of land sliding, zones susceptible to flooding etc.

3.7 LAND USE PATTERN

In view of present development the land can mainly be divided into two parts - Developed area and Undeveloped area. Developed area means that land which is under urban land - use. Undeveloped area includes open vacant fields, ponds, and agricultural land. Around 45 percent of the total land of the town is undeveloped.

On the basis of development the town can be divided mainly into three parts : -

- Haridwar City
- Kankhal , and
- Jwalapur City

It is generally seen that the problems of mixed land - use are more and in the lack of planning whatever development has taken place, has been without any effective control on the land - use. As a result of this the physical development of the town has become a complex of unplanned and mixed land - uses. At one place and in the same building many activities can be seen. Trade, industrial and public land - uses are closely intermixed with the residential land uses. So it is difficult to decide the areas under various types of land - uses but on the basis of survey conducted the approximate areas can be assumed as shown in table 3.3.

Table 3.3

CLASSIFICATION OF LAND - USES IN HARIDWAR TOWN AREA

S. NO.	LAND-USE	AREA (Acres)	% (of total area)	% (of developed area)
	(a) DEVELOPED AREA			
1.	Residential	627.89	21.4	38.7
2.	commercial	30.58	1.0	1.9
3.	Industrial	148.55	5.1	9.2
4.	Community facilities	148.76	5.1	9.2
5.	Transportation & Circulation	105.78	3.6	6.5
6.	Government & Semi-Govt. Offices	33.68	1.1	2.1
7.	Religious	242.98	8.3	15.0
8.	Camping	277.48	9.5	17.1
9.	Tourism	4.95	0.2	0.3
	Sum	1620.65	55.3	100.0

(b) UNDEVELOPED AREA

10.	Open Area	468.18	16.0
11.	Garden	252.69	8.6
12.	Agriculture	315.74	10.8
13.	Forest	42.35	1.4
14.	Pond & River	232.23	7.9
	Sum	1311.19	44.7
	Sum Total	2931.84	100.0

i. RESIDENTIAL: Densely populated residential areas are in the old part of the town. Narrow roads, lack of sanitation and open spaces are the characteristics of this area. Generally there is mixed land - use.

ii. COMMERCIAL: The development of commercial activities has been along the roads and in an unplanned way. In Jwalapur, there is wholesale commercial centre. Commercial area being surrounded on all four sides by other land- uses, the development of this area has become limited. As a result of this encroachment on the roads has become a problem.

iii. INDUSTRIAL: Large and medium scale industries are established mainly in the industrial area of U.P.S.I.D.C. Many small industries are mixed up with residential and commercial land-use.

iv. COMMUNITY FACILITIES: Most of the area covered under this head is under educational and health facilities.

v. TRANSPORTATION AND CIRCULATION: This includes area under roads, railways, bus stand and railway station.

vi. GOVERNMENT AND SEMI - GOVERNMENT OFFICES: Under this head administrative office, courts, police station etc. are included. These are located mainly in Devpura, Jwalapur and towards Bilkeshwar Temple.

vii. RELIGIOUS: Due to religious importance of the town there are many ashrams, dharamshalas etc. Mainly these facilities are present from Devpura to Bhimgoda.

viii. CAMPING: This area is used for the stay of visitors mainly during kumbh fair. For rest of the time this is used as open space.

ix. TOURISM: Here the inflow of tourists is very large but for them only one Tourist Bungalow is there.

CHAPTER : FOUR

EXISTING INFRASTRUCTURE -SERVICES IN HARIDWAR

CHAPTER-4

EXISTING INFRASTRUCTURE SERVICES IN HARIDWAR

4.1 ROAD NETWORK

The development of any town depends heavily upon the road network and the transport facilities available in that town. Not only the physical development but also the social and economic activities of the town are affected by the available road network and transport facilities. Due to the development of town in an unplanned and unphased way most of the roads in Haridwar are narrow and are not sufficient to sustain the present traffic load.

4.1.1 Existing Intra-City Road Network

The origin and development of a city is guided basically by the routes connecting it to other towns and cities. The road connecting two cities with each other is called intra-city road and the roads connecting various parts of a city are called as inter-city roads. The inter - city road network of a town depends upon the intra-city road network, physical characteristics of the town like topography and the availability of various resources.

Haridwar is situated on the State Highway no. 45 which links Haridwar with Delhi, Meerut, Roorkee and Rishikesh. This is the most important intra-city link of Haridwar becuase this not only links Haridwar with the capital, Delhi and other important towns of North India but also provides access to some strategically critical locations along the Indo-Tibetan border. Therefore, the uninterrupted functioning of this route in any condition is highly important.

This state Highway no. 45 passes through very conjestedly developed parts of the town, and moreover, this is the most busy route of this region. The problem has arisen becuase of unplanned and unchecked development along this route.

Besides this, there are two more intra-city road links which connect Haridwar with other cities. These are-

1. Najibabad Road - This connects the town with Bijnor and Najibabad.

2. Laksar Road - This connects the town with Laksar.

Laksar road is also a busy road and passes through densely populated areas of Haridwar. The trade units of the town are centred along this road and the state Highway causing inconvenience to the flow of traffic.

Therefore, Haridwar is well connected by roads with other important cities of North India. The town is also connected to these cities by rail route.

4.1.2 Existing Inter-City Road Network

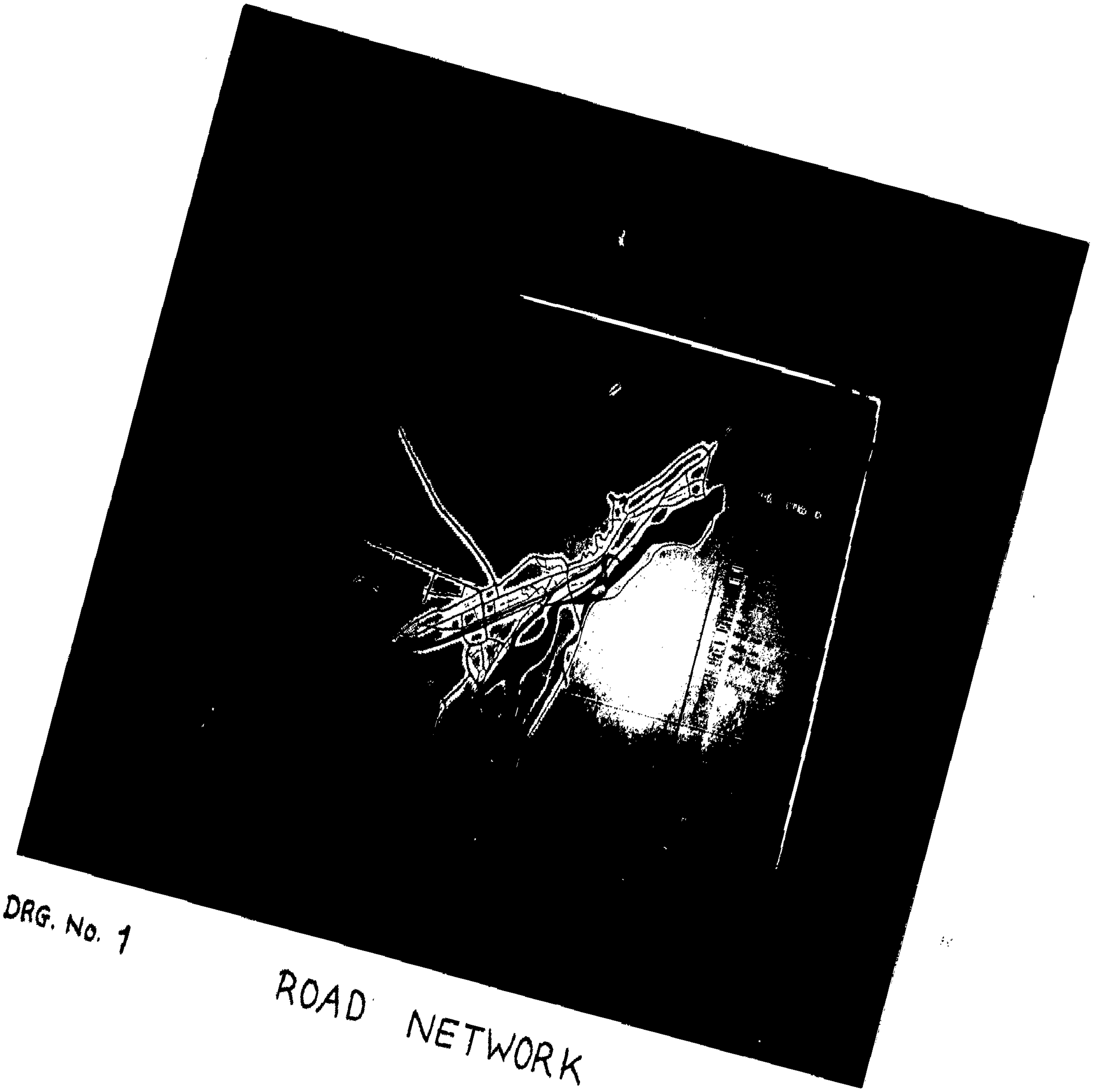
For Haridwar, the inter-city road network has been guided more by the physical characteristics of the area than by the intra-city road network. Due to river Ganga on one side and the Shiwalik mountains on the other side the development of the town has taken place in a linear fashion. The development of the town has been mainly along the state Highway 45 in both directions i.e. towards Roorkee and towards Rishikesh. Due to availability of transport means and the land in Roorkee direction the future physical development of the town is expected along this route.

Due to rapid development of the town most of the city roads are very narrow with buildings on both sides of the road. Due to lack of planning and building

Table 4.1

MAJOR INTRA-CITY ROADS OF HARIDWAR

	Road	Connecting city	Width (metre)
1.	SH 45	Delhi, Rishikesh	60
2.	Najibabad Road	Najibabad, Bijnor	30
3.	Laksar Road	Laksar	45



DRG. No. 1

ROAD NETWORK

regulations vertical development has also taken place even in the most conjested and densely populated areas like along the road leading to Har-Ki-Pauri. Near Har-Ki-Pauri area the width of the available land is limited with river on one side and hills on the other. With the increase in through traffic need for an alternate route was felt and another road was constructed, to bye-pass this conjested area, passing through Rori-bel-wala and Pant-dweep. Another road bye-passing this area is there along the hills and is known as hill bye-pass but this road is very narrow and zig-zag.

Further development of the town is taking place between the bus stand and Jwalapur along the Jwalapur road, which is straight road connecting Bus Stand to Jwalapur.

Kankhal is one of the important parts of the town and inhibits a considerable part of the population but here the density of population is low as compared to that of the old part of the town and Jwalapur. This is a triangular shaped area with river Ganga and the Ganga Canal forming boundaries on two of its sides. It is like a satellite for the town Haridwar. The road network, here, is in a better shape and the roads are quite wide.

As there is no separate Taxi-stand, these are parked along the road in front of bus stand, further reducing the capacity of the road. The encroachment by shopkeepers and temporary hawkers also results in obstruction to the flow of traffic leading to conjestion.

4.2 WATER SUPPLY NETWORK

Water supply is one of the crucial items of the infrastructure required for urban development. Without guaranteed supply of safe water large scale urban development can not be successfully planned. There are various uses of water such as for domestic, industrial, mining and irrigation purposes. Urban water supply generally caters to the domestic and industrial needs. Therefore, while planning for any city or town, it is necessary to have long range plan of water supply for industry and domestic consumption to expect continued and systematic growth of towns and cities.

A water supply network includes sources of water, storage facilities and the distribution network. Haridwar is having a well functioning water supply network spread over the entire town. There is no scarcity or problem in the supply of safe potable water to any section of the vast spread population.

4.2.1 Present Status of Sources

Haridwar is situated on the bank of river Ganga, the second largest river of India, in the upper Indo-Gangetic plains. River Ganga is a perennial river having good quantity of flow even during dry weather. However, for the water supply of the town, the water is not tapped from the river. Instead, the ground water table being at a small depth of about 25 feet, the water is taken from the ground water reservoir and the river water is let to flow unchanged for the downstream towns and villages for domestic, industrial and irrigation purposes.

For continuous and efficient supply of water the town is divided into 14 sectors. Water from the ground reservoir is taken out through tube wells and infiltration wells. In Jwalapur open wells are also used. Depending upon the need of water, each sector has been provided a number of wells and storage facilities in the form of over head tanks. Due to topographical and land use pattern some sectors depend partly or completely upon nearby sectors.

TABLE-4.2

INFORMATION ABOUT WATER SUPPLY

i.	Number of sector	14
ii.	No. of tube wells/infiltration wells/open wells	30
iii.	Present per day water supply	60 Lakh Gallons or 28 MLD
~~iv.~~	~~Present per capita water supply~~	~~45 GPCD or 205 LPCD~~
v.	Standard per capita water supply	270 LPCD
vi.	In 2001, Required per day water supply	138 Lakh Gallons or 63 MLD.
	Requiring additional 10 Tubewells and 5 over head tanks with 2 Lakh Gallons capacity each.	

SOURCE: MASTER PLAN, HARIDWAR (1985-2001)

MLD - Million litres per day.

GPCD - Gallons per capita per day.

LPCD - Litres per capita per day.

Table - 4.3

DETAILS OF WATER SUPPLY SOURCES

Sector No.	Name of sector	Sources of water supply
1.	JWALAPUR	T.W.-1
		T.W.-2
		T.W.-3
		T.W.-4
		T.W.-5
		T.W.-6
		T.W.-7
		T.W.-8
		O.W.-1
		O.W.- 2
		O.W.- 3
2.	MAYAPUR	T.W.- 9
		T.W.- 10
		T.W.- 11
3.	KANKHAL	T.W.- 12
		T.W.- 13
		Partly from JWALAPUR and BAIRAGI CAMP

(Contd.)

4.	BAIRAGI CAMP	I.W.-1
5.	GAURI SHANKAR DWEEP	S.W.-3 Nos.
6.	CHANDI DWEEP	T.I.W.-2
7.	RORI-BEL-WALA	I.W.-3
		I.W.-3
		I.W.-4
		I.W.-5
		I.W.-6
		I.W.-7
8.	HARIDWAR	From RORI-BEL-WALA
		I.W.-4
		I.W.-5
		I.W.-6
		I.W.-7
		From PANT DWEEP
		I.W.-8
9.	HAR-KI-PAURI	From PANT-DWEEP
		I.W.-8
		From RORI-BEL-WALA
		I.W.-5
		I.W.-6
		I.W.-7

(Contd.)

10.	PANT DWEEP	I.W.-8 I.W.-9
11.	LAL-JI-WALA	From PANT DWEEP I.W.-8
12.	BHOPATWALA	I.W.-10 I.W.-11 I.W.-12 I.W.-13 I.W.-14
13.	BHIMGODA	From BHOPATWALA I.W.-10 I.W.-11
14.	MOTICHUR	From BHOPATWALA I.W.-13 I.W.-14

Total No. of O.W.=3

Total No. of T.W.=13

Total No. of I.W.=14, of which I.W.-2,9,12 are temporary

O.W.-OPEN WELL

T.W.-TUBE WELL

I.W.-INFILTRATION WELL

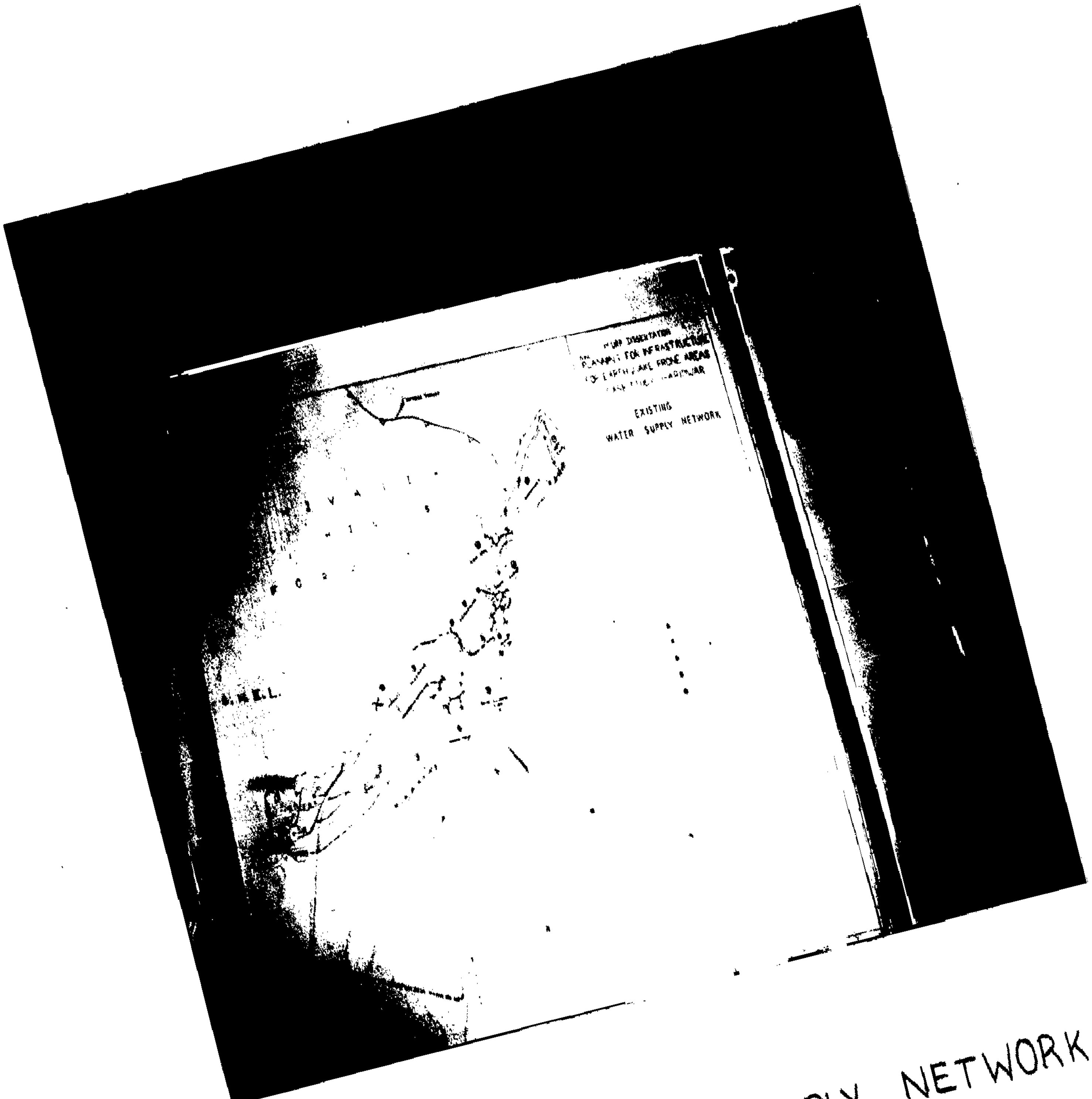
SOURCE: U.P. Jal Nigam, Haridwar

In all, there are three open wells, all in Jwalapur; 13 tube wells and 14 infiltration wells. Sectorwise distribution of sources is presented in table 4.3.

The present sources provide around 60 Lakh Gallons of water per day, which is sufficient to fulfill the domestic and industrial needs of the town. With the increasing population the demand for water is bound to increase. On the basis of 45 GPCD for 3,06,514 population in the year 2001, 138 Lakh Gallons of water ~~will be required. At present total supply is~~ 60 Lakh Gallons. Therefore for the year 2001, 78 Lakh Gallons additional water will be required. To fulfill this need 10 more tube wells and 5 more storage tanks with a capacity of 2 lakh Gallons each will be required. It is assumed that industrial units will have their own sources of water supply.

4.2.2 Existing Water Supply System

As in most of the cities, here also the water is supplied under gravity force. Water is pumped from tube wells or infiltration wells to storage tanks (elevated or over head tanks, as are popularly known), from where it is supplied under gravitational force through a



DRG. No. 2

EXISTING WATER SUPPLY NETWORK

network of distribution pipes which are generally laid below ground surface along the roads.

Taking into consideration the uneven topography of the area, the town is divided into sectors which have more or less complete water supply network within themselves i.e. they have sources, storage facilities and distribution network and at the same time are also connected with adjoining sectors. The storage tanks or reservoivs are located at relatively higher elevation than the supply area to take advantage of the additional head available due to natural topography. Due to good distribution of storage tanks pressure is maintained even at remote sections.

Every part of the city is covered under the water supply network and at present the water supply in the town is satisfactory. The per capita availability of water is 45 Gallons per day i.e. 205 LPCD, which is quite comparable to that in other Indian towns [Ref. Appendix B] and also to the standard of 270 LPCD.

Haridwar (Sector 8) and Bhimgoda (Sector 13) being situated at the foot of Shiwalik hills and the ground water table being at a larger depth, do not have any source within themselves and depend upon the supply from Rori-bel-wala (Sector 7) and Bhopatwala (Sector 12) respectively. Similarly Har-Ki-Pauri (Sector 9) depends upon Rori-bel-wala (Sector 7) and Pant-dweep (Sector 10).

Disposal of sewage is as important as the supply of water. Preferably it should be in closed conduits to avoid nuisance. Stagnation of sewage after a certain period can result in serious health hazards, so safe and timely removal of sewage is necessary to maintain the aesthetics of the area.

4.3 SEWERAGE NETWORK

Sewerage Network consists of sewers for the proper collection of sewage from residential areas, pumping stations to maintain flow at inadequate gradients, sewage treatment plants for the treatment of raw sewage before its disposal and the source into which the sewage is disposed off safely without causing any nuisance.

4.3.1 Existing Sewerage System

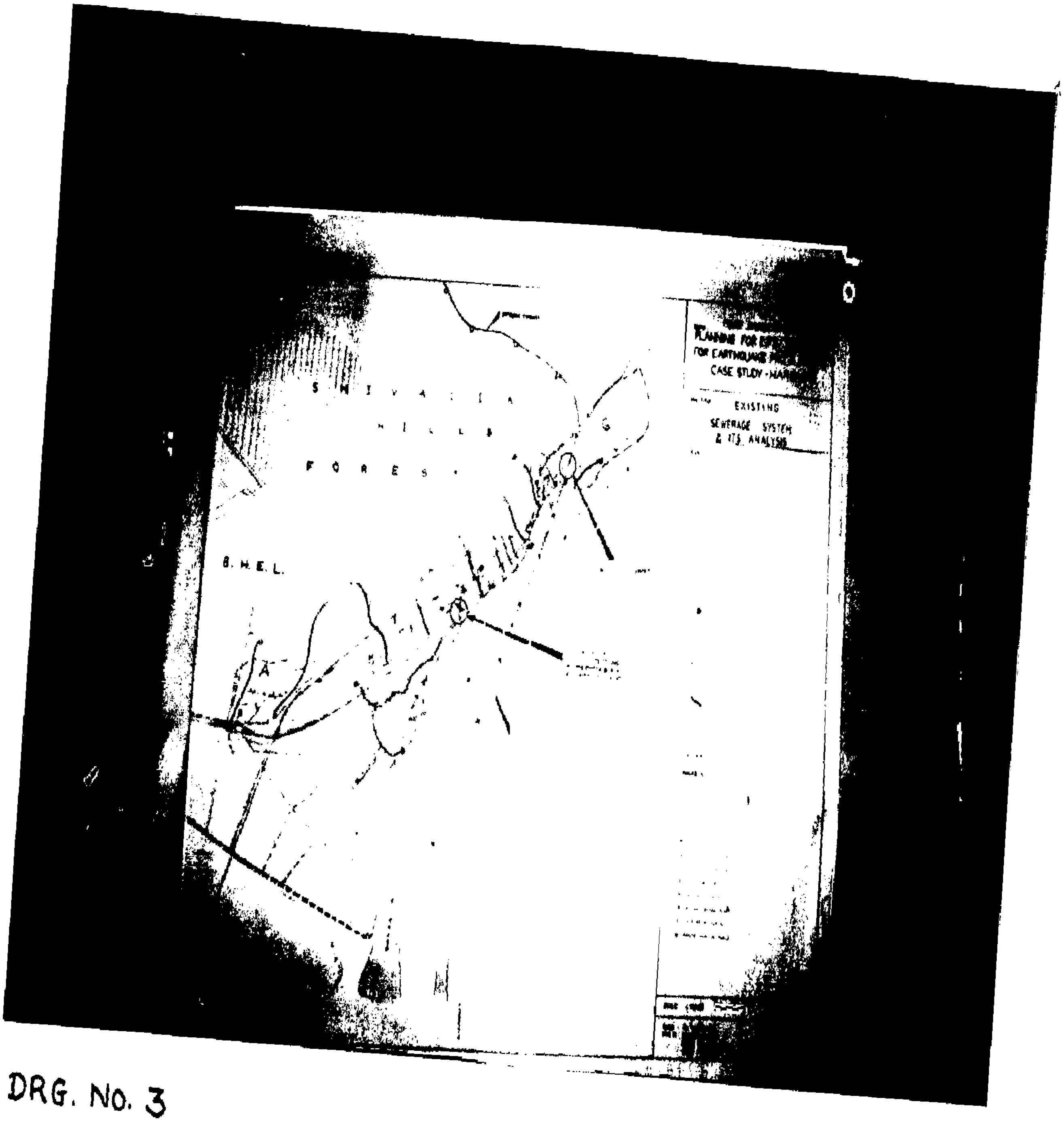
In most part of the town sewer system is there. For proper functioning of the system the town has been divided into 8 zones viz-A,B,C,D,E,F,G, and H, as shown in the Drawing . The existing sewerage system consists of one main outfall gravity sewer running through zone H. Other intercepting sewers and laterals serving the thickly populated areas of other zones join this main sewer at appropriate places. All the sewage of the entire town is taken through this main sewer to the sewage treatment plant at the village Jagjitpur near Kankhal, from where the treated sewage is disposed off in the sewage farm.

The existing sewerage system is not complete. In some areas even though the sewer exists, the branch sewers are absent with the result that a large amount of sewage and sullage is being carried through road side drains and Nalas. In the zones A,B and C the sewer system is inadequate and the sewers are provided only along main roads.

The sewerage system in the town is being looked after by the Ganga Pollution Control Unit, a unit of Jal Nigam. It took charge before the Ardh Kumbh fair of 1992. Earlier, the 12 Nalas which are present in the town, were discharging into the river Ganga, contributing a lot of pollution to the river. The most important work of this unit has been the tapping of these Nalas and connecting them to the sewer system, thus preventing the river Ganga from pollution because some of these Nalas were carrying sewage also alongwith the sullage and storm water.

Due to topography of the area, gravity flow can not be maintained at some places and pumping of sewage is required. To facilitate continuous flow of sewage there are 9 sewage pumping stations. These are shown in the Drawing. The sewage pumping station of zone B pumps the sewage of zone B across the Ganga Canal to zone A.

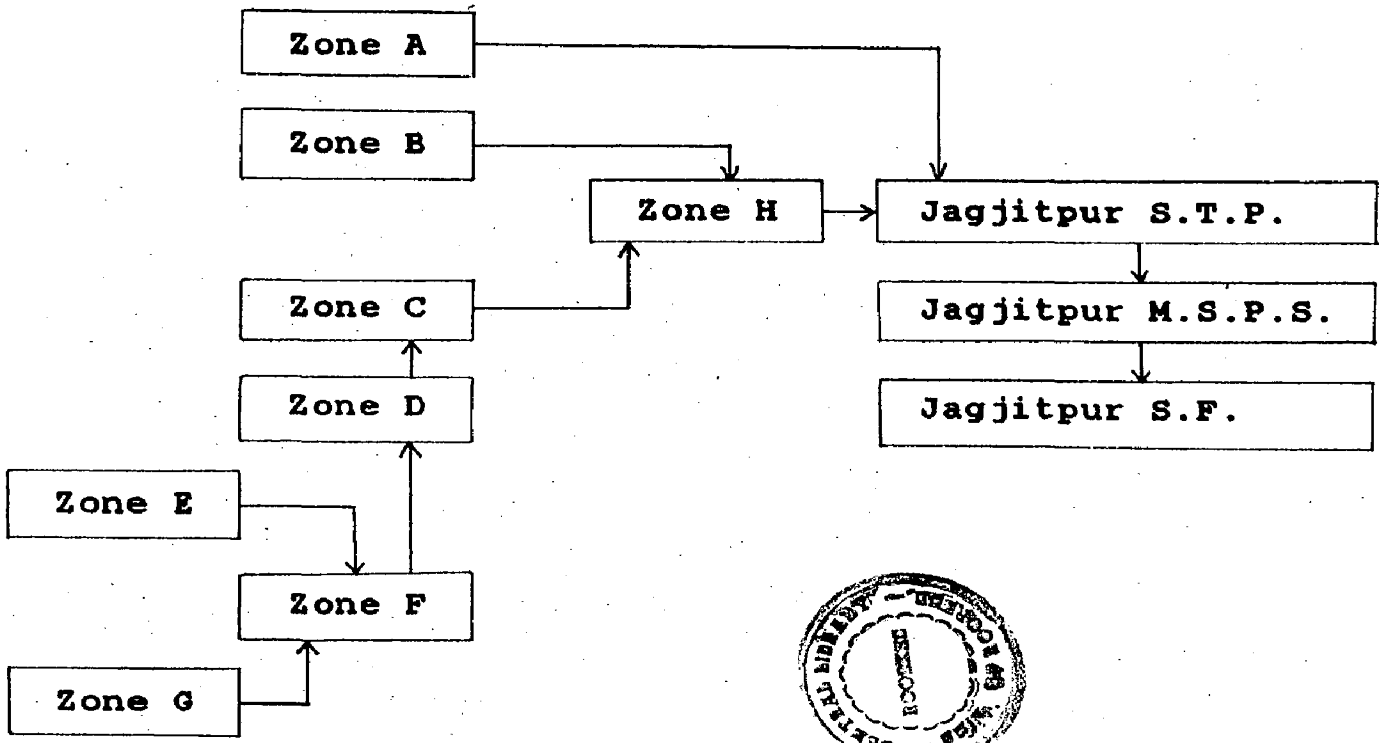
In the zone H gravity flow is maintained throughout. There is one Main Sewage Pumping Station (M.S.P.S.) at the sewage treatment plant.



DRG. NO. 3

EXISTING SEWERAGE SYSTEM
&
ITS ANALYSIS

Development of sewerage system:



S.T.P. - Sewage Treatment Plant

M.S.P.S.- Main Sewage Pumping Station

S.F. - Sewage Farm

4.3.2 Sewage Disposal System

The disposal of sewage does not mean only discharging it into a flowing stream of water or in an open field. It includes the treatment of sewage also before its discharging. The degree of treatment required to be provided to the sewage depends on the quality of sewage, type of the source into which the sewage is to be discharged i.e. whether in a stream of water or in the field and the condition of the source i.e. rate of flow of water and its condition before the discharge or the type of the soil.

In Haridwar there is only one sewage treatment plant at Jagjitpur at which the sewage of the entire Haridwar town is collected and treated. The treated sewage is pumped by the Main Sewage Pumping Station to the sewage farm.

In the monsoon season due to increased flow from Nalas the sewers at some sections overflow. This problem generally arises near rising mains because the pumping stations are not able to pump this increased flow. The capacity of some sewage pumping stations has been increased by providing additional units which can be operated during monsoon season. In this way the problem has to some extent been overcome. The work on increasing the capacity of rest of the stations is under progress.

CHAPTER : FIVE

ANALYSIS AND GUIDELINES

CHAPTER-5

ANALYSIS AND GUIDELINES

Earthquakes cause damage to buildings and various facilities due to ground shaking, ground deformations along zones of structural weaknesses and due to soil related problems.

The ground shaking is generally felt in a large area around the epicentre of the earthquake. The damage can be avoided by making the structures and facilities resistant to vibrations.

Zones of structural weaknesses like faults, thrust etc. are site specific and cause damage to structures laid across them or in the vicinity of it. To reduce the damage, these, at best, can be avoided or various undermentioned measures can be adopted.

Soil related problems can be on both levels - large areal extent or in a small area depending upon the soil type. These areas can be avoided or the strength of soil can be improved, if the problem is in a limited area because this is very costly.

Haridwar falls in zone IV of the seismic zoning map of India which is the second most potential zone for earthquakes. Also, as mentioned earlier, there is one fault, Ganga fault which passes through the town. But there is no problem of liquefaction of soil in this area. Problem of landsliding too is not there. So only the Ganga fault is posing threat to the various infrastructure services of the town.

5.1 ROAD NETWORK

5.1.1 Analysis and potential earthquake hazards

Due to physical barriers of the river Ganga on one side and hills on the other, the growth of the town has been in a linear shape. The state highway has been the basis for this trend. Till 1974 when a fault was traced by some scientists the area was supposed to be free from earthquake hazards but after that some geologic studies have been done in the region and Dr. K.N. Khattri has given his view that the region between Haridwar and Delhi along the DHH ridge is likely to experience a major earthquake.

Since last few years rapid development of Haridwar is taking place but no consideration has been made of the seismic effects.

There are two roads leading to Rishikesh but both of these cross the same Ganga fault and that too at a very small distance. Moreover one of these passes through the most conjested area of Har-Ki-Pauri. The width of this road is around 15 metres or even smaller at some places and 4-5 storeyed buildings are constructed on both sides of the road. In case a major or moderate earthquake hits in this region and the buildings collapse this road is very likely to be blocked by the debris. The other road constructed through Rori-bel-wala and Pant Dweep, a few years back also crosses the same Ganga fault. So the redundancy of this route should be increased by providing alternate routes.

Most of the roads of the town are narrow, especially in the densely populated areas. Some of these can be widened so that the interior areas can be approached in case of emergency.

The roads proposed in the Haridwar Master Plan, 1985-2001 are very good proposals considering the direction of growth of the town, which is between Jwalapur and Bahadarabad. These roads are forming closed loops combining the existing Roorkee-Haridwar road (SH-45) and the proposed parallel roads on both sides of the Ganga canal.

5.1.2 Guidelines and Proposals

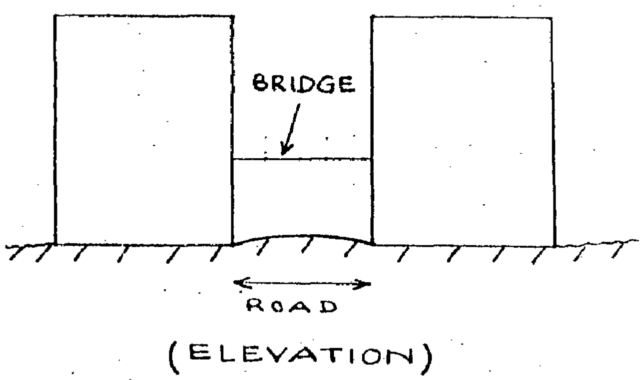
Guidelines

1. There should be redundancy in the road network i.e. there should not be dead ends and any area should have approach from atleast two roads.

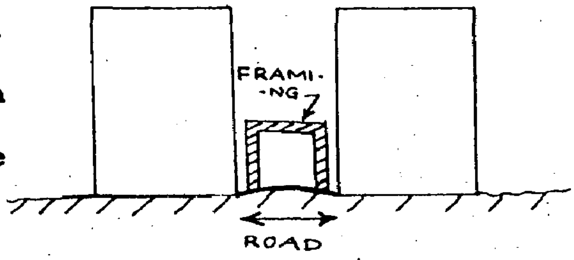
2. To provide redundancy alternate road or bridge should preferably not cross the same fault.

3. Width of a road should be atleast equal to the sum of the heights of the buildings on the two sides of it plus one lane width.

4. In already developed areas where multistoreyed buildings are close apart with a road between them, these can be connected by a bridge abutting the two buildings so that during ground shaking they act as one unit.



5. On narrow but important roads with buildings on both sides of it, framing on the road can be adopted as shown in the figure, so that the road is not blocked in case the buildings collapse towards the road.



6. Roads and bridges should, as far as possible, be avoided across or in the vicinity of a fault.

7. The most comprehensive earthquake resistant design criteria for transportation lifelines is that of the state of California, Department of Transportation (CALTRANS) for Highway bridges. The CALTRANS criteria require that all bridges shall be designed to resist earthquake motions by considering the relationship of the site to active faults, the seismic response of the soil at the site, and the dynamic response characteristics of the total bridge structure.

8. Failure or excessiue subsidence of backfill materials behind abutments being one of the most common seismic damage to bridges, the backfill material should be highly compacted through vibrators.

9. At bridges superstructure should be properly tied to the substructure i.e. piers, particularly at the sliding or roller end.

10. Segments of superstructure of a bridge should be properly tied together.

Proposals

1. To avoid the crossing of Ganga fault near Pant Dweep the proposed (as in Master Plan) bye-pass road on the south of Ganga canal should be connected to the Najibabad road.

   And the Chilla road should be connected to the Rishikesh road through the road at Motichur.

   This can be taken as a long term planning proposal because it requires two bridges over river Ganga.

2. The hill bye-pass near Bhimgoda should be connected to the Rishikesh road at Motichur by a road parallel to the railway line. Though this road will also cross the same Ganga fault but will immediately

provide an alternate route to the new state Highway road which crosses the Ganga fault at Pant Dweep and has three bridges very close to the fault.

The ablve two proposals are meant to increase the redundancy of the Haridwar-Rishikesh route avoiding the Ganga fault.

3. The proposed road (as in Master Plan) along the right bank of river Ganga should be further extended along the river bank and connected to the SH 45 near Dam Kothi.

4. The proposed straight road (as in Master Plan) from Sitapur to Laksar road should be further extended to connect it with the road proposed along the river bank.

5. In the west of Jwalapur the proposed road (as in Master Plan) along the north bank of Ganga Canal and its parallel road of B.H.E.L. should be joined by a cross road as shown in the Drawing.

6. The width of the hill bye pass should be inereased.

7. The width of the road through Kankhal should be increased to 30 M R/w from 20 M R/w.

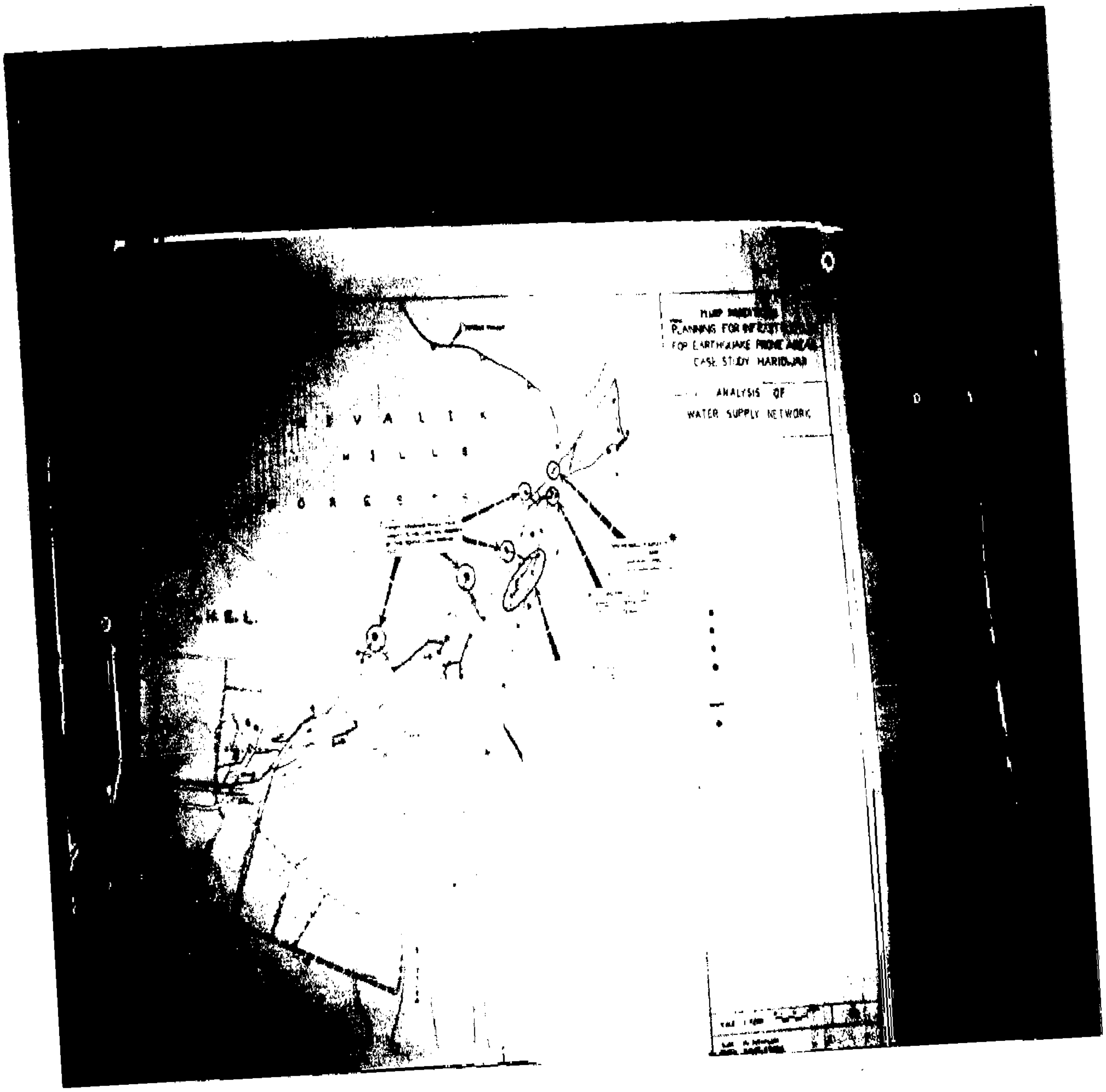
8. For all new construction building bye-laws should conform the heights of buildings along road side to such that the distance between them is more than the sum of their heights plus one lane width.

5.2 WATER SUPPLY NETWORK

5.2.1 Analysis and potential earthquake hazards

Water supply pipelines are generally laid buried under the ground surface and are mostly damaged by the liquefaction of soil. But the problem of soil liquefaction is not there in Haridwar.

Pipeline damage is also experienced at places where there pipelines cross an active fault. Though it is yet not known whether the Ganga fault at Haridwar is an active fault or not, but the water supply pipelines are crossing this fault and this is the most potential location for damage to these pipelines due to an earthquake. It is recommended and is the general practice to provide two or more pipelines instead of one at these locations. But in our case there are only two roads and on both these roads water supply pipelines are already provided. To prevent the suspension of the



DRG. NO. 4

ANALYSIS OF WATER SUPPLY NETWORK

system the two sides of the fault should have the provision for isolating them in case the pipeline is damaged at fault intersection.

One rising main connecting the I.W. 10 and I.W. 11 of Bhopatwala (sector 12) to storage tank of Bhimgoda (sector 13) is also crossing the Ganga fault. Some alternate arrangement should be provided for these I.W..

I.W. 5,6,7 of Rori-bel-wala (sector 7) are connected to the storage tank of Haridwar (sector 8) through I.W. 8 of Pant Dweep (sector 10). In case the main rising main fails all these four wells would become useless. Therefore, I.W. 5,6,7 should separately be also connected to the storage tank.

Besides due to failure at faults a large portion of the system may suffer due to failure or damage of pipeline at any other section. To improve the redundancy of the system small closed loops should be provided in the distribution network. There should be no dead end. Network redundancy is lacking in sector 1; between sector 1-sector 3 and sector 2-sector3. This redundancy needs to be improved by interconnecting the pipelines, within a secor and between two sectors so that if the system failure is there is one sector, water can be provided from other sector.

Another cause of water supply system failure is the failure of a water storage tank, which is generally an elevated or over head tank. This results in not only the suspension of the water supply but may also result in casualities due to fallen structure and the consequent flow of water. In earthquake prone areas at places where the potential for damage is high as in densely populated areas emergency blow off drain system should be provided at storage facilities.

In Haridwar there are 12 nalas, some of which are seasonal. These nalas which are close to water storage tanks can be used as emergency blow off drains.

5.2.2 Guidelines and Proposals

Guidelines

1. Faults; regions of loose soil, landsliding, liquefaction and abrupt changes in geology should be avoided whenever possible.

2. Utility supply system should have more than a single

source. In water supply system this can be achieved through the combined use of surface reservoirs and groundwater basins, multiple importation routes and interconnection with neighbouring water systems. If gravity water is not available, large emergency storage reservoirs may be necessary.

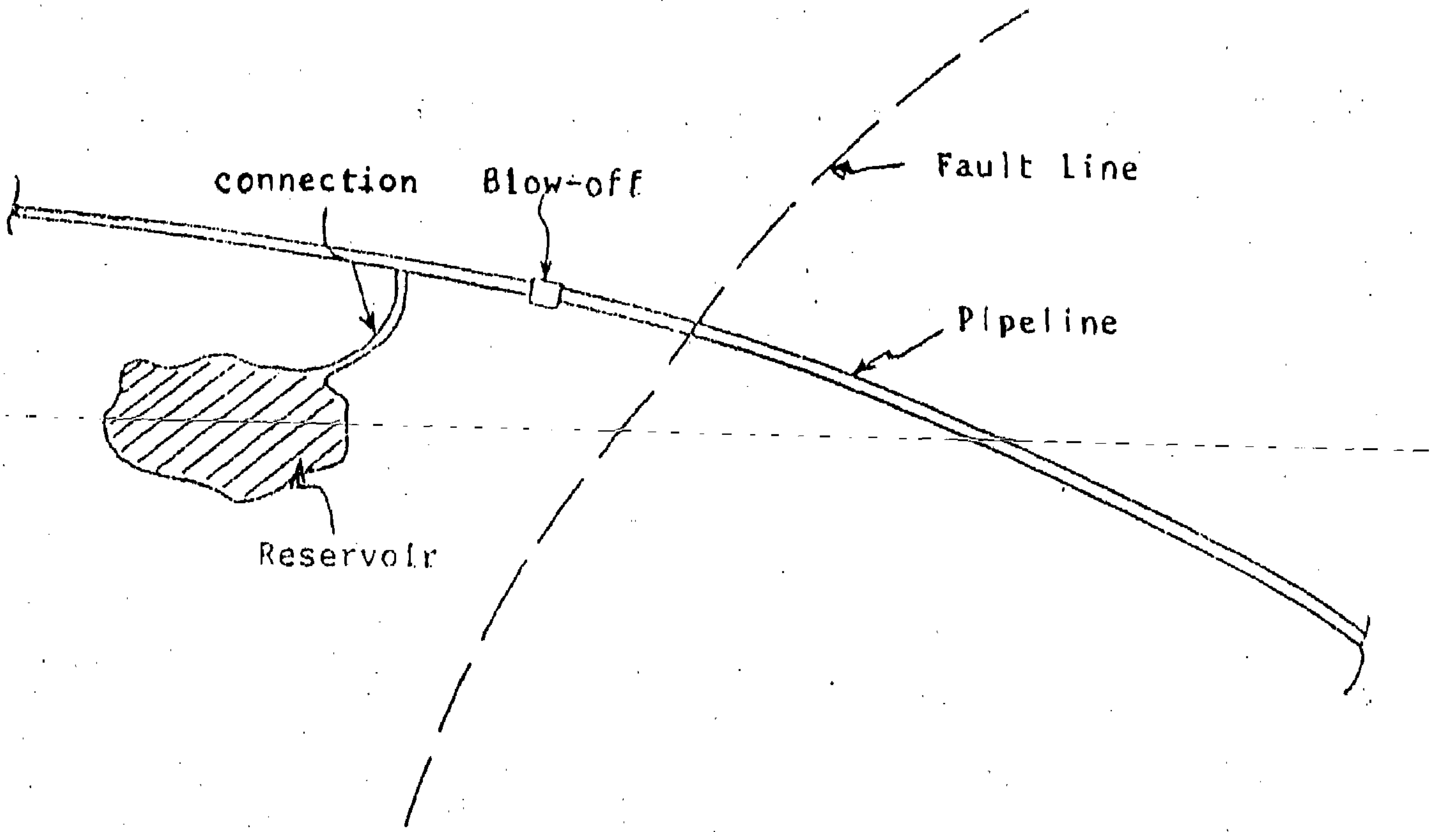
3. Redundancy in the system would help rerouting around damaged areas.

4. Water mains or major distribution pipelines should be interconnected to form closed loops to improve redundancy.

5. Isolation of the network into parts can be achieved through valves and gates. At fault crossing these gates should be closely spaced to facilitate isolation so that service can continue from storage upstream and downstream of the fault.

6. Provide emergency storage down stream from fault zones.

(City of San Francisco has an array of small underground reservoirs in its downstream area.)



Scheme For Pipeline Crossing
a Fault Line.

BLOW OFF VALVE SYSTEM

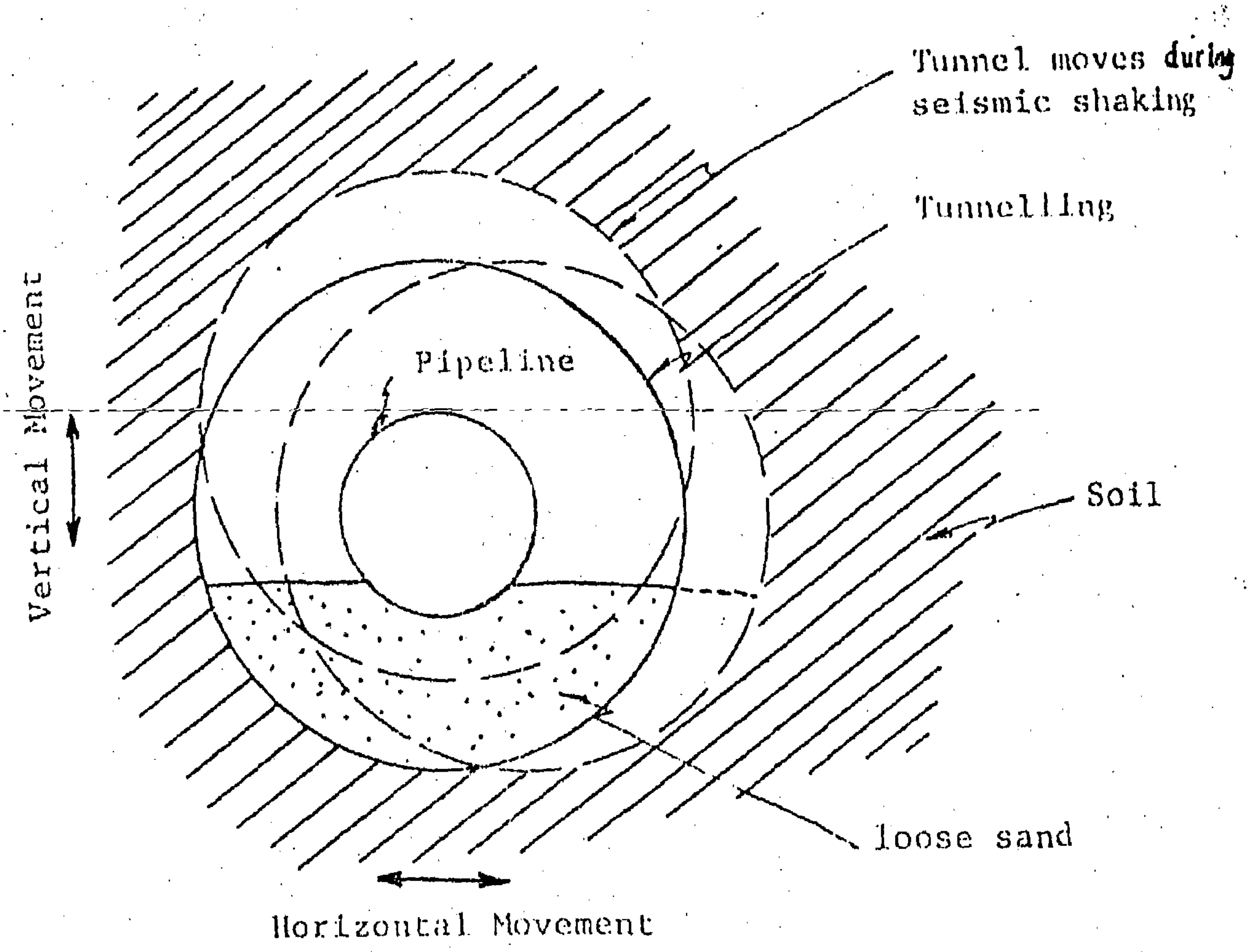
7. At fault crossing the pipeline should be laid at an angle of 70^{o} to 90^{o} to the fault line.

8. Installation of blow off valves near the fault line, where higher sesmic activity is anticipated, should be considered. In this system water is lead to a nearby reservoir after the blow off valve is automatically operated before the rupture of the pipeline at fault crossing during fault displacement.

9. The spacing between valves should be reduced in order to isolate potential breaks. Valves should, therefore, be installed on opposite sides of an active fault.

10. Anchors such as thrust blocks should be excluded within a distance of 400 ft. (preferably within a distance of 1000 ft.) of the fault crossing.

11. Casings or carrier pipes may be used to shelter the conduit where it traverses the fault in order to isolate the pipeline from seismic motion.

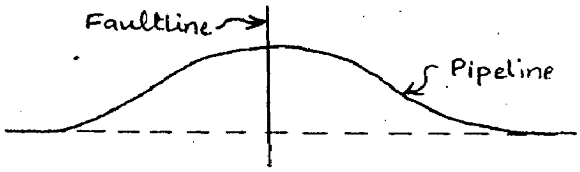


Encasement of a Pipeline
in a Large Tunnel

12. At fault crossing, backfill around the pipe with special material, capable of deforming without significant loss of strength, for example, plastic foams, light weight concretes made with expanded vermiculite aggregates.

13. Where possible, smaller pipes in parallel should be placed instead of a single large pipe. The redundancy thus provided will improve the chances of maintaining some flow even though some of the pipes are damaged.

14. At fault crossings, to provide larger movement capacity, pipelines with flexible or expansion joints should be provided in form of a smooth loop.



15. The fault movement capacity is maximized by minimizing the soil pipeline resistance, which can best be achieved by placing the pipeline aboveground and leaving the line relatively free to slide laterally, longitudinally and to uplift off of its supports. But these often may not be allowed in urban areas.

16. Substantial fault movement capacity of buried pipelines can be provided by shallow burial in a moderately low shear strength backfill so as to limit the longitudinal friction, lateral passive pressure and uplift resistance.

17. At fault crossings the system should be designed for easy and minimum repair. Provisions should be made for ready installation of temporary pipelines above ground, parallel to the damaged lines. Such provisions can be in the form of manholes, and isolating valves located at safe distances on each side of a fault known or suspected to be active.

18. It is also a planning objective to size the distribution reservoirs at two times maximum day demand in pumped zones and 1.5 times maximum day demand in gravity supply zones to sustain deliveries during emergencies.

19. Ductile pipes and flexible joints should be used.

20. Pipelines above ground are especially undersirable on steep slopes.

21. In areas of potential lateral spreading pipelines should be installed parallel to elevation contours and away from local depressions.

22. For pipelines crossing zones of potential liquefaction
    i. densification along the route of the pipeline: practically difficult and non-economical for large areas.
    ii. locate the pipeline aboveground or below the lowest depth of liquefiable soil.
    iii. aboveground pipelines be laid on effective strong supports.

23. Change in foundation material under a single structure should be avoided.

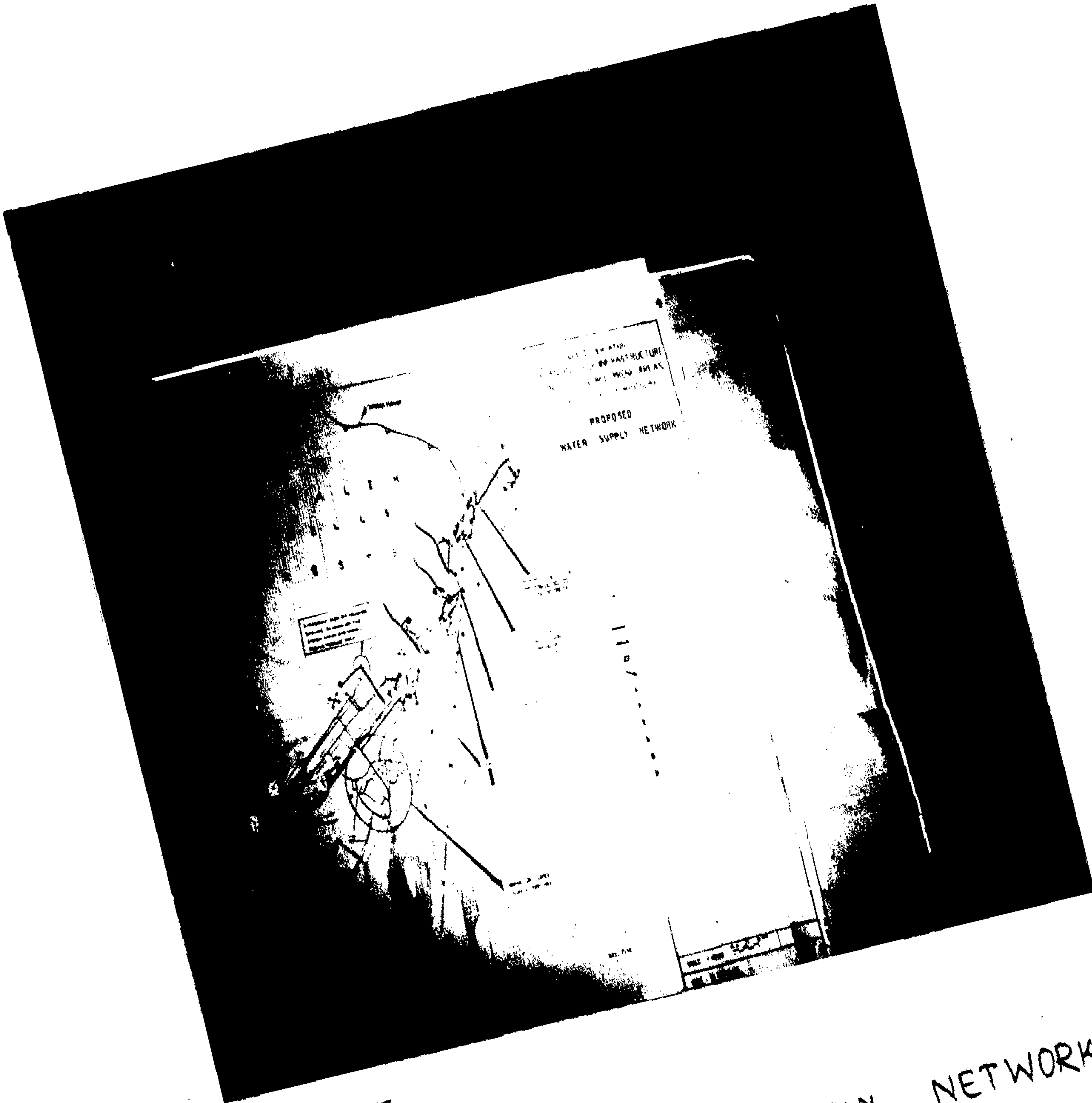
24. Locate the storage facilities as close as possible to the area where the water is to be used but outside the zone of possible deformation, since this reduces the likelihood of an outage between the storage facility and the distribution system.

25. Minimum distance between an elevated storage tank and the nearby structure (including pumping station)

should be at least equal to the sum of the heights of the two.

26. Provide an adequate spillway and emergency blow off drain system at each storage facility.

27. A chlorinated raw-water bye-pass should be installed at any urban water treatment plant as an important safeguard to assure continuity of supply for fire protection.



DRG. NO. 5

PROPOSED WATER SUPPLY NETWORK

6. Join the pipeline of Jwalapur (sector 1) with that of Kankhal (sector 3) through the bridge over Ganga canal and make a closed loop in Kankhal.

7. Provide an adequate spillway and emergency blow off drainage pipeline:

   i. from the storage tank above Mayapur (sector 2) to the Deopura Nala (9).

   ii. from storage tank of Bhimgoda (sector 13) to Bhimgoda Nala (2).

   iii. from storage tank of Haridwar (sector 8) to Kangri Mandir Nala (3).

   iv. from storage tank of Haridwar (sector 8) to Lalta Rao Nala (7).

   v. from storage tanks of Jwalapur (sector 1), which are close to Ganga canal, to the Ganga canal.

   vi. from storage tank of Kankhal (sector 3) to the river Ganga.

5.3 SEWERAGE NETWORK

5.3.1 Analysis and potential earthquake hazards

Like water supply pipelines sewage pipelines are also crossing the fault at two sections. For sewers,

Proposals

1. Provide blow off valves on both sides of the fault in the pipelines crossing the Ganga fault and the water can be taken to the dry section of the Ganga canal on the upstream of Har-Ki-Pauri.

2. Isolating valves can be provided to the pipelines on either side of the fault crossing.

3. A temporary tube well or infiltration well should be constructed on the Bhimgoda side of the fault to provide an alternate for the I.W. 10 and I.W. 11 which supply water to the storage tank from Bhopatwala side of the fault to Bhimgoda side of the fault with the rising main crossing the fault.

4. As an alternate route connect the I.W. 5,6,7 of Rori-bel-wala (sector 7) directly to the storage tank of Haridwar (sector 8) besides being connected via I.W. 8 of Pant Dweep (sector 10).

5. Make closed loops in Jwalapur (sector 1) by interconnecting the pipelines.

either these should avoid the fault crossing or isolation in the form of casing to the movements can be provided.

Another major problem of the sewerage system in Haridwar is that the whole sewage of zone C,D,E,F and G is pumped across the Ganga canal into the outfall gravity sewer running through Kankhal (zone H) by a single sewage pumping station at Dam Kothi. In case this pumping station fails or the rising main through which it pumps the sewage across Ganga canal fails, the whole sewage will get accumulated at this pumping station. So there should be some alternate arrangement for this.

5.3.2 Guidelines and Proposals

<u>Guidelines</u>

1. Water and sewage pipelines should be provided on either side of a road.

2. In parallel construction water lines be located atleast 10 ft. (3 metre) horizontally away from and at a higher elevation than sewers.

3. At crossings the water mains be located a minimum distance above the sewer.

4. Sewerage system and the sewers should be flexible.

5. Regarding the post earthquake contamination of water well, all septic tanks and cesspools within a specified distance from a water well should be abondoned, cleaned and backfilled when other methods of sewage disposal are available. A well should be abondoned if no other source of disposal is available.

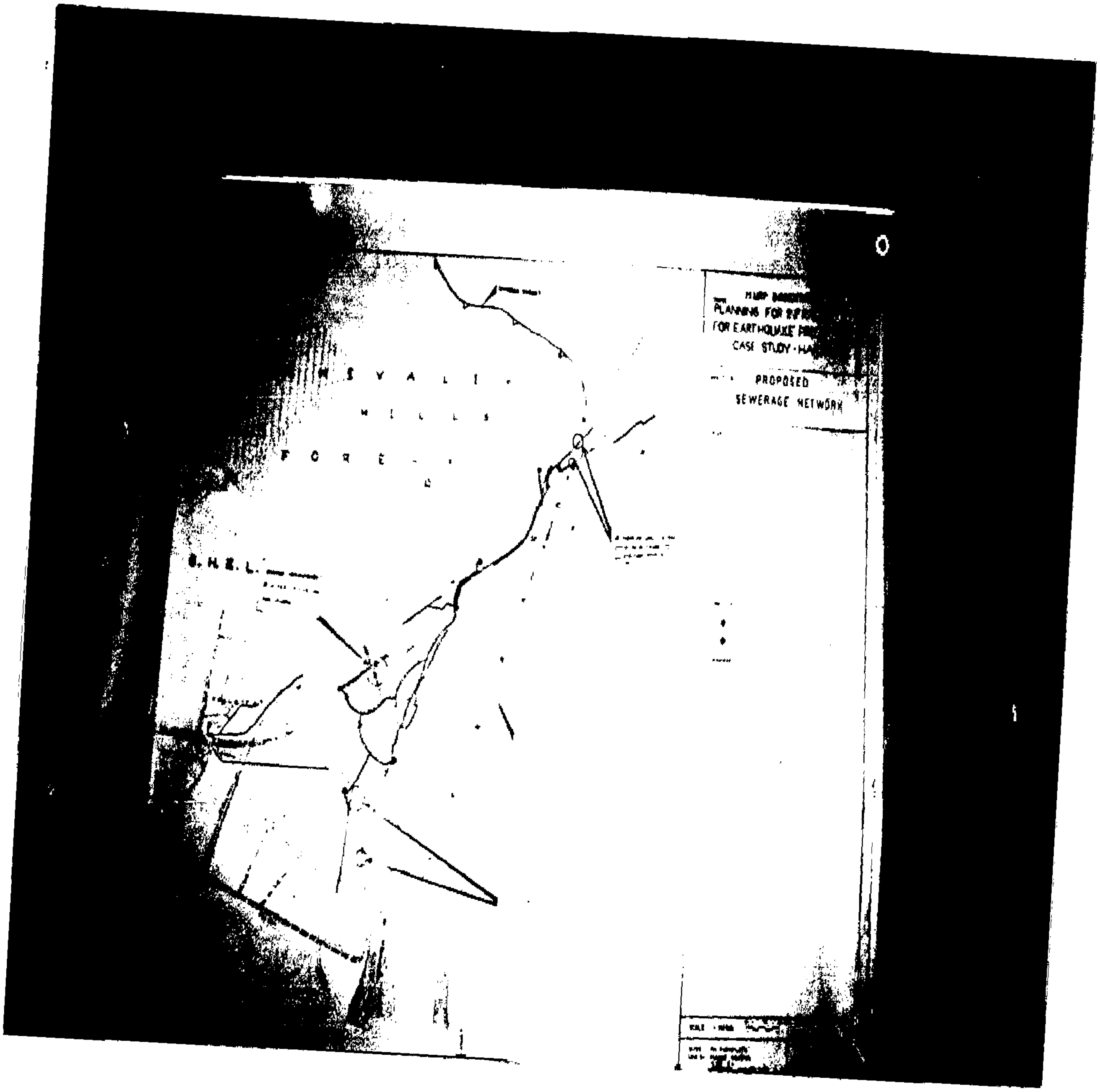
6. Sewage treatment plants should preferably be constructed underground except in areas of high liquefaction potential.

7. Alteration of original ground profile by large scale cut and fill is found to increase the vulnerablity of buried pipes to seismic damage.

8. Plastic pipes have some recognised advantages in strength and flexibility over rigid and brittle clay pipes.

Proposals

1. To isolate the sewage pipelines from seismic motion where these cross Ganga fault, casings or carrier pipes should be used to shelter these pipelines.



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PROPOSED SEWERAGE NETWORK

2. To provide redundancy in the system a standby arrangement of pumping station at Govind Puri in zome B near the bridge over Ganga canal should be made. Sewage pumping stations of both zone B and zone C (near Dam Kothi) should be connected to this pumping station.

This pumping station should pump the sewage across Ganga canal into another outfall gravity sewer which will take it to the sewage treatment plant at Jagjitpur.

3. A bye-pass should be provided between in-coming and out-going sewers at sewage treatment plant.

CHAPTER : SIX

CONCLUSIONS & RECOMMENDATIONS

CHAPTER-6

CONCLUSION AND RECOMMENDATIONS

From the text of this dissertation it can be concluded that planning for lifelines in earthquake prone areas can reduce the indirect as well as direct losses to various facilities due to earthquake effects.

The state of the art requires the analysis of data from damages in the past earthquakes to determine the vulnerability of various components and on this basis to estimate the possible damages in other areas. Predisaster planning should then be undertaken based on adequate damage estimates.

It will be very difficult and also uneconomical to make various facilities earthquake-proof and some damages are bound to occur. Therefore, it is necessary for restoring the services within minimum time to plan beforehand for these damages and the remedial measures to be taken.

There is enormous scope for research in this field of lifeline earthquake engineering. The present research work is being done only in a few countries like USA, Japan and China, which are very prone to this natural disaster. Till recent past whatever research has been done was concerned with individual components. Since last few years the work is being done considering the whole system. But before practicing them in the field more research is needed to support the results from these studies. Criteria have been evolved to find out the performance reliability of various networks, through model studies. Seismologists are working to evolve strategies for predicting earthquakes.

In India a lot of work has been done on `building earthquake engineering' but very little attention has been paid towards this field. In context of our country the foremost thing is to prepare detailed regional as well as local or town level hazard maps.

Planning as a whole should be done at two levels- Zone level and Micro zone level. India has been divided into five seismic zones. Now the zone level planning would require research and studies at regional level or zone level to find the major zones of structural weaknesses and on this will depend the planning for settlements i.e. alternate sites for the entire township. Within one zone now should be made several microzones where lócal geologic features should be studied and on this basis locational planning for various structures and facilities be undertaken. Some major recommendations for the locational planning are as follows:-

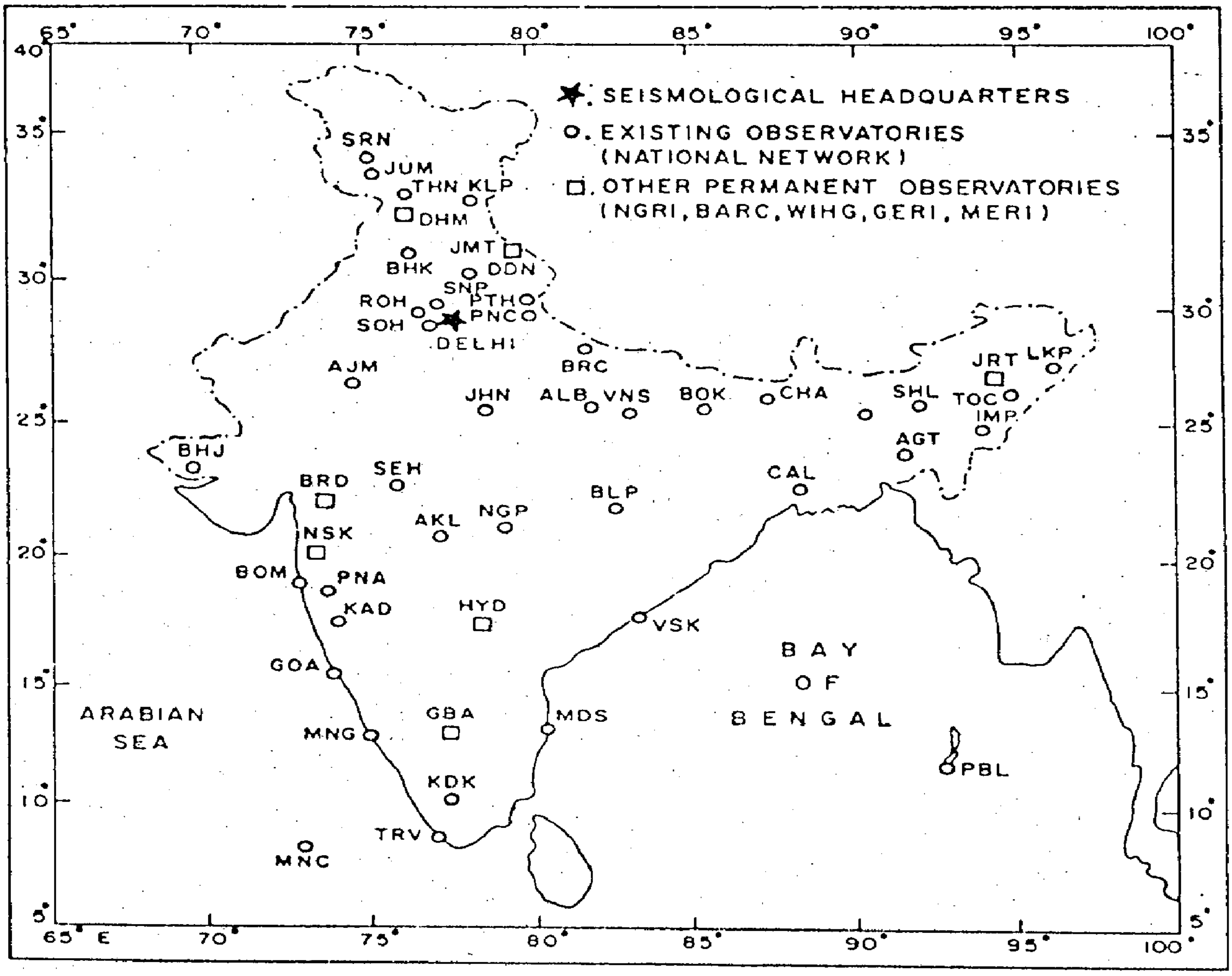
1. No permanent structure should be made astride an active fault.

2. Open spaces should be left on and around faults.

3. Low rise high density development should be preferred to high rise buildings in earthquake prone areas.

4. Areas where soil liquefaction is a problem, should be avoided for any development.

APPENDIX - A



Seismological observatories in India.

APPENDIX - B

PER CAPITA WATER SUPPLY IN INDIAN CITIES (1981)

S.No.	Name of the Town/City	Per Capita Water Supply Gallons/Day
1.	Kanpur	41.1
2.	Agra	25.5
3.	Varanasi	45.0
4.	Allahabad	45.0
5.	Lucknow	45.0
6.	Bombay	47.6
7.	Calcutta	31.5
8.	Delhi	40.0
9.	Banglore	44.5
10.	Hyderabad	40.0

Source : Water Works, Allahabad.

APPENDIX

SUGGESTED RELIABILITY LEVELS FOR LIFELINES

LIFELINE		RELIABILITY WITHIN INTENSITY AREA: HIGH INTENSITY GROUND MOTION-(MMI IX-X WITH SURFACE FAULTING)	RELIABILITY WITHIN INTENSITY AREA: MODERATE INTENSITY GROUND MOTION - (MMI VI-VII)
Highway, Freeway, Railroad	Bridges *	Level A - no collapses	Fully functional
	Roadways	Level B	Fully functional
Water Supply System	Storage Reservoirs*	No failure that will endanger lives	Fully functional
	For fire fighting	Level A - Adequate storage available	Fully functional
	Treatment facilities	Level A	Fully functional
	Distribution	Level B - Tank Trucks available for potable water	Fully functional
Sewage System	Collection*	Level C	Level A
	Treatment facilities*	Level B	Fully functional

Reliability Level A: 5% or less of intensity area without service for one day; fully restored in 1 week.

Reliability Level B: 20% or less of intensity area without service for 1 week; fully restored in 1 month.

Reliability Level C: 50% or less of intensity area without service for 1 week; 20% or less without service for 1 month; and fully restored in 3 months.

* : Hazard of loss of life and private property.

Source: Duke and Moran (1975).

GLOSSARY

G L O S S A R Y

EARTHQUAKE : The momentary shaking in the crust of the earth is called an **earthquake.**

EPICENTRE : The geographical point on the surface of the earth vertically above the focus of an earthquake is termed as **epicentre** of that particular earthquake.

FAULT : A fault is a fracture in the rocks of the earth's crust developed due to shear failure of the rocks, and along which there has been relative displacement of the blocks.

FISSURE : A surface of fracture or a crack in rock along which there is a distinct separation. It is often filled with mineral - bearing material.

FOCUS : It is the point or place in the earth's crust from where the disturbance in the form of seismic waves causing an earthquake originates, i.e. it is the originating source of the elastic waves which cause shaking of the ground. It is also called **Hypocentre.**

FOLD : Folds are defined as **bends** or curvatures or undulations developed in the rocks of the earth's crust as a result of stresses to which these rocks have been subjected from time to time in the past history of the earth.

INTENSITY OF EARTHQUAKE : The **intensity** of an earthquake at a place is a measure of the effects of the earthquake, and is indicated by a number according to the Modified Mercalli scale of Seismic Intensities. (Ref. Appendix D of IS : 1893 - 1984)

LANDSLIDE : Movements of the superficial rock masses which may be slow or rapid, minor or major and may involve consolidated rocks or unconsolidated loose material and may take place in any manner and in any direction are grouped as **Landslides.**

LIQUEFACTION : **Liquefaction** is a state in saturated cohesionless soil wherein the effective shear strength is reduced to neglegible value for all engineering purposes due to pore pressures caused by vibrations during an earthquake when they approach the total confining pressure. In this condition the soil tends to behave like a fluid mass.

MAGNITUDE OF EARTHQUAKE (Richter's Magnitude): The magnitude of an earthquake is the logarithm to the base 10 of the maximum trace amplitude, expressed in microns, with which the standard short period torsion seismometer would register the earthquake at an epicentral distance of 100 km. The magnitude M is thus a number which is a measure of energy released in an earthquake.

RIDGE : A general term for a long, narrow elevation of the Earth's surface, usually sharp - crested with steep sides, occuring either independenthy or as part of a larger mountain or hill.

A sub-surface ridge is a long, narrow elevation of the rock strata with respect to the surrounding rock mass.

SEISMIC WAVES :A general term for all elastic waves produced by earthquakes or generated artificially by explosions. It includes both **body waves** and **surface waves**.

SUBSIDENCE : It is defined as sinking or settling of the ground in almost vertically downward direction which may occur because of removal of the support from the underground or due to compaction of the weaker rocks under the load from overlying mass.

THRUST : An overriding movement of one crustal unit over another.

A thrust fault is a fault with a dip of 45 deg. or less over much of its extent, on which the hanging wall appears to have moved upward relative to the footwall. Horizontal compression rather than vertical displacement is its characteristic feature.

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