A Culture at Risk:
An Initial Assessment of Seismic Vulnerabilities in Upper Dharamsala, India

Submitted to the Flora Family Foundation

October 31, 2006

GEOHAZARDS INTERNATIONAL

A Nonprofit Working Toward Global Earthquake Safety

200 Town and Country Village
Palo Alto, CA 94301 USA
Tel.: (650) 614-9050
Fax: (650) 614-9051
www.geohaz.org
India: +91 98106 00821

Executive Summary

A team assembled by GeoHazards International (GHI) conducted an initial assessment of earthquake vulnerabilities in Dharamsala, India from September 2-5, 2006, with funding from the Flora Family Foundation. Dharamsala is located in the foothills of the Himalaya Mountains, in the northern Indian state of Himachal Pradesh. Numerous massive earthquakes leading to significant damage and loss of life have occurred on faults along the front of the Himalaya Mountains, which stretch from Pakistan to Burma. Earth scientists believe enormous earthquakes with magnitudes of 8.0 to 8.5 are overdue on several large sections of these faults. The most recent Himalayan earthquake, a magnitude 7.6 temblor in Kashmir in October 2005, was significantly smaller than the overdue earthquakes but still killed approximately 75,000 people in Pakistan and India. The Dharamsala area is vulnerable to a similar level of devastation from a large earthquake.

Dharamsala is comprised of several settlements at various elevations above the Kangra Valley. McLeod Ganj, currently the center of the area's Tibetan community, is a former British hill station that was nearly destroyed by the 1905 Kangra earthquake and then abandoned by the British. In 1960, the spiritual and political leader of Tibet, His Holiness the 14th Dalai Lama, established his government-in-exile there after being granted asylum by the Indian government. The Dharamsala area is now home to a number of Tibetan cultural institutions, and plays a central role in Tibetan efforts to preserve their culture and national identity.

The GHI team visited Upper Dharamsala (McLeod Ganj, the Central Tibetan Administration area, Forsyth Ganj, and Bhagsunag) and focused on two groups of buildings with cultural importance to the Tibetan community, the Library of Tibetan Works and Archives (LTWA) campus and the Tsuglag Khang (Main Temple) complex. These buildings contain collections of significant manuscripts, bronzes, and thangkas (scroll paintings) brought out of Tibet by refugees. On the LTWA campus, the team inspected both the interior and exterior of the main building and annex, and screened the remaining buildings from outside. The team also observed the geology, the seismic vulnerability of other buildings important to the community, and construction practices in Upper Dharamsala.

The LTWA main building is likely to be badly damaged—but not collapse—when subjected to the level of ground shaking expected in Dharamsala. Some masonry elements, such as the brick parapet and walls between columns in the building frame might collapse, and the exterior walls might shed stones. Falling bricks or stones could injure or kill people both inside and outside, and damage library collections. Further structural analyses and design of seismic protection measures for masonry elements, equipment, water pipes, collections storage and display, and library shelving are needed. The Tsuglag Khang's collections of manuscripts, thangkas, and bronze and clay images lack seismic protection measures. The annex is much more vulnerable to collapse than the main building because of its configuration and construction type. An in-depth engineering analysis would help the LTWA leaders decide whether it is better to reduce the vulnerability of collapse by retrofitting the building, change its use and relocate people and important collections, or replace it with a new building that will resist earthquake shaking and better serve the functional needs of the LTWA. The chance of earthquake induced land sliding of

up to a meter is moderate to high, but the chance of catastrophic or extensive and rapid ground movement that would endangers people and building contents is low. There is little engineering documentation of either the buildings or the geology and soil conditions. There are a few design drawings, but no drawings of the building as it was actually constructed. Geological mapping and geotechnical investigations also are needed.

The Tsuglag Khang is a complex structure, and its behavior during an earthquake needs to be determined by detailed engineering analysis. A number of deficiencies are likely to lead to earthquake damage to both the original building and the surrounding canopy structures. The chance of earthquake-induced landslides is low. Engineering documentation does not exist for either the original building or the canopy structures. Drawings of the building and canopies as built, geological mapping, and geotechnical investigation are needed.

The assessment team observed earthquake vulnerabilities in buildings located throughout Upper Dharamsala. Most buildings were constructed without earthquake-resistant features, and construction quality appears poor. Many buildings as tall as four and five stories are on steep, landslide-prone slopes. Other buildings of considerable importance, such as those at the Tibetan Children's Village, also appear vulnerable to earthquakes. A strong earthquake will devastate the area. The Tibetan community in Dharamsala should undertake a comprehensive approach to reducing and managing earthquake risk. The effort would include a broader assessment of vulnerabilities, improving community awareness, developing a long-range plan to reduce the risk and to prevent constructing new vulnerable buildings, and the preparation of an emergency response plan for the area based on estimates of damage to buildings, roads and other infrastructure.

Assessment Team Members

William R. Cotton, R.G., C.E.G.
Chief Engineering Geologist
Cotton, Shires and Associates, Inc.

Melvyn Green, S.E.
Principal
Melvyn Green and Associates, Inc.

William T. Holmes, S.E.
Principal
Rutherford & Chekene

Hari Kumar
Country Coordinator, India
GeoHazards International

Janise Rodgers, Ph.D., P.E.
Project Manager
GeoHazards International

L. Thomas Tobin, P.E.
Chief Operating Officer
GeoHazards International

Acknowledgments

GeoHazards International expresses its appreciation to the following persons and organizations that provided technical advice, information, or logistical assistance:

Rinchen Dharlo, Tibet Fund
Professor Kailash Khattri, Professor Emeritus, Wadia Institute of Himalayan Geology
Romi Khosla, Architect, Romi Khosla Design Studios
Geshe Lhakdor, Director, Library of Tibetan Works and Archives
Tsering Phuntsok, Senior Mason, Retired, McLeod Ganj
Desang Tsering, Secretary, Office of His Holiness the Dalai Lama

GEOHAZARDS INTERNATIONAL
A Nonprofit Working Toward Global Earthquake Safety

Table of Contents

Executive Summary 2
Table of Contents 5
Introduction 7
  Location and General Description 7
  Scope 7
Seismic Hazard 8
  Seismotectonic Overview 8
  Estimates of Future Earthquake Shaking 9
Local Geology and Site Hazards 9
  Geologic Overview 9
  Earthquake-induced Landslide Potential 10
Library of Tibetan Works and Archives 11
  Site Conditions and Hazards 11
    Soil Conditions and Local Geology 11
    Potential for Earthquake-induced Ground Failure 12
  Main Building 12
    General Building Description 12
    Lateral Force-resisting System 13
    Condition 13
    Seismic Deficiencies 14
  Annex Building 14
    General Building Description 14
    Lateral Force-resisting System 14
    Condition 15
    Seismic Deficiencies 15
  Library Staff and Scholars' Residences 15
    Screening for Potential Seismic Hazards 15
    Results of Rapid Visual Screening 15
    Recommendations 18
  Collections and Contents 18
    General Description 18
    Seismic Protection Deficiencies 19
  Recommendations 20
Tsuglag Khang (Main Temple) 21
  Site Conditions and Hazards 21
    Soil Conditions and Local Geology 21
    Potential for Earthquake-induced Ground Failure 21
  Original Temple Building 21
    General Building Description 21
    Lateral Force-resisting System 22
    Condition 22
    Seismic Deficiencies 22
  Canopy Structures and Additions 23

General Building Description 23
Lateral Force-resisting System 24
Condition 24
Seismic Deficiencies 24
Adjacent Structures 25
General Description of Buildings 25
Potential Seismic Deficiencies 25
Collections and Contents 25
General Description 25
Seismic Protection Deficiencies 25
Recommendations 26
Other Areas of Seismic Vulnerability 26
Tibetan Children's Village 26
Office of His Holiness the Dalai Lama 27
McLeod Ganj Commercial and Residential Buildings 27
Local Technical Capacity and Oversight Capability 28
Tibetan Building Design Professionals, Tradespeople, and Maintenance Personnel 28
Local Regulatory Environment 29
Conclusions 29
Observations 29
Recommendations 30
Appendix A. Examples of Rapid Visual Screening Forms 33

Introduction

Location and General Description

Dharamsala[*] is located in the foothills of the Himalaya Mountains in the northern Indian state of Himachal Pradesh. Dharamsala lies between the Kangra Valley and the Dhauladhar Range, which has peaks approximately 17,000 feet in elevation. Dharamsala is the general name for a group of several distinct settlements located above the Kangra Valley at elevations that vary from 4,000 to 6,500 feet.

Lower Dharamsala, including Kotwali Bazaar, is a primarily Indian community located near the valley floor. McLeod Ganj is the predominately Tibetan community located several kilometers uphill from Lower Dharamsala. The Tsuglag Khang, or Main Temple, is located in McLeod Ganj. There are also a number of commercial and residential buildings in McLeod Ganj. The Library of Tibetan Works and Archives (LTWA) campus and the Tibetan government-in-exile complex are located between Lower Dharamsala and McLeod Ganj. Several other communities, including Forsyth Ganj (home to the Tibetan Children's Village) and Bhagsunag, are located within several kilometers of McLeod Ganj.

The region where modern Dharamsala is located was occupied originally by various groups of people, including the Gaddi tribes people, some of whom still live in the area today. During the British colonial period, McLeod Ganj was a hill station providing respite from the summer heat. The 1905 Kangra earthquake nearly destroyed McLeod Ganj and it remained virtually uninhabited until the arrival of the Tibetans in 1960. The Dharamsala area is now the location of the Central Tibetan Administration (CTA), the Tibetan government-in-exile.

Communist China invaded Tibet in 1949. After a Tibetan uprising was violently suppressed by the Chinese government in 1959, the spiritual and political leader of Tibet, His Holiness the 14th Dalai Lama, escaped to India, where he received asylum from the Indian government. In 1960, His Holiness moved the CTA to Dharamsala. Since the arrival of the Tibetans, McLeod Ganj has become a tourist destination. The community is also home to a number of Buddhist monasteries, nunneries, and organizations working to preserve Tibetan culture and provide social services for Tibetan refugees.

Scope

This report presents the findings of a GHI assessment team that visited the Dharamsala area September 2-5, 2006. The team consisted of an engineering geologist with expertise in earthquake-induced landslides, a structural engineer with expertise in masonry structures and historic preservation, a structural engineer with expertise in reinforced concrete structures, a GHI seismic safety policy and preparedness specialist, and two GHI staff engineers. Several persons

---

[*] There are several variant spellings for Dharamsala; Dharmsala, Dharmshala, and Dharamshala are used by some writers.

not on the assessment team, including a seismologist and an architect, provided additional expertise and recommendations.

This report contains the team's recommendations based on the following activities:

- Assessment of the region's geology and seismotectonic setting;
- Determination of likely earthquake shaking levels;
- Assessment of earthquake-induced landslide potential at the LTWA and Tsuglag Khang sites, and in the McLeod Ganj area in general;
- Initial seismic assessment of the building structures, contents, and other components such as equipment, shelving and piping at the LTWA main building and annex, and Tsuglag Khang;
- Visual survey of the LTWA campus and some adjacent buildings;
- Initial investigations into local Tibetan technical capacity and the local regulatory environment; and
- Limited observation of conditions at the Tibetan Children's Village and commercial and residential structures in McLeod Ganj.

Seismic Hazard

Seismotectonic Overview

The development of the Himalayan mountain ranges shaped the Dharamsala region, its geology and its seismic hazard. The tectonic plate that includes the Indian subcontinent is moving northward at a rate of approximately 40 mm per year and colliding with the Eurasian plate. This continent-to-continent collision started approximately 50 million years ago and created the Himalayan mountain ranges, the world's highest mountains, and one of the most active earthquake belts in the world. A vast region of highly folded rocks and large active thrust faults characterize the region. Huge thrust faults slope downward to the north under the mountains. Most of the great earthquakes occur along these tectonic features. The faults act as energy reservoirs accumulating strain until their stored energy is released as large, deadly and destructive earthquakes. Massive earthquakes, with magnitudes approaching or exceeding M 8.0 (magnitude 8) have occurred along the Himalayan mountain front leading to significant damage and loss of life. Great earthquakes occurred in the years 1803 (M8.1 Kumaon, India), 1897 (M8.3 Shillong, India), 1905 (M7.8 Kangra, India), 1934 (M8.2 Bihar, India and Nepal), 1950 (M8.5 Assam, India), and 2005 (M7.6, Kashmir). Geologic and historical evidence exists for even larger events during earlier times. Earth scientists have identified several sections of the plate boundary that have been storing energy since these larger events occurred centuries ago. These "seismic gaps" have the potential to generate enormous earthquakes larger than those listed above. One gap is located to the east and one to the west of Dharamsala. Some scientists believe that the fault in the Dharamsala area will also break if a great earthquake occurs in one of the gaps.

The most destructive earthquake affecting the Dharamsala region in historic times was the 1905 M 7.8 Kangra earthquake. This earthquake caused widespread destruction to buildings and homes, and more than 20,000 deaths in the Kangra-Dharamsala area. It was associated with permanent ground displacement from fault slip, landslides and rockfalls. Ground shaking was estimated to range in intensity from that sufficient to cause considerable damage to poorly built or badly designed structures, to that sufficient to cause considerable damage to well designed and constructed buildings. Moderate earthquakes of M 5.0 to M 5.7 also struck the Dharamsala area in 1978 and 1986.

Estimates of Future Earthquake Shaking

Earth scientists at the Wadia Institute of Himalayan Geology considered historic earthquakes, plate motion, and regional geology to estimate the peak ground acceleration for the McLeod Ganj area to be 0.7g (70-percent of the acceleration due to gravity) with 10-percent probability of exceedance in 50 years. This probability is used to determine the design level of earthquake shaking in the International Building Code. This means that a building would have a 10-percent chance of experiencing shaking of 0.7g or stronger during its lifetime, assuming a standard design life of 50 years. This level of shaking is similar to that expected in zones of very high earthquake hazard, including parts of the San Francisco Bay Area. Probabilistic seismic hazard maps prepared by the Global Seismic Hazard Assessment Project (GSHAP), a worldwide earthquake hazard estimation project, give a lower estimate of 0.27g for the Kangra area, but many earth scientists familiar with the area consider the GSHAP estimates for the Himalayan region to be low.

Ground surface displacement resulting from the next great earthquake could be as much as 10 meters based on the existing rate of convergence between the Indian and Eurasian plates, and the time since the last great earthquake in the Dharamsala region. Surface fault rupture from such an earthquake would extend hundreds of kilometers, and the duration of ground shaking could be as much as a few minutes. The intensity of ground shaking associated with such an earthquake would be severe.

Local Geology and Site Hazards

Geologic Overview

The Dharamsala region is characterized by high, steep, topography. Its mountains are part of the Dhauladhar Range (9,000 to 17,000 foot elevation), a part of the Sub-Himalaya that forms the southern front of the Himalayan mountain ranges. The Dhauladhar Range has a general east-west trend and is a result of the high rate of tectonic uplift of the region. The southern slope has a series of large steep-walled stream canyons and narrow, north-south trending mountain ridges. The undeformed, alluvium-covered Ganga Plain lies south of the mountain front. McLeod Ganj, like many mountain communities, was built along the axis of a prominent mountain ridgeline that extends from the crest of the Dhauladhar mountains to the floor of the Kanga Valley. Below the ridge axis, the natural mountainside slopes range from 30 to 50 degrees.

The geologic materials underlying Upper Dharamsala are a relatively strong bedrock unit with weak surface deposits. The bedrock is composed of strong, thick-bedded sandstone interlayered with weak, thin-bedded shale and siltstone. The sandstone is light tan, thick-bedded to massive, and moderately to highly fractured. The shale and siltstone is red-brown, highly fractured, faint to thin-bedded, and highly weathered. The shale and siltstone sections form weak intervals in the bedrock that promote development of thick soils and comprise deposits on the slopes. The bedrock structure is inclined downward to the north at moderate angles (25 to 35 degrees), and perpendicular to the north-south trend of the Dharamsala ridgeline. This relationship provides a relatively stable foundation condition along the crest of the ridgeline where most of the roads and buildings are located.

Thick overburden materials derived from deep weathering of the underlying bedrock cover the slopes of the Dharamsala ridge. These surface materials include colluvial soils (meaning soils moving downhill under the force of gravity or deposited by downhill movement) and landslide debris. Most of the slopes are covered by colluvium that commonly develops a uniform slope of large, angular, isolated sandstone blocks set in a matrix of clay- and silt-rich soil. The colluvial slopes are subject to gravity driven processes of "soil creep" and, over time, movement can destroy foundations that are not designed to resist the resulting forces.

Thick-bedded, resistant sandstone bedrock exposed along the McLeod Ganj ridge (left). Landslide debris exposed on the hillside uphill from the LTWA site (right).

Landslide deposits exist within the colluvial material and display the characteristic topographic expression of failing ground, shown above. The formation of a landslide within a colluvial slope requires the development of a below-ground slip surface along which the landslide is displaced down slope. Once formed, a slip surface provides a weak link that is vulnerable to future triggering events such as heavy storms or strong earthquake shaking.

Earthquake-induced Landslide Potential

The portion of the McLeod Ganj community that occupies the axis of the ridgeline appears to be located on relatively stable ground. While stable bedrock is located at shallow depth along the ridgeline, the mountainside slopes are mantled with relatively unstable colluvium and landslide debris. The location of McLeod Ganj with respect to the ridgeline is shown in the two photos below.

McLeod Ganj viewed from the west, with the Dhauladhar range to the north (left of the photo) and the Kangra Valley to the south. Most buildings in this view are along the axis of the ridgeline on relatively stable ground.

McLeod Ganj viewed from the east. Many of the buildings in this view are on the side slopes of the ridge on relatively unstable ground.

The chance of earthquake-induced reactivation or displacement of the existing landslides is high. Some of the observed landslide deposits are stable, showing no evidence of recent movement, while others show clear signs of recent surface displacement. Roads leading up to McLeod Ganj (i.e., Upper Dharamsala) and many of the buildings on the slopes around the edges of the community are on landslides. The long-term stability of the colluvial slopes and the isolated landslide deposits is unknown. However, the probability of failure is high in a large earthquake and/or during prolonged monsoon conditions.

Library of Tibetan Works and Archives

Site Conditions and Hazards

Soil Conditions and Local Geology

The LTWA is situated on gently sloping ground that is underlain by a thick section of colluvium. Field observations and construction photographs indicate that the LTWA is constructed on colluvial debris. However, immediately upslope of the LTWA the mountainside becomes considerably steeper, strongly suggesting that the LTWA might be situated on the upper region of a large landslide. Careful examination of outcrops surrounding the LTWA site did not reveal in-place, stable bedrock. There is no evidence that any of the building foundations (i.e., LTWA main building or annex) have been damaged by gravity-induced creep or sliding, but the site is underlain by potentially unstable colluvium and/or landslide debris.

Potential for Earthquake-induced Ground Failure

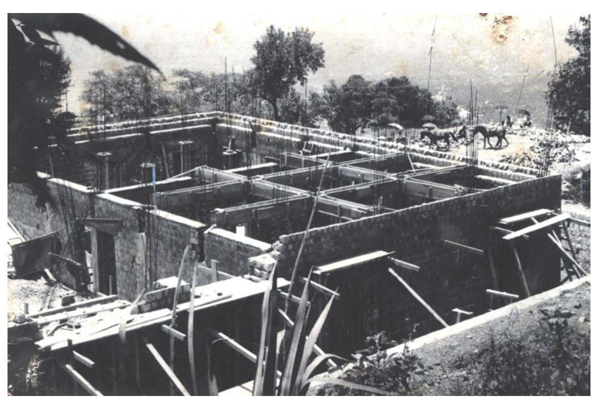
The potential chance for earthquake-induced ground failure is moderate to high. Up to several feet of permanent ground displacement could result from severe and prolonged earthquake shaking. However, the chance of catastrophic ground failure that would destroy buildings is low.

Main Building

General Building Description

The main building on the Library of Tibetan Works and Archives campus is the only building in the area built with traditional Tibetan architectural appearance. The structural system is not traditional; it is a concrete frame with stone masonry or brick masonry walls filling the space between columns and beams, and stone masonry veneer on the exterior. The building is two stories high with a partial third story on the back half of the building. The building was designed by architect Romi Khosla and constructed in 1970 by workers from the Tibetan community. The incomplete set of drawings approved by municipal authorities in Dharamsala describes a different building than what was built. Very few drawings of the actual building are available.

The building houses a number of functions, including a museum, manuscript storage, libraries of foreign and Tibetan-language books, classrooms, a bookstore, work areas for scholars, electronic equipment, audiovisual and digital archives, and offices. A wide sidewalk surrounds the building where members of the community circumambulate.* The hill on the backside of the building is held back by a large stone retaining wall.

LTWA Main Building (left) and during construction (right). Historical photos courtesy LTWA.

* In Tibetan Buddhism, it is considered auspicious to walk repeatedly around temples or other buildings of religious significance in the clockwise direction while reciting prayers.

Lateral Force-resisting System

The lateral force resisting system (structural members that resist earthquake forces) is a reinforced concrete frame with stone masonry walls between exterior columns and some interior columns. The columns, beams and column-beam connections lack sufficient amounts of adequately placed reinforcing steel mandated by current building codes that would allow the frame to undergo significant deformation and damage during earthquake shaking without collapse. The reinforced concrete columns rest on square spread footings. The foundation conditions under the stone walls are unknown, but some settlement was observed at the front of the building. The exterior masonry walls taper from approximately 36 inches at the base to approximately 24 inches at the top of the second story, and were constructed of three courses of stones. Only the exterior faces of the outermost course of stones were architecturally dressed. The other faces and the interior courses were planar, not rounded (stones that are rounded can significantly decrease the strength of the wall). Interior partition walls in both directions were constructed of either unreinforced stone masonry or unreinforced brick masonry. The brick masonry parapet at the top of the second story could fall during an earthquake on persons on the walkway below. The partial third floor was not designed by the architect of the original two-story building. The third floor is constructed of reinforced concrete with unreinforced brick masonry infill walls between columns. The connection between the third story and the rest of the structure is uncertain.



LTWA main building under construction. Historical photos courtesy LTWA.

Condition

The building is in relatively good condition. There is some water damage on the back wall of the third floor. Exterior seasonal mold during the monsoon is not problematic, but detracts from the aesthetics of the building. Yearly cleaning after the monsoon using an environmentally friendly fungicide might help reduce fungal growth and improve the appearance of the building.

The retaining wall behind the library appears to be in relatively good condition, and does not show cracking, bulging, or other signs of distress. However, one section of the wall has been replaced, presumably due to distress, at an unknown but relatively recent date. In addition, some of the weep holes in the wall might have been plugged with fine-grained debris, preventing water from draining properly.

Seismic Deficiencies

The main building's concrete frame and masonry walls are not likely to have the strength to resist strong earthquake shaking without significant damage. The frame does not have enough properly placed reinforcing steel to resist earthquake shaking without extensive damage. However, the thick exterior stone walls and significant number of interior masonry walls add strength and stiffness to the frame and make it unlikely that the building would collapse. Some interior partition walls, especially those constructed of unreinforced brick masonry, might be prone to out-of-plane failure (bricks might fall into the rooms) that would endanger both occupants and contents located near the wall.

Annex Building

General Building Description

The annex building occupies a narrow, sloping site between residential buildings near the main library building. The annex was designed by architect Romi Khosla and constructed in 1981. The structure is four stories tall and steps down a sloping site. The building is irregular in plan and elevation, and is tall and narrow. Some structural drawings exist, but they do not show the locations of interior masonry walls, and might not have been followed during construction.

The annex houses offices and several archives. The archives include a collection of historic photos, a collection of architectural photos and other documentation of buildings in Lhasa, and an archive of refugee correspondence that is important for documenting recent Tibetan history and the hardships imposed by the Chinese occupation of Tibet.

Front and side elevation views of the LTWA annex.

Lateral Force-resisting System

The annex's lateral force resisting system consists of a reinforced concrete frame with unreinforced masonry walls, and numerous four-inch unreinforced brick masonry interior partition walls. The frame is incomplete, meaning that beams and columns are not continuous from the foundation to the roof or from one end of the building to the other. Four-inch brick masonry partition walls are particularly weak compared to thicker masonry walls, and are likely to fall into the adjacent rooms during earthquake shaking. The configuration and alignment of these brick partitions is unclear, and as-built drawings will be necessary to accurately locate the walls. Foundation details shown on the drawings should be verified in the field.

Condition

The building appears to be in relatively good condition. There are some cracks, possibly due to settlement, and localized water damage.

Seismic Deficiencies

The annex has numerous vertical and plan irregularities that are likely to increase earthquake-imposed deformations and lead to damage. The structural system appears weak, with an incomplete frame and thin unreinforced brick walls. The combination of these characteristics, along with the sloping site, makes the annex vulnerable to collapse. The numerous four-inch brick partition walls are likely to fail under strong earthquake shaking, endangering persons and contents inside. An in-depth engineering analysis is necessary to determine the likely behavior of the building and develop possible retrofit schemes. The archives and the material they contain are also in need seismic protection (possibly by relocation).

Library Staff and Scholars' Residences

The LTWA has approximately 15 residential buildings under its jurisdiction. LTWA residential buildings house library staff and their families, as well as scholars doing research. The persons residing in library buildings possess a wealth of irreplaceable cultural knowledge. Loss of some or all of these buildings and the people they house would be a significant setback to the LTWA and its goal of preserving Tibetan culture, in addition to the tragedy of lost lives.

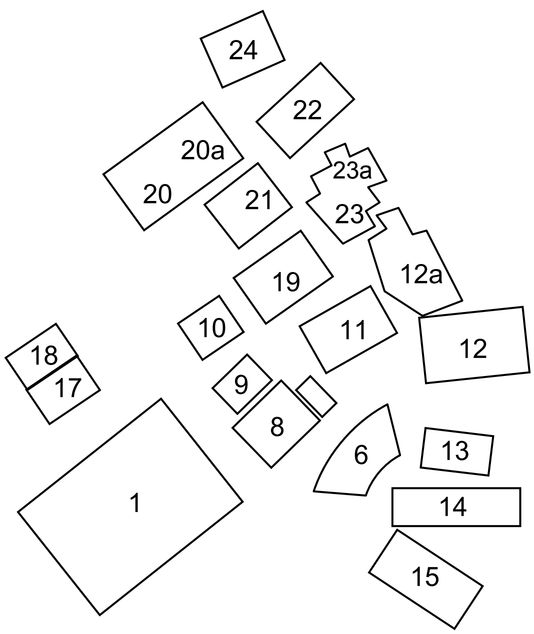
Screening for Potential Seismic Hazards

Rapid visual screening is a procedure for conducting a "sidewalk survey" intended to quickly identify, inventory, and rank buildings considered potentially hazardous in earthquakes without the high cost of detailed analysis. Engineers, facility managers and owners developed the procedure in the United States. It is an inexpensive method to evaluate numerous buildings, identify those most likely to be hazardous during earthquakes, and compare their relative vulnerability for setting priorities for mitigating those hazards. The buildings are observed from the exterior to determine the building's features and probable lateral force resisting system. The basic screening procedure is readily adaptable to local conditions, regulatory needs, and building types in a particular location or country. The GHI team used a rapid visual screening procedure described in a document (FEMA 154, *Rapid Visual Screening of Buildings: A Handbook*) available from the Federal Emergency Management Agency. The assessment team then applied their design and evaluation experience, thus going somewhat beyond the typical sidewalk survey.

Results of Rapid Visual Screening

Many of the buildings on the LTWA campus are masonry bearing wall buildings, with either reinforced concrete floors and roofs, or reinforced concrete floors and wooden roofs with metal coverings. This type of building has collapsed in numerous earthquakes worldwide. Due to their greater weight, reinforced concrete floors and roofs pose a greater danger to occupants than wooden ones if the walls collapse. Other campus buildings have reinforced concrete frames, masonry infill walls and reinforced concrete floors and roofs. Buildings with concrete frames and masonry walls might not be safe and require a more detailed evaluation. The project team concluded that more detailed evaluations are needed.

The site plan for the LTWA campus is below. The assessment team assigned numbers for screening purposes. The site plan is not to scale, and there is some uncertainty in the relative location and orientation of buildings 20-24 because of a lack of clear sight lines for spatially locating buildings. Miscellaneous buildings such as toilet blocks and storage sheds are not shown. The site plan shows only surveyed buildings under the jurisdiction of the LTWA.



Site plan of LTWA campus (includes only buildings under LTWA jurisdiction).

The table below contains basic information on each building surveyed, such as construction type, whether the floors and roofs can serve as rigid or flexible diaphragms (horizontal structural members) and whether life threatening conditions are present. About one-third of LTWA residential buildings are reinforced concrete frame buildings with masonry infill walls (loads are carried by the frame), and the others are unreinforced masonry bearing wall buildings (loads are carried by the walls). Unreinforced masonry buildings are generally more vulnerable than reinforced concrete frame buildings, and would be a higher priority for retrofit based solely on vulnerability without considering building importance, number of occupants, and use. These additional factors are important, and ranking of the residential buildings for assessment and potential seismic strengthening should be done in conjunction with the LTWA leadership. *All of the buildings surveyed are potentially unsafe during earthquakes and further evaluation by a qualified engineer is recommended for each structure.* Many of the residential buildings are similar, so only several typical buildings need in-depth evaluation and seismic retrofit designs. The results can then be applied to others of that type, significantly reducing engineering costs.

Only the LTWA main building and annex were inspected from the inside for hazards from non-structural components (such as piping, masonry parapets, light fixtures, doors, and lightweight partition walls), building equipment, interior brick partition walls, and contents.

Summary of Rapid Visual Screening Results for LTWA campus and surroundings

Building Number	**Name**	**Use**	**Stories**	**Construction Type**				**Issues and Needs**					
				Concrete Frame		Unreinforced Masonry Bearing Wall		Life Safety Concerns		Non-Structural Components	Building Equip.	Interior Walls	Contents
				Diaphragms		Diaphragms							
				Rigid	Flex	Rigid	Rigid & Flex	Users	Visitors				
1	LTWA	Library/multi	2, 3	X				X	X	X	X	X	X
2	Judicial	Office/Court	3	X		X		X	X				
2A	Judicial Annex	Office/Court	3	X				X	X				
3	CTA Offices	Office	2	X				X					
4	Dept. of Home	Office	2	X				X					
5	Parliament	Office	2	X				X	X				
6	LTWA Annex	Office	3	X				X	X	X		X	X
7	Nechung Café	Dining	4	X				X	X				
8		Residential	3	X				X					
9		Residential	2				X	X					
10		Residential	2			X		X					
11		Residential	2				X	X					
12		Residential	3			X		X					
12A		Residential	2			X		X					
13		Residential	2				X	X					
14		Residential	2, 3			X		X					
15		Residential	3			X		X					
16	Research Ctr.	Office/Res	3	X				X					
17		Residential	2	X				X					
18		Residential	1			X		X					
19		Residential	3	X				X					
20		Residential	2	X				X					
21		Residential	2				X	X					
22		Residential	2				X	X					
23		Residential	2	X				X					
23A		Residential	2	X				X					

Notes:
Concrete frame buildings have concrete columns, beams and roof and floor slabs, and unreinforced masonry exterior walls.
Diaphragms refer to the floors and roof. Rigid diaphragms are constructed of concrete, and flexible diaphragms are constructed of wood or another flexible material.
Rigid and Flex indicates structures with concrete second floor and wood framed roof. Roof covering is generally metal.
Number of stories is typically measured above grade.
Buildings not under the jurisdiction of the LTWA are shaded gray.

Several typical residential buildings on the LTWA campus are shown below. Other buildings are similar in construction type, number of stories, and appearance.

Building 8 (left) is a three-story masonry bearing wall building. Building 19 (center) is a reinforced concrete frame building. Buildings 11, 12 and 12A (right) are masonry bearing wall buildings. The close spacing of buildings makes persons between them in danger of falling hazards.

Recommendations

All of the buildings on the LTWA campus are potentially hazardous during earthquakes and should be evaluated in more detail. Because many of the buildings are similar, a few representative buildings could be evaluated and the results used to decide which retrofit strategies apply to the other buildings of that type. The retrofit methods contained in the Indian building code might be appropriate for most of the small masonry buildings.

Collections and Contents

General Description

The LTWA collections consist of the following major types of objects:

- Tibetan-language Buddhist manuscripts hand-painted on parchment
- Small to medium-sized bronzes, including many images of the Buddha
- Thangkas (scroll paintings) mounted on fabric
- Modern examples of traditional Tibetan arts
- Tibetan-language books
- Foreign language books related to Tibet and Buddhism
- Audiovisual archives of teachings by the Dalai Lama and others
- A digital archive of all manuscripts and teachings
- Letters and correspondence from Tibetan refugees
- Photographs and other documentation of Tibetan history and architecture

The majority of the manuscripts, bronzes, and thangkas were taken from Tibet by refugees. Many of the manuscripts and bronzes are several centuries old and represent the last physical links to monasteries destroyed by the Chinese government during the Cultural Revolution.

A manuscript written during the thirteenth century (left), and unsecured manuscript storage racks and climate control equipment (right).

Bronzes (left) and thangkas (right) in the museum area of the LTWA.

Seismic Protection Deficiencies

The manuscripts are stored in unanchored and unbraced open racks, and there are no shelf restraints. The racks will likely topple and spill the manuscripts, injuring anyone in the room and possibly damaging the manuscripts. Humidity control equipment in the manuscript storage room is unsecured. The water pipes that service the toilet block on the second floor could break and cause water damage in the manuscript room on the first (ground) floor. The second floor plumbing might also pose other, non-seismic threats to objects stored below from such events as backups or overflows.

Many items in the museum are displayed in glass-fronted cases that are not attached to the wall and are likely to topple in an earthquake. The pending redesign of the museum interior should consider seismic protection. The library stacks are very tall and unbraced, with no shelf restraints. They will likely topple in a strong earthquake, dumping piles of books on the floor. Library workers have office space adjacent to the stacks and are at serious risk of severe injury or death from falling books. Library books are not classified by call number, so sorting them out after an earthquake will be a major undertaking. In the annex, the refugee correspondence archive is stored in tall, open shelving that is not attached to the wall. In addition, no conservation measures are currently in place. The photo archive is presently in a similarly unsecured state.

Recommendations

1. Prepare a facilities master plan for the LTWA campus that integrates seismic safety improvements with collection conservation, museum design, land use, and future construction and remodeling of library-administered buildings. Correcting seismic deficiencies on the LTWA campus will be a long-term process that should be integrated with maintenance and other projects.

2. Decide on the seismic performance objectives for each of the LTWA buildings. Performance can be described in terms of the amount of damage acceptable to LTWA decision makers.

3. Prepare as-built engineering drawings for the LTWA main building and annex. As-built drawings are a prerequisite for engineering work.

4. Search the LTWA archives for photographs and documents related to the construction of LTWA buildings to determine the construction sequence and as-built conditions of the buildings.

5. Conduct an engineering analysis of the LTWA buildings, and design seismic protection measures. The results of the analysis are necessary for identifying the best methods to reduce seismic vulnerability. The evaluation would consist of the following studies and design measures:
    a. Determine whether the structural elements that resist gravity load are adequate.
    b. Evaluate how the entire structure will perform during an earthquake through engineering calculations and physical testing of existing building materials.
    c. Evaluate the effect of constructing a proposed third floor addition.
    d. Determine the capacity of the brick and stone masonry walls to resist forces required to brace shelving, cabinets, or other elements.
    e. Design measures to retrofit the brick partition walls (if required).
    f. Design the bracing and anchorage for storage components and equipment not located in the museum.
    g. Design seismic protection measures for the museum collection in conjunction with museum consultant.

6. Implement measures to protect human life and collections in the main LTWA building:
   a. Implement retrofit measures needed to improve the performance of the main building and its masonry walls;
   b. Brace storage shelves and collections displays to resist shaking and implement conservation measures; and
   c. Create an off-site backup of the LTWA digital archives, documentation of collections and copies of original documents.

7. Retrofit the LTWA annex to reduce the chance of collapse, change its use and relocate people and important collections, or demolish and replace it with a new, safer building that meets the functional needs of the library. The LTWA staff should consider relocating some functions currently housed in the annex while deciding what to do with the building.

8. Prepare a detailed geologic map of the site and assess conditions. Before the start of the fieldwork, a topographic base map of sufficient scale (i.e., 1:6,000) and coverage is needed.

9. Investigate subsurface soil conditions and the embedment characteristics of the building foundations. If necessary, collect and test soil samples.

Tsuglag Khang (Main Temple)

Site Conditions and Hazards

Soil Conditions and Local Geology

The Tsuglag Khang is situated along the axis of a prominent bedrock ridgeline in the southern part of McLeod Ganj. The building foundation is situated on relatively stable bedrock and/or thin soils. There is no evidence in the exterior elements of the Tsuglag Khang that suggests the structure is affected by gravity-driven slope failure. Landslide deposits were not found within the Tsuglag Khang site.

Potential for Earthquake-induced Ground Failure

The potential chance of earthquake-induced ground failure is low.

Original Temple Building

General Building Description

The original temple building was constructed at the top of a hill in 1970. It had two stories above grade with a balcony, and one story downhill. Since then, buildings and canopies were constructed adjacent to the original building. Buildings now extend four stories or more below the temple's on-grade floor down the slopes of the hill. The structure is near the offices and residence of His Holiness the Dalai Lama.


Tsuglag Khang complex, yellow buildings at center, and residence of His Holiness the Dalai Lama, upper left (left photo). Front of original temple building at the second floor level (right photo).

The temple consists of a large main hall on the second floor that contains three large images, a collection of manuscripts, thangkas, and smaller images. The third floor contains rooms where ceremonial music is played and sacred objects, including clay images, small bronzes, and thangkas are kept.

Lateral Force-resisting System

The lateral force-resisting system of the original building is a reinforced concrete frame with masonry walls filling the spaces between exterior beams and columns. Large box structures approximately five feet high containing prayer wheels were added to three sides of the second floor several years after the initial construction, and will affect the movement of the frame during an earthquake. A reinforced concrete frame was added to one side, and steel beams were added to the ceiling and rear of the main hall after minor damage occurred in the 1986 earthquake.

Condition

The building appears to be in good condition, but it sustained a small amount of damage at the second story in the 1986 earthquake, which was repaired using the measures described above. Water damage was not observed. Minor cracking of unknown origin was observed in the third story ceiling.

Seismic Deficiencies

Damage to the temple during future earthquakes is likely because the adjacent canopies are not separated adequately from the temple building, but are not connected to it either. The canopies will pound against the building as they sway during earthquakes. Some of the canopies intersect with the original building partway down the second story walls where pounding damage is potentially more severe because it directly impacts supporting walls and columns. The original building does not have sufficient amounts of properly placed reinforcing steel to resist earthquake shaking, and plain reinforcing steel (meaning it has a smooth surface) was used, which results in a weaker bond between concrete and rebar than the more desirable deformed rebar. Vertical irregularities in the structure also might lead to damage. The temple, canopies and additions must be analyzed together.

Concrete framing added to the side of the original temple building following the 1986 earthquake (left), and intersection of canopy with original temple structure where floors slabs do not align (right).

Canopy Structures and Additions

General Building Description

Several reinforced concrete canopy structures surround the original temple building. These canopies are reinforced concrete frame structures with circular columns and rectangular beams, topped by a reinforced concrete slab. In addition, several other reinforced concrete frame structures have been constructed adjacent to the temple, including residential quarters and an additional temple room built in 1989. These structures, which were added since 1970, step down the sides of the hill on which the original temple building is located. The Tsuglag Khang complex is extremely complicated, with numerous levels, staircases, rooms, and retaining wall structures. To the team's knowledge, as-built structural drawings are not available.

Canopies (left) and minor damage due to differential movement during the distant October 8, 2005 Kashmir earthquake (right).

Lateral Force-resisting System

Reinforced concrete frames consisting of beams and columns resist earthquake-induced forces. According to details recounted from memory by senior mason Tsering Phuntsok, who worked on the construction of some of the canopies, adequate transverse reinforcing steel was not provided in either the beams or columns. Vertical reinforcing steel in the columns, which can be observed where it protrudes from the second story roof, is twisted rebar rather than deformed rebar. The remaining reinforcement is unknown. The concrete canopies form near-continuous diaphragms, which means the concrete slabs will transfer earthquake forces in a manner similar to vertical shear walls between the columns and beams. The slabs are considered near-continuous because they have a few openings for light wells, trees, and staircases. There are no walls or partitions in the canopy structures. Some of the additions to the temple, including the 1989 addition, have masonry walls between the columns. Forces from the canopies and other additions are transferred to the underlying soil by spread footings located in many cases behind retaining walls.

Condition

The canopy structures and additions appear to be in relatively good condition. Very minor cracking and spalling (chipping) was observed at the second story. Minor cracking occurred during the distant October 2005 Kashmir earthquake due to inadequate separation.

Seismic Deficiencies

Potential seismic deficiencies include the following:

- The canopy structures were constructed without adequate seismic separation from either the original temple building or each other. The distant 2005 Kashmir earthquake caused differential movement between the canopies and minor spalling was caused by the pounding. A large earthquake would cause significant pounding damage.
- The first story of the canopies is taller than the second story. This configuration might cause damage to concentrate in the first story columns during earthquakes.
- The canopies might have strong beam and weak columns. This increases the likelihood damage would occur in the columns. Extensive column damage could lead to partial collapse.
- Canopies over light wells rest on short columns. Short columns must resist very large earthquake forces, making them vulnerable to damage.
- Proper amounts and placement of reinforcing steel were not used in the reinforced concrete members. This condition results in brittle concrete that can be heavily damaged or potentially collapse due to strong shaking.
- Irregular boundary conditions (connection or contact with structures on one side but not another) might lead to torsion effects causing the structure to twist during an earthquake, increasing the demands on the frames and leading to more damage.

Adjacent Structures

General Description of Buildings

A number of residential buildings were constructed adjacent to the Tsuglag Khang with adequate separation distance so that they will act independent of the temple building and canopies during an earthquake. Many of these are multi-story reinforced concrete frame buildings with masonry walls between the columns on a relatively steep slope.

Potential Seismic Deficiencies

Many of the adjacent buildings appear to have seismic deficiencies common to most buildings in the general McLeod Ganj area. Deficiencies include a lack of proper reinforcing steel in beams, columns and walls, vertical and plan irregularities, and unreinforced masonry walls.

Collections and Contents

General Description

The original temple building houses a number of culturally significant items. The main temple hall contains a collection of manuscripts, thangkas, two large bronze images, one large silver image, and numerous smaller bronzes brought out of Tibet. The third story rooms contain several clay images, possibly brought from Tibet, and numerous bronzes brought from Tibet, some of considerable age. The third story also has at least one centuries-old thangka on display.

Large and small bronzes in the main hall (left); bronzes, clay statues, and thangka on the third floor (right).

Seismic Protection Deficiencies

The manuscripts in the main temple hall are displayed in very tall cabinets with glass fronts. The cabinets are not fastened to the wall and will likely topple during earthquakes, breaking the glass and dumping the manuscripts onto the floor. On the third floor, the oldest images are stored in a tall, glass-fronted cabinet that is not fastened to the wall. These cabinets do not have proper latches or restraints to prevent the images from falling out during strong shaking. The brittle clay images will need special mounting to prevent damage during strong shaking.

Recommendations

1. Search the LTWA archives for photographs and documents related to the construction of the Tsuglag Khang to determine the construction sequence and as-built conditions of the buildings.

2. Prepare as-built engineering drawings for the Tsuglag Khang. As-built drawings are a prerequisite for engineering work.

3. Conduct a engineering analysis of the Tsuglag Khang complex. The results of this analysis are necessary for identifying the best methods to reduce seismic vulnerability. No additional structures should be added until their effects on the seismic behavior of the complex can be ascertained.

4. Prepare a detailed geologic map of the site and assess conditions. Before the start of the fieldwork, a topographic base map of sufficient scale (i.e., 1:6,000) and coverage is needed.

5. Investigate the subsurface soil conditions and the embedment characteristics of the building foundations. If necessary, soil samples should be collected and tested.

Other Areas of Seismic Vulnerability

Residential, commercial and school buildings in the Upper Dharamsala area are vulnerable to earthquake damage, and the entire community is at risk from potentially unsafe buildings. A comprehensive, long-term approach that involves improved building practices, mitigation of existing hazards and emergency preparation is necessary to reduce this risk. Projects carried out at the LTWA and Tsuglag Khang that involve earthquake safety decision-making, strengthening of buildings and bracing building contents are teaching opportunities for the entire community. Decisions by leaders to improve the resilience of the cultural heritage send a strong and observable message that earthquake safety is important and that there are concrete steps people can take to address the risk. Without a community wide effort to prepare for earthquakes and reduce risk, the potential loss of life is large. In Upper Dharamsala, devastation on the scale of that observed by two assessment team members in Pakistan following the 2005 Kashmir earthquake is likely if a large earthquake occurs nearby. Despite the relatively few random rubble stone masonry buildings, a type which collapsed and killed many in Pakistan, there are enough vulnerable buildings of other types to kill and injure many people.

Tibetan Children's Village

The Tibetan Children's Village (TCV) is a large residential school campus located in Forysyth Ganj, several kilometers from McLeod Ganj. The TCV provides Tibetan cultural education to

Tibetan children who come from distant places, including Tibet, to receive an education. The assessment team walked through the campus and observed a number of seismically vulnerable buildings. Assessments should be conducted at other area schools that serve the community, since they are also likely to have seismic vulnerabilities. Building collapses and the resulting deaths of children at the TCV and other schools would be devastating from a humanitarian point of view and would present a significant setback to efforts to pass Tibetan culture on to the next generation.

Seismically vulnerable buildings at Tibetan Children's Village.

Office of His Holiness the Dalai Lama

The assessment team was not able to go inside the Dalai Lama's office complex. However, during the May 2006 reconnaissance visit, two team members observed a building under renovation inside the complex. This building was an unreinforced masonry building with a wooden roof, a type of construction typically vulnerable to strong shaking. The residence and other office buildings were not reviewed, but if their construction is similar to other area buildings observed during the assessment visit (i.e., unreinforced masonry or concrete with inadequate reinforcing steel), they might be vulnerable to significant earthquake damage.

McLeod Ganj Commercial and Residential Buildings

Many of the commercial and residential buildings in McLeod Ganj have significant seismic vulnerabilities. Multi-story reinforced concrete frames with vertical and plan irregularities and without proper seismic details are common. Most buildings have unreinforced brick walls and rooftop water tanks, and many have unbraced masonry parapets. Were these objects to fall during a daytime earthquake when the narrow streets are crowded with people, they would kill many. Construction quality and the quality of materials, especially concrete, appear to be uniformly poor. Many buildings, especially the newer ones, are constructed on slopes prone to landslides. As McLeod Ganj continues to be built out, this situation will only worsen as the more marginal lots are developed due to lack of land elsewhere.

Commercial building with vertical irregularities in McLeod Ganj (left); buildings on hillsides (right).

Local Technical Capacity and Oversight Capability

Learning is a core value of the community. The LTWA has a new science program intended to instruct monks in the sciences of physics, astronomy, chemistry, neurobiology, and mathematics. The program does not include geology or engineering, but these and other fields of study might be added. There might be interest in developing course work that would teach earth science and engineering, mitigation, preparedness and emergency planning.

Tibetan Building Design Professionals, Tradespeople, and Maintenance Personnel

Tibetan building professionals, tradespeople and maintenance personnel living in the Dharamsala area and elsewhere might provide a significant resource in efforts to improve earthquake safety in the community. These people care about their culture and will continue to serve the community by using their knowledge and skills long after outside organizations such GHI have completed their work. The extent of capabilities among Tibetans in the Dharamsala area and elsewhere is not known completely. However, initial inquiries identified an interest in building the capacity of Tibetans to construct better buildings and to better manage earthquake risk. One engineer and one architect who live in Dharamsala and one architect in Delhi were contacted. These individuals and other professionals could be involved in GHI's work and benefit from working with American experts to learn about earthquake-resistant technology. Their knowledge of the Tibetan community, common culture, and language skills make them ideal change agents for earthquake safety.

The LTWA has maintenance personnel who could be trained to secure falling hazards such as displays, shelving and equipment in the library and archives, brace unreinforced masonry parapets, rooftop water tanks and interior furnishings. These simple projects can reduce risks significantly.

Local Regulatory Environment

The Dharamsala Municipal authorities have jurisdiction over building construction. The Tibetan community must comply with municipal requirements for building permits and follow Indian building codes. The general view is that municipal requirements are not enforced so it is up to the owner to assure quality work and compliance with building plans.

Conclusions

The assessment team found numerous seismic vulnerabilities in the Library of Tibetan Works and Archives campus, at the Tsuglag Khang complex and in the Upper Dharamsala community that threaten the people, collections of culturally significant objects and materials, and cultural institutions during earthquakes that will strike the area. The cultural institutions and community members in Upper Dharamsala play a central role in Tibetan efforts to preserve their culture and national identity. The community will need to make significant, sustained efforts over a number of years to reduce the substantial earthquake risks it currently faces.

Observations

The team focused their assessment efforts on the LTWA campus and the Tsuglag Khang complex, both of which have significant seismic vulnerabilities. They also visited the Tibetan Children's Village, the Central Tibetan Administration area, and commercial structures in McLeod Ganj, as well as observing local geology. These activities uncovered additional vulnerabilities. The team's major observations are as follows:

1. Peak ground acceleration with a 10-percent probability of exceedance in 50 years is estimated to be 70-percent of the acceleration due to gravity (0.7 g). This is similar to that in zones of very high earthquake hazard.

2. The chance of earthquake-induced landslides with several feet of movement at the LTWA site is moderate to high, but the chance of catastrophic ground failure is low for the estimated ground shaking. The chance of earthquake-induced landslides is low at the Tsuglag Khang site.

3. The LTWA main building is likely to sustain heavy damage, but not collapse, under the estimated ground shaking. Interior masonry partition walls that are only four inches thick might collapse and injure or kill occupants and damage contents and collections. Spalling of stones from exterior masonry walls might damage collections inside, and fall on persons near the walls outside. The unreinforced brick parapet is likely to fall on persons near the outside walls.

4. The LTWA annex building is likely to sustain heavy to severe damage, and might suffer partial or total collapse. The many vertical and plan irregularities in beams and columns, and the tall and narrow cross section make the building more prone to severe damage. Numerous weak four-inch brick masonry partition walls might collapse and injure or even kill occupants. The anticipated structural damage is likely to cause significant damage to contents and collections.

5. The Tsuglag Khang is a complex structure due to additions that step down the existing slopes on the site in several directions. A detailed analysis is needed to determine the earthquake response. The GHI team identified a number of deficiencies that are likely to lead to damage during earthquakes. For example, substantial pounding damage is likely because of inadequate separation between building elements.

6. Collections at the LTWA main building and annex, and at the Tsuglag Khang might be damaged by overturning or toppling from their display and storage locations.

7. A number of other structures of importance to the Tibetan community display significant seismic vulnerabilities. Potential vulnerabilities were observed at the Tibetan Children's Village, the Office of His Holiness the Dalai Lama, and many residential and commercial structures in McLeod Ganj.

8. Local capacity to design and build earthquake resistant buildings appears limited. Dharamsala building authorities apparently do not enforce the seismic design provisions in the Indian building code. The team observed several structures under construction that did not have proper seismic detailing, and construction quality appeared poor. Newer structures in McLeod Ganj are sited in landslide areas. There is interest in improving the capabilities of the Tibetan community to build earthquake resistant buildings and to reduce existing earthquake risk.

Recommendations

The GHI team members believe improving the community's capacity to manage earthquake risk and correcting specific deficiencies identified at the LTWA campus and Tsuglag Khang can reduce the earthquake risk facing the Tibetan community. The following recommendations will begin to address the seismic vulnerabilities described in this report:

1. Prepare a facilities master plan for the LTWA campus that integrates seismic safety improvements with collection conservation, museum design, land use, and future construction and remodeling of library-administered buildings. Correcting seismic deficiencies on the LTWA campus will be a long-term process that should be integrated with maintenance and other projects.

2. Decide on the seismic performance objectives for each of the LTWA buildings. Performance can be described in terms of the amount of damage acceptable to LTWA decision makers.

3. Prepare as-built engineering drawings for the LTWA main building and annex, and the Tsuglag Khang. As-built drawings are a prerequisite for engineering work.

4. Search the LTWA archives for photographs and documents related to the construction of LTWA buildings and the Tsuglag Khang to determine the construction sequence and as-built conditions of the buildings.

5. Evaluate all of the buildings on the LTWA campus in more detail. A few representative buildings could be analyzed and the results used to decide which retrofit strategies apply to the other buildings of that type. The retrofit methods contained in the Indian building code might be appropriate for most of the small masonry buildings.

6. Conduct an engineering analysis of the LTWA buildings, and design seismic protection measures. The results of the analysis are necessary for identifying the best methods to reduce seismic vulnerability. The evaluation would consist of the following studies and design measures:
    a. Determine whether the structural elements that resist gravity load are adequate.
    b. Evaluate how the entire structure will perform during an earthquake through engineering calculations and physical testing of existing building materials.
    c. Evaluate the effect of constructing a proposed third floor addition.
    d. Determine the capacity of the brick and stone masonry walls to resist forces required to brace shelving, cabinets, or other elements.
    e. Design measures to retrofit the brick partition walls (if required).
    f. Design the bracing and anchorage for storage components and equipment not located in the museum.
    g. Design seismic protection measures for the museum collection in conjunction with a museum consultant.

7. Implement the following measures to protect human life and collections in the main LTWA building:
    a. Implement retrofit measures needed to improve the performance of the main building and its masonry walls.
    b. Brace storage shelves and collections displays to resist shaking and implement conservation measures.
    c. Create an off-site backup of the LTWA digital archives, documentation of collections and copies of original documents.

8. Retrofit the LTWA annex to reduce the chance of collapse, change its use and relocate people and important collections, or demolish and replace it with a new, safer building that meets the functional needs of the library. The LTWA staff should consider relocating some functions currently housed in the annex while deciding what to do with the building.

9. Conduct a detailed engineering analysis of the Tsuglag Khang complex. The results of this analysis are necessary for identifying the best methods to reduce seismic

vulnerability. No additional structures should be added until their effects on the seismic behavior of the complex can be ascertained.

10. Prepare detailed geologic maps of the LTWA campus and Tsuglag Khang complex sites and assess conditions. Before the start of the fieldwork, a topographic base map of sufficient scale (i.e., 1:6,000) and coverage is needed.

11. Investigate subsurface soil conditions and the embedment characteristics of the building foundations at the LTWA and Tsuglag Khang sites.,Soil samples should be collected and tested if necessary.

12. Perform a detailed seismic assessment of the Tibetan Children's Village (TVC). Seismically vulnerable campus buildings present a significant threat to Tibetan schoolchildren. The TCV community should be involved in earthquake preparedness and mitigation initiatives as soon as possible. Other area schools should be surveyed because they are likely to have seismic deficiencies as well.

13. Tibetan community members in Dharamsala, just as in other earthquake-prone locales worldwide, should be made more aware of their earthquake risk and what they can do to reduce their risk.

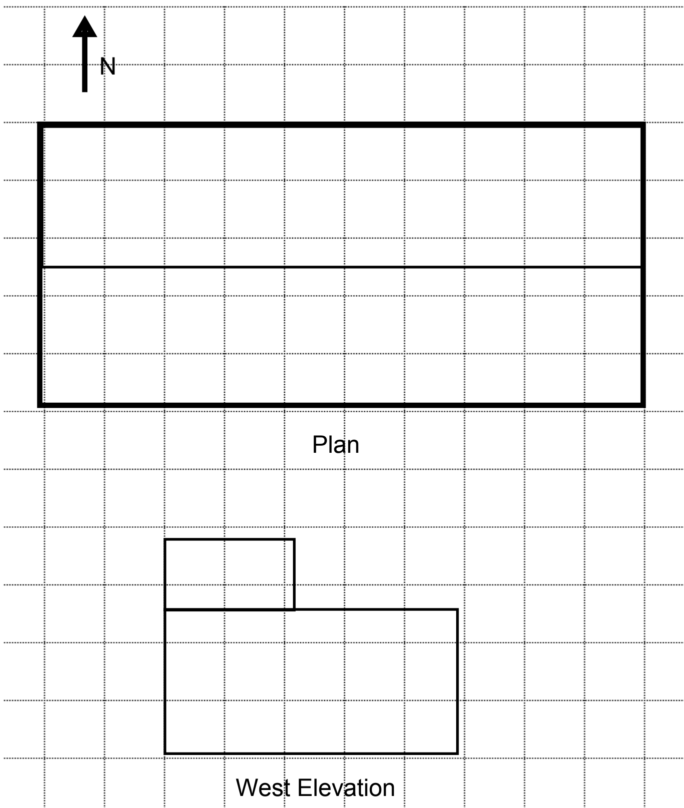
14. The Tibetan community in Dharamsala should undertake a comprehensive approach to reducing and managing earthquake risk. The effort would include a broader assessment of vulnerabilities; improving community awareness; developing a long-range plan to reduce the hazards and to prevent constructing new vulnerable buildings; and the preparation of an emergency response plan for the area based on estimates of damage to buildings, roads and other infrastructure.

Appendix A. Examples of Rapid Visual Screening Forms

Rapid Visual Screening of Buildings for Potential Seismic Hazards

FEMA-154 Data Collection Form

HIGH Seismicity



Scale: Not to scale

Address: LTWA Campus, Dharamsala, India

Zip

Other Identifiers White walls

No. Stories 2, partial 3rd story on back half **Year Built** 1970

Screener J. Rodgers **Date** Sept. 3 2006

Total Floor Area (sq. ft.)

Building Name LTWA Main Building

Use Library, museum, retail, instruction, office

OCCUPANCY			SOIL						TYPE	FALLING HAZARDS
Assembly	Govt	Office	Number of Persons	A Hard Rock	B Avg. Rock	C Dense Soil	D Stiff Soil	E Soft Soil	F Poor Soil	Unreinforced Chimneys / Parapets [x] / Cladding / Other:
Commercial	Historic	Residential	0 – 10 / 11 – 100							
Emer. Services	Industrial	School	101-1000 / 1000+							

BASIC SCORE, MODIFIERS, AND FINAL SCORE, *S*

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	**4.4**	**3.8**	**2.8**	**3.0**	**3.2**	**2.8**	**2.0**	**2.5**	**2.8**	**1.6**	**2.6**	**2.4**	**2.8**	**2.8**	**1.8**
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.4	+0.4	+0.4	+0.4	+0.2	N/A	+0.2	+0.4	+0.4	0.0
High Rise (> 7 stories)	N/A	N/A	+0.6	+0.8	N/A	+0.8	+0.8	+0.6	+0.8	+0.3	N/A	+0.4	N/A	+0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.0	-1.5	N/A	-1.0	-1.0	-1.5	-1.0	-1.0	N/A	-1.0	-1.0	-1.0	-1.0
Plan irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-1.0	-1.0	-0.8	-0.6	-0.8	-0.2	-1.2	-1.0	-0.2	-0.8	-0.8	-1.0	-0.8	-0.2
Post-Benchmark	+2.4	+2.4	+1.4	+1.4	N/A	+1.6	N/A	+1.4	+2.4	N/A	+2.4	N/A	+2.8	+2.6	N/A
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.4	-0.6	-0.6	-0.4	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-1.2	-1.2	-1.0	-1.2	-0.8	-1.2	-0.8	-0.8	-0.4	-1.2	-0.4	-0.6	-0.8

FINAL SCORE, *S* 1.0 (for example purposes; no cutoff score determined)

COMMENTS

Detailed Evaluation Required

YES NO

* = Estimated, subjective, or unreliable data
DNK = Do Not Know

BR = Braced frame
FD = Flexible diaphragm
LM = Light metal

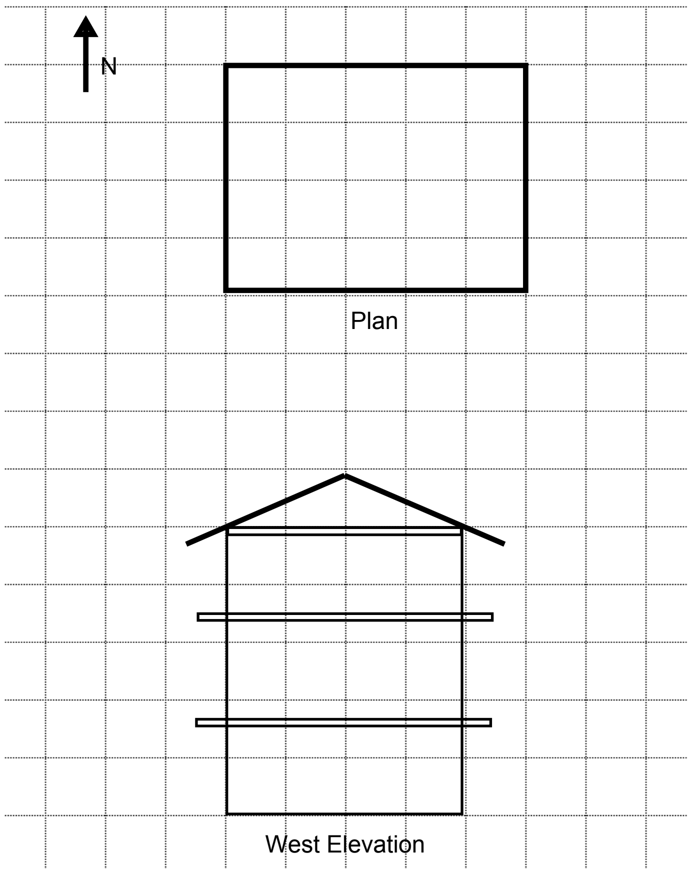
MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm

SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

Rapid Visual Screening of Buildings for Potential Seismic Hazards

FEMA-154 Data Collection Form

HIGH Seismicity



Scale: Not to scale

Address: LTWA Campus, Dharamsala, India

Zip

Other Identifiers Red walls, east of LTWA main bldg

No. Stories 3 **Year Built** ?

Screener J. Rodgers **Date** Sept. 3 2006

Total Floor Area (sq. ft.)

Building Name Building 8

Use Multi-family residence

OCCUPANCY			SOIL	TYPE	FALLING HAZARDS
Assembly Commercial Emer. Services	Govt Historic Industrial	Office Residential School	Number of Persons 0 – 10 11 – 100 101-1000 1000+	A Hard Rock B Avg. Rock C Dense Soil D Stiff Soil E Soft Soil F Poor Soil	☐ Unreinforced Chimneys ☐ Parapets ☐ Cladding ☐ Other:

BASIC SCORE, MODIFIERS, AND FINAL SCORE, S

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	**4.4**	**3.8**	**2.8**	**3.0**	**3.2**	**2.8**	**2.0**	**2.5**	**2.8**	**1.6**	**2.6**	**2.4**	**2.8**	**2.8**	**1.8**
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.4	+0.4	+0.4	+0.4	+0.2	N/A	+0.2	+0.4	+0.4	0.0
High Rise (> 7 stories)	N/A	N/A	+0.6	+0.8	N/A	+0.8	+0.8	+0.6	+0.8	+0.3	N/A	+0.4	N/A	+0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.0	-1.5	N/A	-1.0	-1.0	-1.5	-1.0	-1.0	N/A	-1.0	-1.0	-1.0	-1.0
Plan irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-1.0	-1.0	-0.8	-0.6	-0.8	-0.2	-1.2	-1.0	-0.2	-0.8	-0.8	-1.0	-0.8	-0.2
Post-Benchmark	+2.4	+2.4	+1.4	+1.4	N/A	+1.6	N/A	+1.4	+2.4	N/A	+2.4	N/A	+2.8	+2.6	N/A
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.4	-0.6	-0.6	-0.4	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-1.2	-1.2	-1.0	-1.2	-0.8	-1.2	-0.8	-0.8	-0.4	-1.2	-0.4	-0.6	-0.8

FINAL SCORE, *S* 0.0 (for example purposes; no cutoff score determined)

COMMENTS Frame at front of ground story instead of walls

Detailed Evaluation Required

YES NO

* = Estimated, subjective, or unreliable data
DNK = Do Not Know

BR = Braced frame
FD = Flexible diaphragm
LM = Light metal

MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm

SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill