Technical Guidance Note for

Establishment of National Centre for Hydrology and Meteorology Head Quarter, National Weather, and Flood Warning Centre and Scientific Facilities

Royal Government of Bhutan

Prepared in collaboration between the National Centre for Hydrology and Meteorology and the World Bank

CLIMATE INVESTMENT FUNDS

EUROPEAN UNION

GFDRR Global Facility for Disaster Reduction and Recovery

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Acknowledgement

Bhutan. Bridge. Photo: Adam Singer/Flickr. 2017.

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Editors: Susi Victor and Priya Susan Thom
Graphic design: ULTRA designs, Inc.
Cover photo: Dechen Tshering
Back cover photo: Adam Singer/Flickr

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1. Introduction

The National Centre for Hydrology and Meteorology (NCHM) plans to develop a new campus on a "green field" site to act as the headquarters and principal operations centre with technical and financial assistance from the World Bank. The NCHM is mandated to observe and understand the behaviour of the atmosphere over Bhutan, its interaction with the cryosphere and water bodies, the weather and climate of the country, and the distribution of the country's water resources. The Centre is identified as the nodal agency responsible for generation of information and delivery of products and services on weather, climate, cryosphere, and water resources in Bhutan. It was formed as an autonomous scientific and technical agency in 2016, having previously been a part of the Ministry of Economic Affairs. The establishment of the NCHM has brought together into a single organisation the study of all aspects of meteorology, climatology, hydrology, and cryosphere (glaciology and related science) in Bhutan, as well as aviation meteorology. In December 2019, the National Disaster Management Authority chaired by the Prime Minister designated the NCHM as the National Hydromet Hazard Early Warning Service Provider, pursuant to the Disaster Management Act 2013 to ensure clear and systematic early warning and notification to vulnerable populations and government agencies of threatening hydrometeorological hazards, disaster situations or events in the country.

At present, the NCHM headquarters offices are housed within the erstwhile Ministry of Economic Affairs, now the Ministry of Energy and Natural Resources complex, which is a suite of buildings designed for administrative work and not for the tasks of a science and technology-based organisation. NCHM does not have access to spaces designed for 24/7 operational work. It does not have the specialised facilities needed for instrument maintenance and calibration. Overall, NCHM does not have adequate space for carrying out meteorological observations in compliance with World Meteorological Organization (WMO) regulatory guidance. In order that its capacities may be fully used to the benefit of the citizens of Bhutan and serve as a regional Centre of Excellence on mountain meteorology, it needs to have facilities for education and outreach so that users can learn how best to take advantage of advanced forecast and warning information.

It is evident, therefore, that NCHM, to fulfil its varied mandates, needs to be housed in buildings that properly accommodate its diverse needs and requirements. Any meteorological and hydrological service is a complex amalgam of functions, from making weather observations, to collecting and communicating data in a time-bound manner, delivering operational services, conducting scientific studies and research, maintaining, repairing, and calibrating instruments, and so on. If NCHM is to be properly housed, and to deliver high-quality services to the citizens of Bhutan, it is urgent to plan for a new campus, built specifically to support the many and varied activities that flow from its responsibilities. In making plans for this new campus, it is important to consider not just NCHM's current activities but also those activities which it might carry out in the foreseeable future and beyond. The layout and design of the new campus of buildings should allow for expansion and modification to accommodate the evolving needs of the organisation over the coming decades.

The vision, mission, mandates, and core values of the Centre are elaborated below.

Vision

Centre of Excellence in Hydrology, Meteorology and Cryosphere Science and Services.

Mission

Monitoring and understanding of hydrology, weather, climate, and cryosphere, for timely provision of information and services to protect lives and property and support national needs for ecologically balanced sustainable development.

Core values

a. Commitment and loyalty in delivery of products and services

b. Integrity

c. Professionalism in support of science, research, objectivity, impartiality, and excellence

d. Mutual respect, cultural sensitivity, and non-discrimination.

Goals

The NCHM goals are to

a. Improve results- based decision support services for weather incidents and events that threaten lives and livelihoods;

b. Enhance climate services to understand and adapt to climate-related risks;

c. Develop the capacity to provide integrated and coupled monitoring, detection, and forecast services to support assessment and management of water resources and water-related hazards;

d. Build competence to provide sector-relevant information for socioeconomic development and support the development of integrated environmental services to foster healthy communities and ecosystems; and

e. Sustain a highly skilled professional workforce equipped with training, tools, and infrastructure to fulfil the mission.

Appendix 1 provides a table of indicative room sizes. The photographs of interiors are provided to stimulate thinking about possible options when a bespoke building for a specialised organisation can be designed.

Thimphu river.

1.1 Geography and Climate

Located on the southern slopes of the Himalayas, the altitude of Bhutan ranges from over 7,000 m in the north to about 200 m in the south; it therefore experiences a wide variety of climatic conditions and is home to a diversity of ecosystems. Most of the human habitation is confined to the steep valleys and gorges which are cut into the southern flanks of the Himalayas by fast-flowing rivers.

Meteorology both straddles and encompasses many facets of human knowledge and behaviour. Weather, which is the day-to-day manifestation of meteorology to the layperson, is shaped by the landscape but it is also a force that shapes the culture and the livelihoods of the people who live there. Weather is a universal experience of the poor, the wealthy, and the urban and the rural dweller; it is a constant presence in our lives and yet is ever changing. The weather experienced in a country, region, or valley is an integral part of the identity of that country, region, or valley—just as much as the native vegetation or the dwellings, which are themselves shaped by the prevailing conditions.

Meteorology, which is the scientific study of weather, offers a completely different facet and perspective. Meteorology seeks out the universal physical laws and forces which govern the behaviour of weather. These same laws apply everywhere across the globe, although their local manifestations are so different and diverse. There have been tremendous scientific advances in meteorology over the past 75 years, bringing weather forecasting from the realm of magic and mystery into a realm of scientific rigour and reliability. Of all the physical sciences it is the one which has been most focused on translating theoretical insights into practical products and services of immediate benefit to people and to society. Paradoxically, it has also brought us a deeper knowledge of the fragility of our environment and the depth of damage which we are inflicting on the seemingly boundless atmosphere.

Hydrology too has benefitted from a combination of careful observation and measurement and improved theoretical understanding to deliver significant and meaningful benefits to society. In this case, it is the understanding and prediction of water flows—water which is essential to life in all its forms, but which can become such a destructive force on occasion. Bhutan, with its high Himalayan peaks, has the added challenges presented by water in its solid or frozen state, as snow and glacial ice accumulate and then melt to feed fast-flowing and fast-flooding rivers.

1.2 A new Headquarters Campus for NCHM – the rationale

At present the NCHM HQ functions are accommodated in standard office buildings within a government compound close to downtown Thimphu. The forecast offices (meteorology and hydrology) are located in an adjacent building that has significant drawbacks in regard to providing operational spaces; the operations rooms are rather small, and are divided by supporting columns, effectively breaking up the working space into even smaller units. There are no laboratory facilities for the maintenance and calibration of equipment, much less the sort of facilities that would be needed for water quality work and sedimentation analysis.

The benefits that will flow from the provision of a well-designed HQ campus for NCHM are multi-fold. At an operational level, it will facilitate the provision of top quality meteorological and hydrological products and services to the citizens of Bhutan, including the critical early warning services. At a broader level, it will support food security, hydropower, transport, tourism, and other key economic activities through facilitating more extensive and more targeted meteorological and hydrological services. These services will help minimise the vulnerability of the Bhutanese economy to shocks deriving from natural hazards. At a technical level, the facilities will support the operation, maintenance and calibration of equipment that comprises the essential

meteorological and hydrological observing network of the country. At an ICT level, it will provide a "nerve centre" for the collection of meteorological and hydrological data, and its exchange with the global community. At a scientific level, it will support excellence in meteorology and hydrology through providing opportunities for experts to gather and exchange knowledge; indeed it could well host a Regional Centre of Excellence in key subjects such as Mountain Meteorology or Glaciology.

There are no specific facilities for accommodating educational groups, nor those for hosting meetings and conferences. In short, the physical facilities do not, in any sense, support the very particular needs of a scientific and technical organisation that is focused on public services, services that should be underpinned by a strong organisational identity and a very visible public presence.

An added challenge arises from the need for resilient 24/7 operational services, and ensuring that adequate staff are always available to sustain these services. Experiences during the COVID-19 epidemic, in Bhutan and elsewhere, exposed the difficulties of maintaining operations during these interruptions to the normal functioning of society – interruptions that can also be caused by severe weather events, or seismic occurrences. These latter are precisely the occasions when fully-functioning meteorological and hydrological services are most needed by society to ensure the safety and security of citizens. The clear inference is that a sufficient number of NCHM staff should reside in close proximity to the operational offices, as the best way to ensure their availability and the resilient provision of essential services.

These many considerations lead to the conclusion that a new, purpose-built, campus should be provided for NCHM, comprising specific buildings devoted to administration, to operational service provision, to technical laboratories, to educational and meeting spaces, to a variety of other support functions, and to residential accommodation for sufficient staff that will guarantee resilient services. The campus should also allow for the siting of weather observing equipment, including provision for balloon launches to gather upper-air data. It would clearly be impossible to accommodate all of these diverse needs on the existing site, and the space required will be such that a suitable site is unlikely to be found near the centre of Thimphu.

1.3 Some logistical and design considerations

Any project to develop a new headquarters for the NCHM Bhutan needs to be mindful of the diverse perspectives that surround the topics of meteorology, hydrology, and weather.

As noted above, the buildings will need to accommodate and support scientific work of the highest order as well as experimentation, instrument maintenance, and calibration. They will need to sustain not just the 24/7 operations of weather and flood forecasting but also the advanced technology and telecommunications that connect national meteorological services (NMHSs) globally and facilitate the gathering of weather data, the 'raw material' of weather products and services. The buildings will need to provide spaces for education and outreach and offer an open and welcoming experience for schoolchildren and other visitors.

Apart from addressing the technical and logistical needs, the buildings will need to incorporate the traditional architectural styles of Bhutan. They will also need to project the important place which the NCHM has within the community in Bhutan, as a government agency focused on public service. It goes without saying that the buildings themselves need to be resilient to natural hazards, including flooding, heavy rain, lightning, strong winds, and seismic events.

This brief will attempt to define, as completely as possible, the different needs that must be accommodated in the new headquarters campus

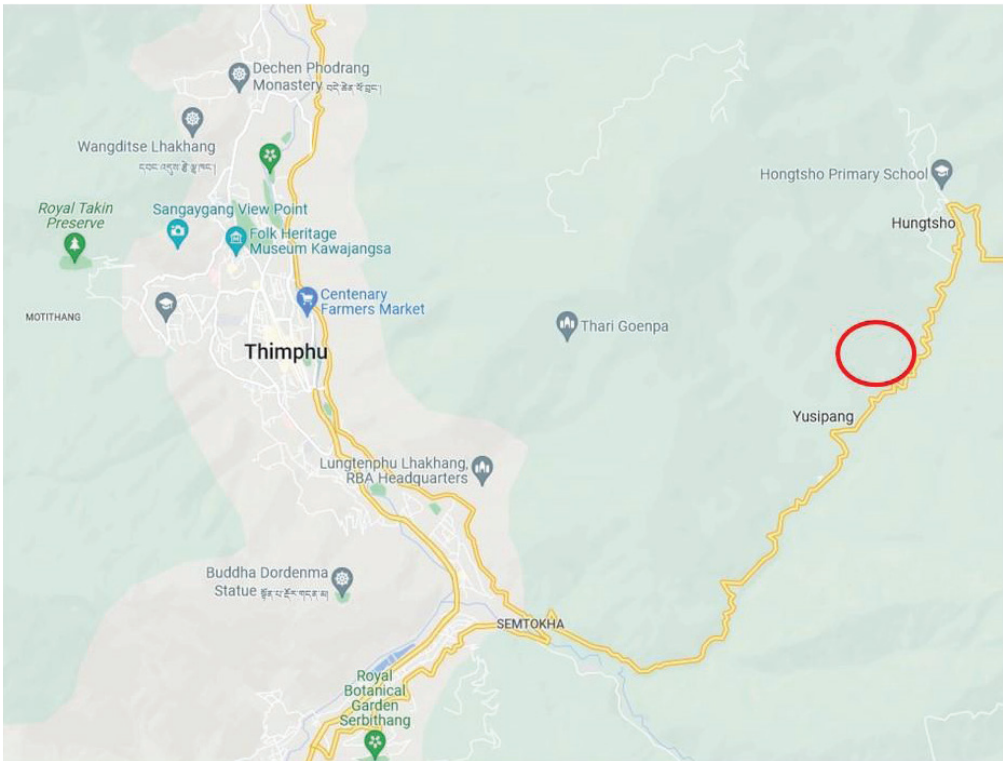
for the NCHM, ranging across a wide variety of requirements and context. The descriptions and definitions will be grouped according to purpose; for example, the requirements for a conference centre will be provided separately from the needs of the 24/7 operations centre for weather and hydrology forecasting; the accommodation requirements will also be separate.

The campus may be thought of as an assemblage of different physical buildings or as different functions and requirements brought together in a group of connected buildings. The traditional architectural styles of Bhutan incorporate many examples of building complexes that house a multitude of functions, especially dzongs and monasteries. These styles may provide an inspiration, adapted as necessary to the scientific and operational requirements which are paramount. The 2014 publication '*Bhutanese Architecture Guidelines'* from the Ministry of Works and Human Settlement provides a rich source of reference and guidance in respect to the traditional building forms and styles that have evolved in Bhutan in response both to the physical environment and the cultural landscape. In addition, the planning and design will also be guided by the Bhutan Building Regulations 2018, Building Code of Bhutan 2018, and respective local development control regulations where applicable.

1.4 Location

The site which has been identified as the most favourable location for the new NCHM campus lies about 15 minutes' drive from Thimphu main city, close to the Thimphu – Wangdue national highway. Land acquisition is in progress and the Centre is pursuing relevant agencies and local governments for the requisite permits. However, the site is typical of any other in the vicinity of Thimphu in that it is steeply sloping and in an area of forest and scrub. The area of the proposed site is around 5 acres. The altitude of the site is around 2,800 m above sea level, which is 350 m higher than Thimphu.

Figure 1: Site location at Yusipang outside Thimphu



Source: Google Maps.

Figure 2: Site location, showing also nearby government facilities

Source: Google Earth.

Some photographs taken at the site are provided below, to give an impression of the nature of the uneven, rocky ground.

Figure 3: Photographs of the proposed site for the NCHM campus

Source: Gerald Fleming.

Considering the steep slope of the site and the constant seismic risks in Bhutan, in general none of the operational buildings should be more than two stories in height. Movement between the principal buildings might be facilitated by protective walkways to shield both from heavy rains and intense sunshine. Efficient drainage will need to be provided to keep heavy rainfall and flash floods from threatening the buildings with inundation, and it will be particularly important to similarly protect ducting for power lines and communication links. It is of key importance that this complex of buildings be as resilient as possible to natural hazards, as it is precisely at the times of those hazards that the guidance and advice from the National Weather and Flood Warning Centre (NWFWC) will be most needed.

The location of the site in a rural area, accessed by a road which is susceptible to blocking by landslides, dictates that sufficient accommodation be provided on site to ensure that the critical 24/7 work of the NWFWC, the operational heart of the NCHM, can be maintained by those living on site or nearby. The location also dictates that access by car and bus will be necessary and the campus design should incorporate internal circulation roads, parking facilities, safe bus stops, etc. Given the altitude, it can be expected that winter conditions will bring snow and ice, so road gradients will need careful design to allow for this risk.

Small river in the Jigme Singye Wangchuck National Park, Bhutan. Photo: only_fabrizio.

2. Overview of the NCHM

Figure 4 presents the organogram of the NCHM. A re-organisation in mid-2022 saw the creation of the Technical Standard and Research Division, among other changes. The approximate numbers in each location and their work position, insofar as it is relevant to the design brief for the buildings, is given in Table 1. A brief description of the divisions and their responsibilities is given in the following paragraphs.

2.1 The Secretariat

The Secretariat is the top-level organisational and administrative unit of the NCHM. Led by the Director, the Secretariat encompasses a number of cross-organisation functions such as finance, human resource management, procurement, stores, and administration. Office vehicle drivers are also assigned to the organisation.

Figure 4: NCHM organogram following reorganisation

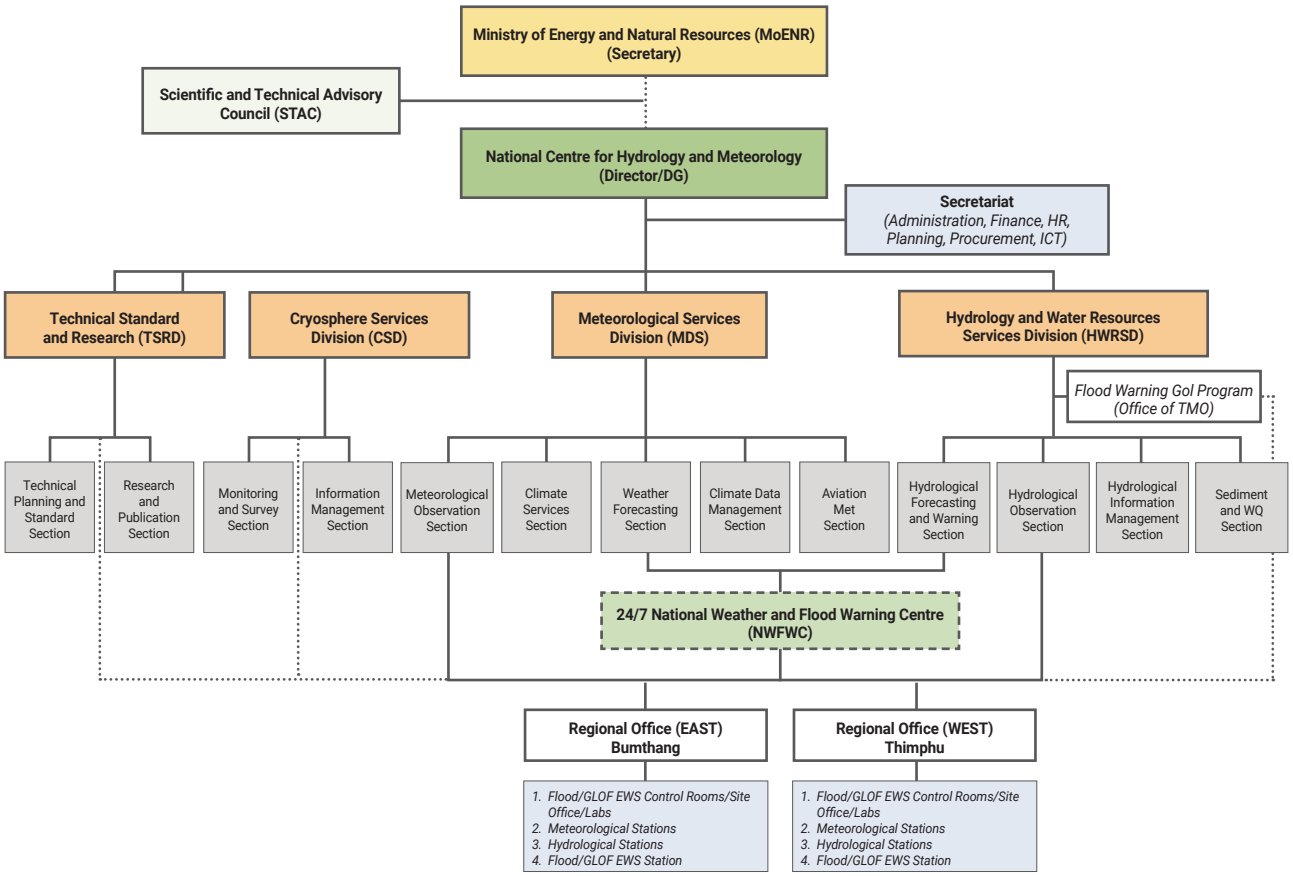


Table 1. Staff numbers by division and by location

Location/Function	Secretariat	Technical Standards and Research Division	Cryosphere Services Division	Weather and Climate Services Division	Hydrology and Water Resources Services Division	Total
Director/Chiefs	1	1	1	1	1	5
HQ - for 9–5 work	12	3	7	14	16	52
NWFWC shift work	—	—	—	8	5	13
Paro Airport	—	—	—	9		9
Laboratories	—	3	—	—	4	7
Drivers	8	—	—	—	—	8
Other locations	—	—	—	25	91	116
Totals	21	7	8	57	117	210

2.2 Technical Standards and Research Division

This is a new division which will have responsibility for ensuring that the appropriate technical standards relating to meteorological and hydrological work, as laid down by the WMO and others, are applied in all NCHM activities. The division also has the responsibility of coordinating all the research work carried out within the organisation.

2.3 Cryosphere Services Division

This is a small division of eight persons involved in research and understanding of the behaviour of the cryosphere (snow/ice/glaciers) and to help predict the risk of glacial lake outburst floods (GLOFs) and similar hazards related to the cryosphere.

2.4 Meteorological Services Division

This division is responsible for the preparation and delivery of forecast and warning services, and some of the staff of this division support the 24/7 forecast operations. The total staff strength of the division is 57, with 23 of these working in HQ; of these, approximately 8 work on a 24/7 shift basis in the NWFWC with the remainder working on a 9-to-5 basis. The division is also responsible for maintaining the climatological records of weather conditions in Bhutan and providing climatological services and products based on these records.

2.5 Hydrology and Water Resources Division

This division is responsible for the weather and hydrology observation network of the NCHM. Numerically, it is by far the largest division with more than 100 staff members; however, the majority of these are stationed at the observing sites across Bhutan. Around 26 staff members of this division are based in the headquarters complex; this includes some based in the NWFWC and some working in the laboratories.

The more senior staff of the division are engaged in overseeing the smooth operation of the observing infrastructure and planning for replacements and improvements as they are needed.

Overall, the number of staff who will require to be accommodated at the new NCHM campus is somewhat less than 90, of whom about 57 will be working normal office hours while approximately 13 will cover the 24/7 forecast operations—suggesting that 2 or 3 staff will be on duty at any given time. There are also approximately 7 staff who will be based in the calibration and water quality laboratories and 8 drivers.

3. Building for the Future

In designing a new campus for the NCHM, it is very important to look at the future needs of the organisation. The buildings which are planned and constructed now may well provide a home for the NCHM for a century or more. While it is clearly impossible to foresee all the needs and requirements that might arise over such a long period, it is necessary to make provision for the likely development of the organisation over the coming decade at least.

These developments can be anticipated through comparing the capabilities of the NCHM today with the capabilities of National Meteorological and Hydrological Services (NMHSs) in small but technically advanced countries such as Singapore; Hong Kong, China; Iceland; and Denmark etc. The range of services provided by these NMHSs would be an appropriate goal for the NCHM in Bhutan, and the new campus for the organisation should provide the physical infrastructure that would support this level of development.

Some of the developments that can be anticipated and that will need to be catered for in any new campus for the NCHM are as follows:

3.1 Observing Infrastructure

a. **Synoptic station.** Provision should be made for the establishment of a full synoptic station within the grounds of the new campus. The WMO recommends an enclosure of 25 m x 25 m, situated as far as possible from buildings, trees, and other possible structures that might affect the meteorological parameters being measured (especially temperature, relative humidity, wind speed, and wind direction). Figure 5 depicts a typical layout for the instrument enclosure of a synoptic station.

b. **Calibration laboratory for meteorological equipment:** a facility to support the repair, maintenance, and routine calibration of meteorological observing equipment.

c. **Hydrology and sediment laboratory:** a facility for repairing, testing, and calibrating hydrological instrumentation and also for soil and sediment analysis.

d. **Upper-air balloon launch site.** At present there are no upper-air stations in Bhutan, a significant gap in the meteorological observing infrastructure. As part of the design of the campus, a site for upper-air balloon launches should be identified and designated and, if possible, a building provided to accommodate this activity. Alternatively, an auto-launcher might be used; as illustrated in Figure 6, these are typically the size of a small shipping container.

e. **Facilities for reception of weather satellite data,** especially from the geostationary satellites operated by EUMETSAT, HIMAWARI SAT, IRIDIUM SAT, and INSAT. Satellite re-broadcast facilities such as EUMETCAST use standard Digital Video Broadcasting (DVB) satellite dishes (such as are used for TV reception by satellite) which are small and easily mounted on the roof or wall of a building.

f. **Weather radar.** The local staff of NCHM and experts in radar meteorology should be engaged to explore whether it would make sense to set up a weather radar in Thimphu (given the surrounding topography).

g. **Seismological equipment.** It would be worthwhile to consult the Department of Geology and Mines in Bhutan to determine whether they might wish to locate some seismological equipment on the new NCHM campus.

h. The **installation of equipment for air quality monitoring** should also be allowed for.

Figure 5: Typical layout of a full synoptic weather observation site

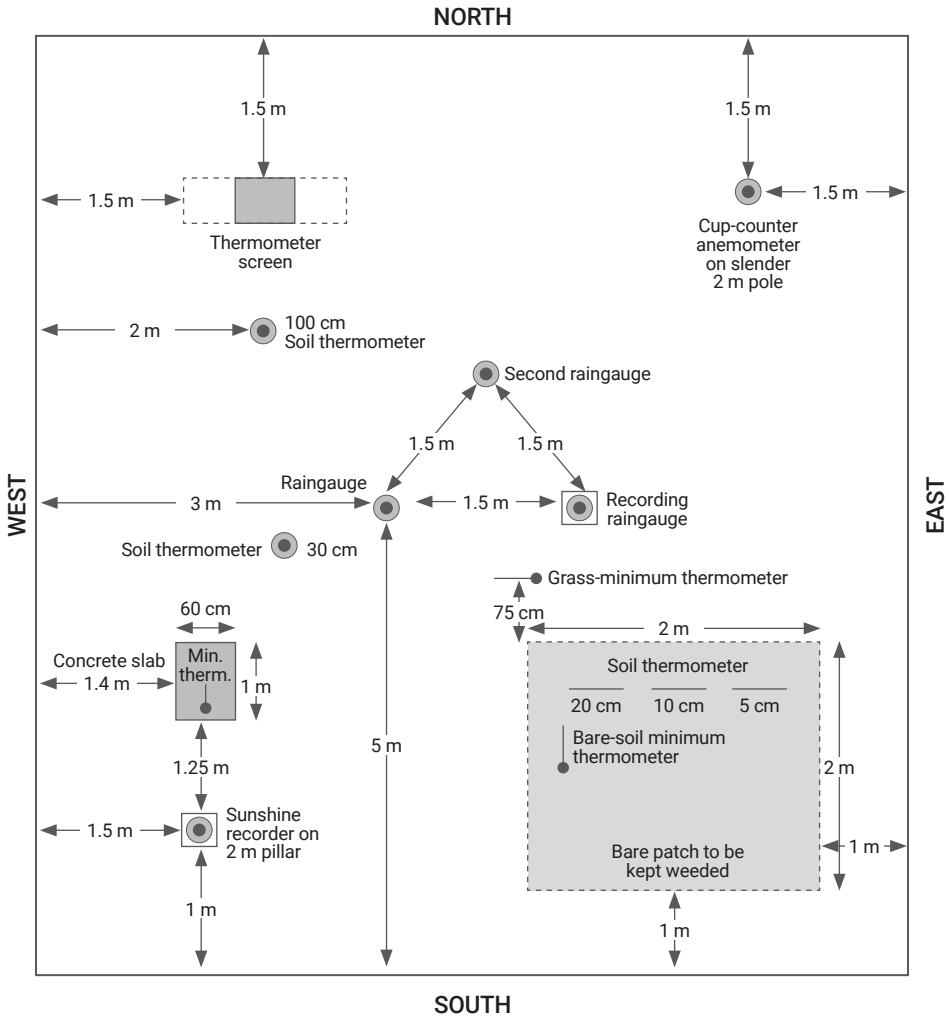


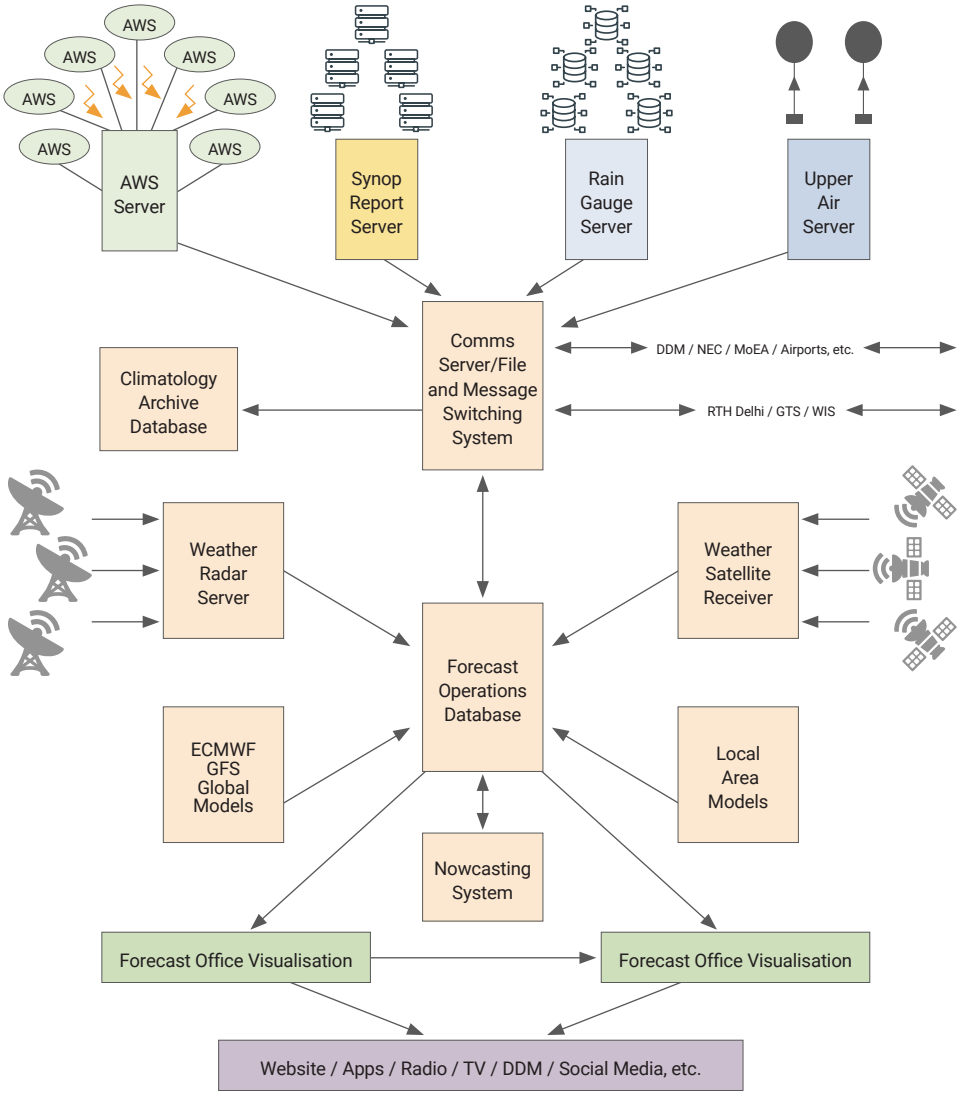
Figure 6: Weather balloon auto launcher

Source: www.vaisala.com.

3.2 ICT Infrastructure

a. The NCHM lacks a fully functioning Meteorological Data Centre which would act as the collection and storage hub for meteorological data and products. A Meteorological Data Centre would comprise a number of elements such as servers to collect Automatic Weather Station (AWS) data, servers to automatically collect synoptic station reports, servers for weather satellite reception and processing and for weather radar reception and processing, an integrated file and message switching system (to handle data communication internally and also with the WMO Information System network), a forecast operations database, data visualisation systems (for the forecasters to use), a meteorological production system, a data archive, a Climate Data Management System (CDMS), and a High Performance Computing (HPC) facility for the running of local-area numerical weather prediction (NWP) models. Figure 7 provides a schematic of the different elements that may comprise a Meteorological Data Centre.

Figure 7: Schematic of a meteorological data centre and technical ICT system



Note: AWS = Automatic Weather Station; ECMWF = European Centre for Medium-Range Weather Forecasting; GFS = Global Forecast System; WIS = WMO Information System; GTS = Global Telecommunications System; RTH = Regional Telecommunications Hub; MoEA = Ministry of Economic Affairs; DDM = Department of Disaster Management; NEC = National Environment Commission.

b. The collection and distribution of weather data should be a 24/7 activity. Thus, trained information and communication technology (ICT) technical experts should ideally be available to oversee this operation and to take corrective actions should there be interruptions to the data flows. They will need to be accommodated near the data centre.

c. Similarly, the hydrologists will need to be able to collect and view data in real time from the gauges and other measurement devices placed in rivers and streams.

d. The need for resilient 24/7 operations also demands the provision of a back-up generator and uninterruptible power supply (UPS) facilities on site to maintain ICT and forecast office operations in the event of a general power outage in the locality. Associated with the back-up generator will be the need for a secure area for fuel storage surrounded by a bund to contain any fuel leaks etc.

e. Similarly, communication links need to be duplicated (for example, fibre broadband and microwave links or two fibre broadband links that are physically separate and routed to different telecom suppliers) to ensure the continuous flow of essential data.

f. In addition to the specialised needs of the NWFWC, there will be a need for an email server, a shared file server, print servers, and similar equipment that support normal office working. Appropriate ICT security systems, such as firewalls, will also need to be accommodated.

3.3 Services

a. **Aviation services.** Such services will maintain 24/7 meteorological watch over the airspace of the Bhutanese Flight Information Region (FIR) and provide forecast and warning services to aviation including TAFs, TRENDs, SIGMETs, and aerodrome warnings. While it may be possible to locate these services at Paro Airport, it may be more practical and more efficient to locate them in the NWFWC where the aviation forecasters would have easy access to all the data and facilities made available through the new Meteorological Data Centre. At the very least there should be an aviation forecasting contingency desk located in the NWFWC to act as a back-up to forecasting operations at Paro.

b. A close working relationship must be maintained with the National Emergency Operations Centre (NEOC). The new building that will house the NWFWC will need an area for the conduct of teleconferences with the NEOC and district-level bodies engaged in emergency management.

c. Broadcast services will also need to be facilitated within the NWFWC, allowing live radio and television broadcasts to be provided from the centre in addition to the possibility of recording forecast segments, podcasts, and other material suitable for dissemination through the internet.

d. While flood warnings are currently issued by the NCHM on a detect-and-warn basis, routine forecasts of river levels are not disseminated. It is noteworthy that Bhutan has a very significant hydro-electrical sector; forecasts of water levels in rivers are also of significant interest to other sectors such as agriculture, construction, road engineering, and tourism as well as for day-to-day water resource management. The new complex should make provision for a continuously manned desk to oversee river levels, examine the output of flood models, and issue routine advisories on river water levels as well as flood warnings when these are necessary.

e. **Monthly and seasonal forecasting.** As a member of the South Asia Climate Outlook Forum (SASCOF), the NCHM has access to extensive research and guidance on climate forecasts in the monthly to seasonal range and disseminates these to many users. There is also an increasing amount of such guidance freely available from global NWP centres such as the ECMWF. This area of service requirement is likely to grow significantly in the coming years

as the skill of the model guidance at these time ranges increases, potentially providing more valuable guidance to many key users.

f. **Weather observing.** The complex is intended to include a new synoptic observatory and an upper-air balloon-launch facility; the staff who operate these services will need office accommodation within the campus.

Most of the above services will need to be accommodated in the new 'operational' building that will house the staff to provide 24/7 forecast and warning services, the ICT infrastructure to support NCHM operations and communications (both within the country to the regional office and the observing network and outside the country to the WIS and to other NMHSs in the region), and the staff to monitor and oversee all the ICT activities.

A substantial number of other staff need to be accommodated, who will normally work on a '9:00 AM to 5:00 PM' pattern. These include the senior management and the planning and administrative staff of the organisation, those engaged in research and development, engineers, hydrologists, meteorologists, climatologists, glaciologists, systems analysts and application developers, instrument specialists, sectoral specialists (such as agro-meteorologists), and so on. It will ultimately be a matter of discussion between the client (the NCHM) and the design team how to distribute the housing of 'operational' and the 'non-operational' staff in different buildings, but for the purposes of this design brief, we will assume that the NWFWC building will house all the operational activities, together with some educational spaces, and that a separate building will house all of the "9:00 AM to 17:00 PM" staff.

An important area of activity of the NCMH is that of public education and outreach. This covers many aspects, ranging from visits of schoolchildren through to international high-level academic conferences on themes related to hydrometeorology. The design will need to take these activities into account, providing for a range of spaces where groups of different sizes can be accommodated and which can support audio-visual presentations and other important educational and conference facilities. In addition to the more traditional forms of learning, a facility incorporating design computers, 3-D printers, and similar technology will be required to host hackathons and other forms of collaborative, hands-on learning and innovation opportunities.

The practical daily needs of staff must also be considered. A canteen or restaurant facility will be needed, with the capacity to cater for meals to approximately 60 staff. This should have an open and pleasant aspect to help the staff relax during time away from the desk. As some of the staff work on a 24/7 roster, they will require accommodation on the campus to facilitate their rest periods. Sports and recreation facilities should be provided to encourage informal mixing of staff and healthy outdoor pursuits.

Substantial storage areas will be needed; this campus will be the headquarters for the national organisation and thus the point of delivery for many supplies, not just for the on-campus activities but for the various regional offices and observing stations all over Bhutan.

The campus itself will also need to be protected, maintained, and cared for and the design should incorporate appropriate facilities for caretakers, cleaners, maintenance staff, gardeners etc.

4. Details of Required Accommodation

4.1 HQ Building

This building should accommodate the staff of the Secretariat together with the other senior officers and the planning and research staff of other divisions who do not need routine interaction with the operational work of the NWFWC.

a. **Entrance hall/reception area.** This building will incorporate the main reception area for visitors. This reception area should be a generous space, sufficiently large to allow groups of 20–30 to congregate together with a reception desk. Access from the entrance hall/reception area to the remainder of the building will need to be controlled for security purposes via the use of a door operated via a swipe card, fingerprint recognition system, or similar. The Entrance Hall may also be used for permanent or temporary exhibition of posters and items relevant to the work of the NCHM, and therefore some display area might be included in the design.

b. **Director's Office.** This office should be large enough to accommodate a desk for the Director in L-shape configuration with approximate dimensions 2m by 1.8m. The room should have space for a separate table with at least six chairs suitable for hosting small or informal meetings.

An anteroom to the Director's Office should be provided, to accommodate a desk and work-

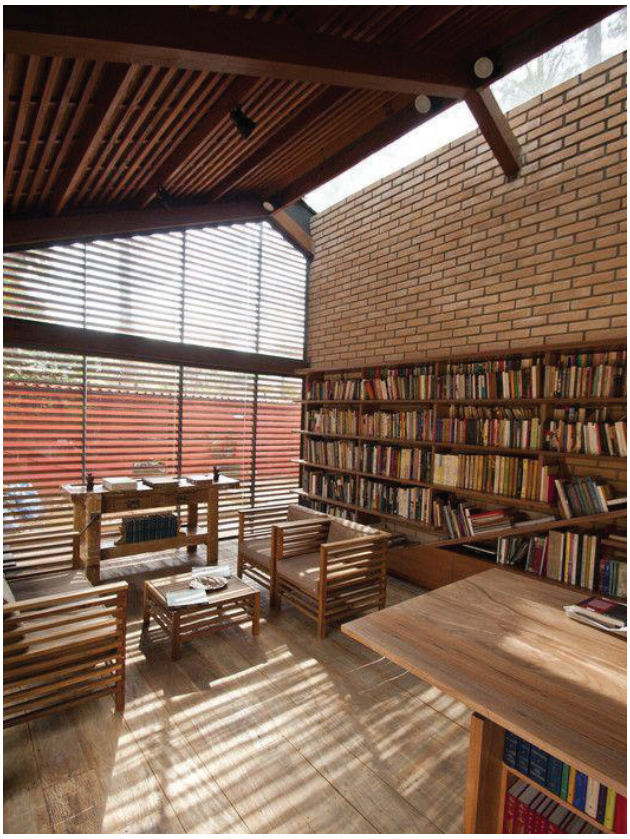
Figure 8: A reception area example

Source: www.dezeen.com.

ing space for the Director's personal assistant (PA). There should be two means of entry to the Director's office: one via the office of the PA and another directly from the corridor. The offices between them should be suitable for accommodating extensive storage of files.

c. **Library/Reading room.** Provision should be made in the HQ building for a small library and reading room to facilitate the study of academic texts, journals etc. This should be located in a part of the building benefitting from good natural light. It should be sized to accommodate four to six persons working/reading simultaneously. The library should be designed for comfortable browsing and reading and should also be equipped with WiFi or similar services for those using laptops.

Figure 9: An attractive and welcoming library space



Source: www.dezeen.com.

d. **Climatological archive.** The preservation of records of meteorological, hydrological, and glaciological observations is one of the most important responsibilities of an NMHS. Many of these observations are preserved in paper records, some of which can be fragile. Thus it is important that a suitable storage area be provided, equipped with temperature and humidity control and a suitable shelving system to accommodate these records and to allow them to be easily and safely accessed without undue disturbance to surrounding records. The room should be sized with a view to accommodate future as well as existing records; a space of at least 40 m^2 is suggested.

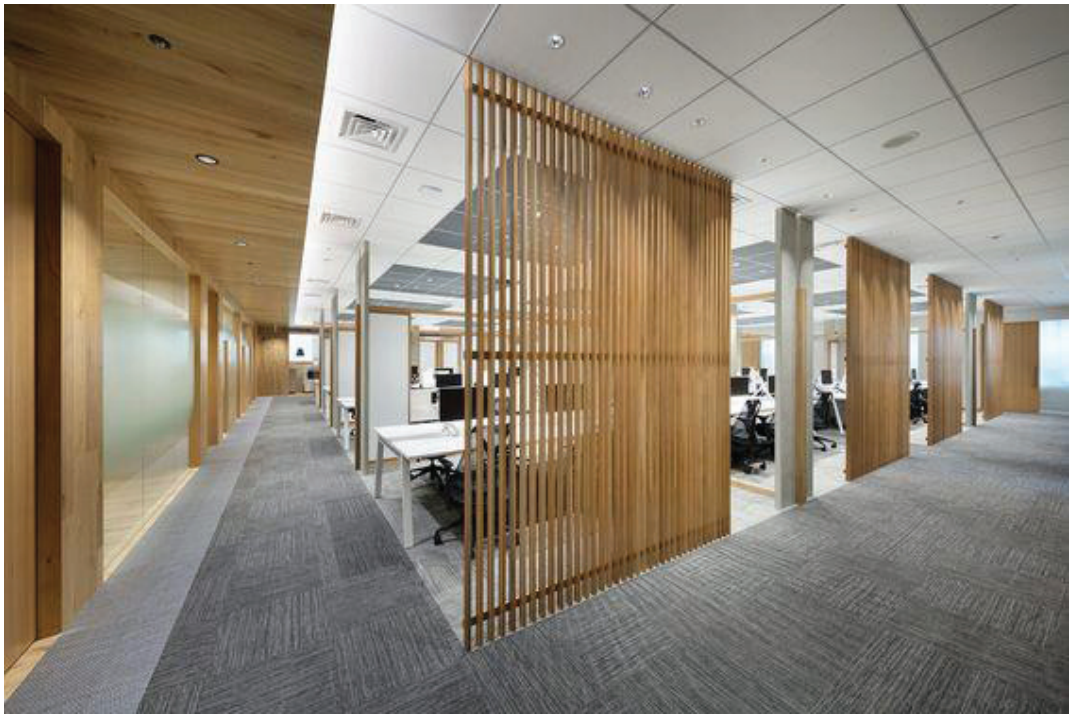
e. **Chief's offices.** Each of the four divisional chiefs will need an office similar in scale to that of the Director, allowing for a large working desk and a separate informal meeting area equipped with a table and four to six chairs.

f. **Other office space.** The HQ building will also need to accommodate between 50 and 60 staff working in regular '9 to 5' (non-operational) positions. An open plan office is preferred, with informally divided spaces that can accommodate (typically) six to eight staff members.

   All working desks should be provided with four electrical socket outlets and network connections with Cat6 cabling. The working spaces should be sized to accommodate at least one storage press and one filing cabinet for each of the working desks. The design should allow for approximately 9 m^2 for each working area, to include space for a desk, chair, filing cabinet or other storage, and circulation.

   To contribute to a quiet working environment, some consideration might be given to providing small 'machine rooms' to accommodate the base units of personal computers (PCs) and workstations, connected to the working desks via KVM (Keyboard, Video, Mouse) extenders, Citrix connections, or similar. This would help ensure a quiet environment for the staff and a clean, dust-free environment for the computing equipment, to the benefit of both.

Figure 10: Example of open-plan office area divided into different spaces



Source: www.dezeen.com.

Figure 11: Example of a board-room type of meeting room

Source: www.dezeen.com.

g. **Meeting rooms.** A small conference room/boardroom with accommodation for approximately 20 persons should be located in the HQ building close to the Director's Office. This room should be equipped with audio-visual facilities and connectivity to facilitate remote access to meetings held there.

   Three other small meeting rooms should be provided within this building, of varying sizes—from a room to accommodate 4 persons up to a room to accommodate 10 persons. All the rooms should be equipped with audio-visual equipment and connectivity to facilitate remote access to meetings held there.

h. **Toilet/washing facilities.** The building should be provided with toilet/washing facilities suitable for the use of 60 staff.

i. **Cleaning and storage space.** Some rooms will need to be set aside for cleaning and building maintenance staff to store equipment and tools etc. In particular, cleaning staff will need access to a sluice sink or similar facility and space to store cleaning equipment.

4.2 National Weather and Flood Warning Centre Building

This building will accommodate all the 24/7 operational functions of the NCHM, including weather and flood forecasting and warning services, together with the communications and computing data centre which will be the central collection and processing facility for meteorological and hydrological data. It will also provide standard office accommodation for some of the support staff.

Operational forecast room. This room will accommodate all the weather and flood forecasting operations. The room will need to be designed to take a video wall for the display of multiple screens of information, so it will need a clear ceiling height of at least 3.5m (not including any ceiling voids or raised flooring for the provision of services). The room should be large enough to accommodate six separate work positions with generous circulation space. The work positions should all face the video wall and should ideally incorporate curved/L-shaped desks with ample space for mounting up to four widescreen monitors side by side. (monitor sizes can be up to 27", typically 61cm wide). The six work positions are designated as follows:

a. Weather Forecast One
b. Weather Forecast Two
c. Flood Forecast One
d. Aviation Forecast Contingency
e. Emergency Forecast Desk
f. ICT Oversight and Monitoring.

Each desk should be supplied with eight electrical power sockets and network connections with Cat6 cabling. It should always be borne in mind that a 24/7 office will suffer wear and tear at approximately four times the rate of a standard '9 to 5' office, so the materials specified for floor coverings, finishes, and furnishings should be hard-wearing and resilient.

The forecast room will typically be of significant interest to visitors as the operational 'heart' of the organisation. There is a need to strike a balance between allowing guests (ranging from school groups to ministers or other VIPs) to visit the room and allowing those assigned to operational tasks to carry out their important work without interruption or distraction. The design may wish to address this balance through provision of a space where the room can be viewed by visiting groups without unduly disturbing the forecasters.

The first photograph below (Figure 12) shows the operational forecast room of the Danish Met Institute (DMI) in Copenhagen. This is situated in a 'normal' office building and not especially built for DMI. The following three photographs (Figure 13 to Figure 15) show the operational forecast room in Muscat, Oman, where the meteorological service was able to commission a specially designed building for its activities.

Figure 12: Operational forecast room in the Danish Met Institute (Note the ceiling height, the video wall, and the 'standing' desk)

Source: Tim Hewson.

Figure 13: Overview of the operational forecast room, Muscat, Oman

Source: Kieran Commins.

Figure 14: Operational forecast room Muscat, Oman – Video wall

Source: Gerald Fleming.

Figure 15: Operational forecast room Muscat, Oman – Looking back at the forecasters' desks

Source: Gerald Fleming.

This latter example provides a good idea of what is possible if a building/room can be designed from scratch to accommodate the requirements of operational weather and flood forecasting. Note that the Muscat office is 'double height' with a viewing gallery/mezzanine in the rear, allowing visitors to view the room without disturbing the forecasters. Note also the generous curved desks that are used.

Studio/presentation room. A space adjacent to the Operational Forecast Room will be needed for the preparation and delivery of weather broadcasts, preparation of video inserts for publication on the NCHM website and on social media, and for remote connection to deliver weather briefings to the NEOC. This space should be sound-proofed and should, like the operations room, have at least a 3.5m ceiling height to accommodate studio lighting. One wall will house a display screen or chroma-key area. The dimensions of the room should be at least 6m by 5m but it could be larger if it is to double-up as a training room.

Education space. The NWFWC building should incorporate a dedicated education space capable of accommodating school class visits and similar groups. The space should incorporate audio-visual and other facilities that may be used in educational activities. This can be an enclosed space or designed as more open, perhaps with a view to the Operational Forecast Room (although in that case there would need to be good sound-proofing to avoid the inevitable noise of schoolchildren that could be a disturbance to the operational work).

The educational space should be welcoming and informal in nature, with space for group activities as well as more formal presentations. It would be useful to locate toilet and washroom facilities adjacent to this educational space.

Figure 16: An informal seating space for accommodating school groups

Source: www.archdaily.com.

Data centre. This room will house the servers and other computer equipment for the organisation, and will be the centre of communications for receiving weather data of national and international origin. It will also house networking equipment such as routers and switches, IT security equipment such as firewalls, storage areas for backup/tape or archival storage, power and networking cabling, and extensive ducting for air conditioning and cooling.

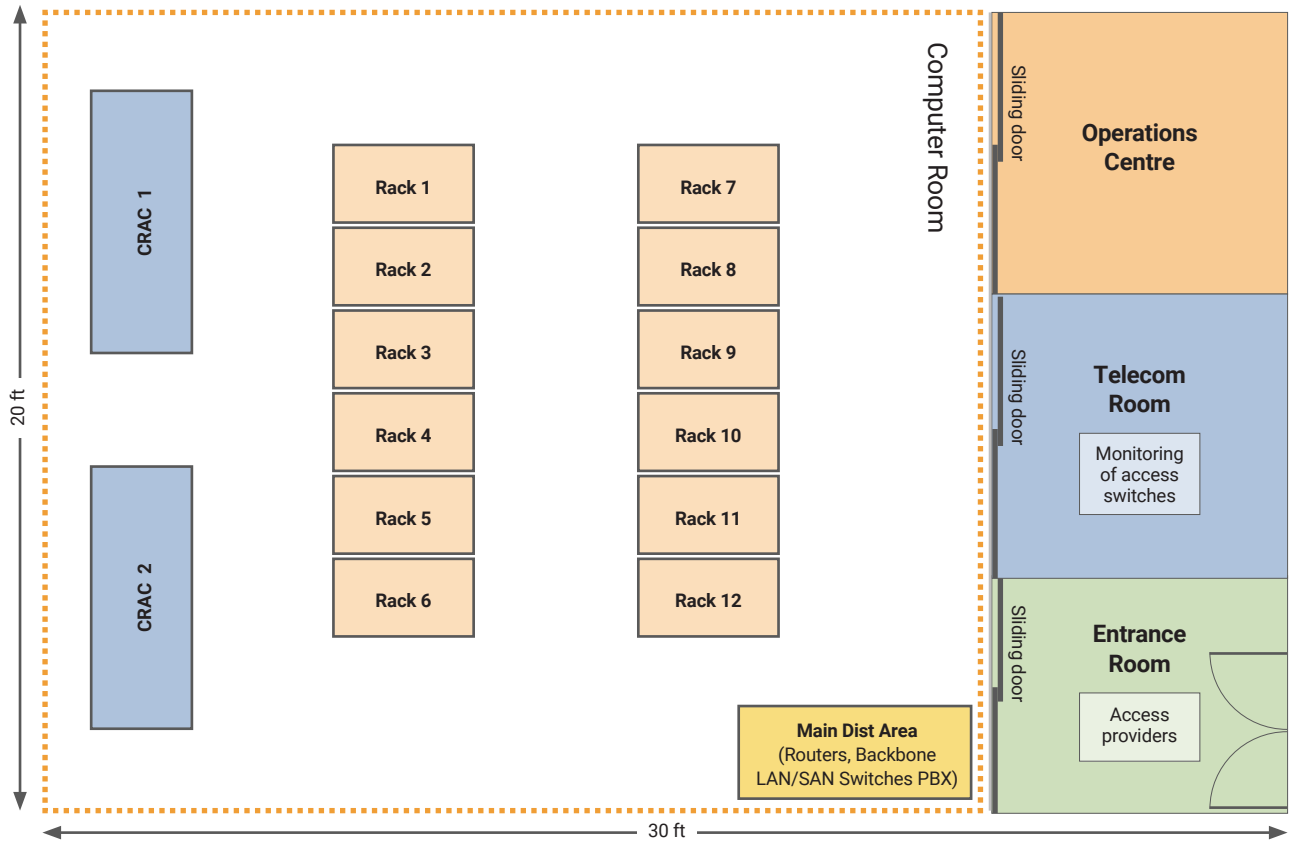
ICT equipment is generally mounted in freestanding rack cabinets for ease of access and efficient cooling. The standard rack size, known as the 42U rack, is 2m high, 60cm wide, and 96 cm deep (6' 7" high, 24" wide and 38" deep). The racks are generally arranged in rows interspersed with cooling equipment housed in racks of similar dimensions. The Meteorological Data Centre should be capable of accommodating at least 16 racks, arranged in two rows of 8 racks each. Generous space is needed at the rear of the racks to facilitate cabling etc.

Air handling is critical in a data centre and some designs call for underfloor air ducts, which imply a raised floor of 45–50cm above the concrete base. Cabling can be handled through cable trays that are either underfloor or overhead (or both). Fire suppression systems are also generally fitted (either sprinkler systems or using inert gasses) and the pipework for this will also need to be accommodated. As with the Operational Forecast Room, a ceiling height of at least 3.5m above the raised floor will be required.

An office space overlooking or connected to the data centre should be provided to facilitate monitoring of the many computing and communication processes that will be carried out. Access to the data centre should be controlled by swipe card, fingerprint recognition, or similar systems to ensure full security.

It must be stressed that the detailed design parameters of the hydromet data centre will need to be agreed with specialist engineers to ensure that all the technical requirements of this complex part of the building can be included.

Figure 17: Possible layout of a 12-rack data centre



Kitchen facilities. As this building will be used by staff on 24/7 shifts, a small kitchen/eating area will be required where staff can prepare and consume food without leaving the vicinity of their operational working areas. This will need to incorporate dishwashing facilities and some storage lockers for personal effects.

Other office space. The NWFWC building will also need to accommodate approximately 8 support staff working in regular '9 to 5' (non-operational) positions. These should be accommodated in an open-plan working area with groups of office desks. All working desks should be provided with four electrical socket outlets and network connections with Cat6 cabling. The open-plan area should be sized to accommodate at least one storage press and one filing cabinet for each of the working desks.

The design should include provision for one or two small meeting areas capable of accommodating six to eight persons. All the rooms should be equipped with audio-visual equipment and connectivity to facilitate remote access to meetings held there.

Toilet/washing facilities. The building should be provided with toilet/washing facilities suitable for the use of 15 staff. As these facilities will be in constant use, seven days a week, they should be designed so as to be easily and quickly cleaned.

Cleaning and storage space. Some rooms will need to be set aside for cleaning and building maintenance staff to store equipment and tools etc. In particular, cleaning staff will need access to a sluice sink or similar facility and space to store cleaning equipment.

Disaster resilience. The data centre and the Operational Forecast Room will be the 'nerve centre' of the NCHM, and the equipment in it will be valuable, as will the data stored there. It is therefore very important that this building is protected against potential damage such as that caused by flooding, earth tremors, very high or very low temperatures, and strong winds. Note that flooding can often be caused by internal factors such as leaking or burst pipes; the design of the mechanical and electrical systems should be such as to minimise this risk. Ideally the computer systems should be replicated or backed up either at another data centre site owned by the government or in the 'cloud'. The option of maintaining the capability to provide forecast services from another site (perhaps at Paro Airport?) should be considered if the entire building or campus site is compromised in any way.

4.3 Conference Hall

The conference hall should be capable of fulfilling multiple functions. Set out in conference mode, it should be able to accommodate an audience of 150 persons in total as well as providing a raised dais and lectern for speakers etc. The conference hall must incorporate excellent audio-visual facilities and should allow proceedings to be filmed/live-streamed as well as facilitating delivery of presentations to the audience from speakers located remotely.

In alternate modes, the conference hall should be capable of subdivision into two or three smaller spaces that could be used for either formal meetings or more informal purposes such as school group activities. Each of the two or three spaces should be equipped with independent audio-visual facilities, including connectivity to facilitate remote engagement. The smaller spaces should ideally not be of equal size, to comfortably accommodate different sized groups. For example, the space might be divided into three areas with provision for approximately 30/50/70 persons, which would enable different spaces to be configured for group sizes of 30, 50, 70, 100, 120, or 150, depending on the combination of spaces employed.

The conference hall should incorporate an informal gathering area or foyer with standing room for 80 persons, and it should have integral toilet/washing facilities adequate in scale to cater for the

Figure 18: A bright and welcoming conference hall

Source: www.dezeen.com.

Figure 19: Conference hall with windows arranged for easy space division

Source: www.dezeen.com.

maximum possible number of attendees. As this facility may be used for hosting school groups, a proportion of the toilet/washing facilities should be suitably sized for children.

4.4 Calibration Laboratory

The maintenance and calibration laboratory will be a space where meteorological and hydrological instruments can be reconditioned, maintained, and calibrated. It will need to accommodate some workshop equipment as well as specialised, delicate, and precise equipment such as a calibration chamber for temperature and humidity instruments, a stirred liquid bath for temperature calibration, a rain gauge calibration unit, a pressure controller for calibration of barometric equipment etc.

The building will need to be equipped with laboratory-type working benches and intervals of clear floor space to accommodate floor-mounted equipment. The building should accommodate 8 to 10 separate working spaces for the different items of specialist equipment; the indicative size is 9 m by 14 m or similar. Dividing the space into two rooms should be considered, to keep the more delicate and precise equipment separate from the heavier workshop-type equipment; in this case, the overall floor area may need to be larger. A wide entry door, equipped with a roller-shutter door or similar and with a threshold flush with the floor level will be required to facilitate the moving of heavy equipment in and out of the building using a motorised pallet truck or comparable equipment.

The laboratory benches should be supplied with stabilised mains power supply. Because of the precise and delicate nature of the calibration work, it will be important for the workbenches to be of solid construction to minimise any possible external vibration or other factors which may interfere with the activities.

Generous ceiling heights should be specified for the calibration laboratory—at least 3.5 m clear with ventilation ducting and services above this height if these are to be connected from the ceiling.

4.5 Sediment and Water Quality Laboratory

A separate laboratory space will be required to analyse sediment samples and water quality. The size (floor area and ceiling height) should be similar to the maintenance and calibration laboratory, and both facilities can be housed in the same building. Given the somewhat different nature of the activities to be carried out in the sediment and water quality laboratory, the principal extra requirement will be for safe and convenient handling of water with sinks and water baths built into the laboratory benches. A fume cupboard should also be provided, with fume extraction rates which are compliant with the relevant standards.

A safe and secure area for the storage of chemicals should be provided within the sediment and water quality laboratory. This should be in the form of a walk-in storage room with suitable shelving; the space should be well-ventilated and should offer suitable fire protection. The access should be through a security door and frame with double locks.

As with the calibration and maintenance laboratory, it should be possible to access the sediment and water quality laboratory via a wide entry door, equipped with a roller-shutter door or similar and with a threshold flush with the floor level, suitable for accommodating a motorised pallet truck or comparable equipment. The same external door can be used to provide access to both facilities if this can be conveniently incorporated into the design of the building.

4.6 Stores and Equipment Maintenance Workshop

This space will provide for the storage and distribution of all equipment and consumables

required for the routine operations of the NCHM. The stores will need to carry a stock of meteorological equipment (such as specialised charts and maps, spare instruments, consumables for upper-air observations etc.) as well as the normal office supplies such as paper and stationary, printer supplies, office furniture and the like. The store will need to be equipped with metal racks or similar on which the items can be placed. The building should comprise the storage area itself and an office for the storekeeper and supporting staff; office space should be designed to accommodate at least three persons.

The space made available for storage should be somewhat larger than that designated for the laboratories; perhaps 150 m^2. This excludes space for offices and toilet/washrooms. The storage area should be accessible from outside via a wide entry door, equipped with a roller-shutter door or similar and with a threshold flush with the floor level, suitable for accommodating a motorised pallet truck or comparable equipment. The same external door can be used to provide access to both facilities if this can be conveniently incorporated into the design of the building.

The area allocated for stores can be incorporated into one of the other buildings on the campus if this fits within the overall design concept, or it can be a stand-alone building. Given its purpose, the stores will need to be located on the ground floor if it is to be incorporated into a building which also accommodates other functions.

4.7 Vehicle Garage and Workshop

The NCHM makes use of approximately 10 government pool vehicles to facilitate its work; these are primarily 4x4 pick-up type small trucks. It also has the need for a small boat to facilitate water sampling and other hydrological work, together with a boat trailer for transport.

There is a need for a workshop to enable routine maintenance of these vehicles, such as oil and filter changes, lubrication, tyre changes, safety checks etc. This should be sized to accommodate two vehicles simultaneously or one vehicle and a boat trailer. One of these two spaces should have provision for safe working on the underside of the vehicles, either through the provision of a hydraulic lift or a service/inspection pit (with easy access). An area adjacent to the vehicle workshop should be designated for secure parking for these vehicles and boat trailers.

There are seven drivers attached to the NCHM, and they will need some office space and a small kitchen adjacent to the car garage and workshop areas. Toilet/washing facilities will also be required. Keeping in mind that working on vehicles inevitably generates a degree of oily dirt and grease, the cleaning/washing facilities should cater to this requirement.

4.8 Canteen/Restaurant

Around 60 staff are likely to report for work at the campus on any given day; this may be augmented with groups attending conferences or workshops. A canteen or restaurant facility will be required to provide these workers with food (at the very least a midday meal but possibly also a breakfast and evening meal service). This facility should be located in a stand-alone building with both indoor and outdoor seating provided. Kitchen facilities should be up to full professional standards and should comply with all the relevant hygiene and public health regulations regarding food storage and preparation, ventilation etc. The building should incorporate two sets of toilet/washroom facilities: one for the canteen/restaurant staff and another for the users. A seating capacity of 40 persons at any given time is proposed as a guide.

4.9 24/7 Staff Accommodation Facility

The NCHM has the responsibility to provide uninterrupted services to the citizens of Bhutan 24/7. To provide this level of reliability and resilience, some of the key operational staff will

Figure 20: Housing apartments grouped around a communal courtyard

Source: www.archdaily.com.

Figure 21: A more open arrangement of housing units around a shared outdoor space

Source: www.archdaily.com.

Figure 22: Duplex-style houses/ apartments with deep overhang balconies

Source: www.archdaily.com.

be required to live on the campus within easy reach of the NWFWC in all climatic conditions. Therefore, the campus must include some staff accommodation facilities. These should be at some distance from the office buildings so that staff can fully enjoy their rest periods. A mix of single-person and multiple-person accommodation will be needed, to allow for the relevant staff to be housed with their families.

It is proposed to provide nine separate accommodation units within one or more buildings. Of these, four should be designed as two-bedroom accommodation, with en-suite facilities, kitchen, and living areas included, with the remaining designed as three-bedroom units. The accommodation units should be self-contained, each with their own door to shared circulation space. An enclosed garden space should be provided with the units for the use of the residents.

The choice of housing styles should follow local building and design conventions. A few illustrations of possible housing arrangements are shown below but these are just to stimulate thinking as to the possible layout of accommodation (for example, as separate dwellings, as apartments within a single building block, or as some other variant). Given the (rather limited) size of the site that is likely to be available for the accommodation units, they will need to be designed carefully so as to maximise the internal living spaces while not taking up too much of the site.

4.10 Sports Facilities

Some sports facilities should be included on the campus to encourage the healthy recreation of staff during their rest periods. While these will largely revolve around outdoor activities, a sports pavilion should be provided that would incorporate changing rooms with locker and shower facilities. The pavilion might also incorporate a viewing area facing the sports ground, some lounge or recreation area, and facilities to provide light refreshments to the staff.

4.11 Child-minding/Creche

A space will need to be provided for a creche/child-minding for the younger children of staff who are on duty. The design should consider accommodating around 20 young children and should be a bright, airy space with integral toilet/washrooms (suitable for young children) together with some basic kitchen facilities (such as sink, microwave, fridge, and associated work areas). The creche could be incorporated into one of the other buildings (such as the canteen or the HQ building) or it could be a separate structure.

4.12 Weather-Related Scientific Observations

As noted earlier, space should be reserved in the campus for the establishment of a full synoptic station for meteorological measurements. The WMO's recommendations are that this area be 25m x 25m; securely fenced; and, insofar as possible, away from trees, buildings, walls, or other obstructions.

A separate area should be set aside for the launching of upper-air balloons, an activity which is not yet practiced by the NCHM but which is planned for the future. Balloons can be launched manually or via auto-launchers; in either case a hydrogen gas generator is required to provide the balloon with suitable buoyancy. As hydrogen gas is extremely flammable the site for launching the balloons should be at some distance from other buildings, to minimise the possible impacts in case of an accident.

An area of 15m x 15m should be set aside for the possible future installation of a facility for the launching of upper-air balloons (see Figure 6 above). Both this area and the area for the synoptic station, as mentioned above, should be provided with electrical power through underground cables and also with suitable ducting for telecommunication and telemetry cables which should all run back to the operational ICT room within the NWFWC building.

4.13 Communications/Power Supply Area

The provision of highly reliable power and communication facilities to the NCHM campus will be essential.

Given the size and the probable requirements for electrical power, it is likely that a medium-voltage connection will be required with the Bhutan Power Corporation (BPC). Therefore, a suitable site will need to be set aside for the connection point and transformer station to take in the electrical supply and to transform it into 230V single-phase or 400V three-phase supplies to the various buildings on the NCHM campus. Underground wiring ducts and suitable access points should be provided from this connection point/transformer to the different buildings and other relevant places around the campus.

It is also planned to generate electricity on site using solar panels. The connection to the BPC distribution network will therefore need to provide for the possible two-way flow of power into and out of the NCHM site in cases where the power generation capacity of the solar panels exceeds the immediate requirements of the buildings on campus.

To ensure the resilience of the power supply, a generator will be required together with an array of batteries to sustain electrical power during the generator start-up phase; together the generator and battery array constitute an Uninterruptible Power Supply (UPS) system. A fuel tank will be required to feed the generator and this will need to be surrounded by a bund to contain any spillage etc.

The communication facilities that will be required (and which will need to be duplicated for resilience) may consist of a mix of cable/fibre broadband and microwave links. Besides connections to the broader internet and telephony network, it is likely that one or more microwave links will be needed to facilitate reception of weather observations, for example, from the proposed weather radar site on high ground to the southwest of Thimphu. There will also be a need to locate satellite reception dishes to facilitate the collection of data from weather satellites.

It is therefore envisaged that a communications tower be provided on a suitable area of the site, away from the main buildings and connected to all of them with underground ducting suitable for communication cabling. It will be very important that the communications and power supply areas are fenced and have other adequate security measures.

4.14 Solar Field

The NCHM plans to derive substantial electricity from a solar panel farm located on-site. An area of 1 acre (0.4 ha or approximately 65 m x 65 m) should be set aside for this purpose, and suitable ducting for electrical cables should be provided to join this facility with the power supply areas as mentioned above.

4.15 Water Storage

A raised water storage tank, facilitating gravity feed, will be required to ensure the continuous supply of water to the many buildings on the new NCHM campus. The capacity of this water storage tower should be at least 15 m^3.

4.16 Vehicle Parking

Extensive car parking will be required, both for the staff attending daily and for those who may be attending events at the conference centre. Parking will also be required for buses and minibuses which may be used to bring school children on visits to the campus. Suggested car parking provision should be as follows:

- **70 parking spaces for cars.** Of these, at least 5 should be designated for disabled access and sized accordingly.
- **Parking space for large (52-seater) buses.** The design of the bus parking bay, together with the entry and exit roads, should allow for easy and safe manoeuvrability for buses, keeping in mind that the presence of buses on the campus will often be accompanied by the presence of small children.

- **3 parking spaces for minibuses (15 to 22 seater).** As with the larger buses, the parking bays, entry, and exit roads should be laid out to allow easy manoeuvrability and with safety in mind.

This level of car parking (which may well be overestimated) together with the associated roads for circulation etc., would occupy a considerable portion of a 5-acre site—perhaps as much as 30%.

Given the steeply sloping nature of the site and to aid safe and efficient handling of vehicular traffic, it may be sensible to organise the internal roads in a one-way system. This would reduce the area to be paved and add to the safety of the circulation.

4.17 Recreation Area

The design of the campus should incorporate an informal park-like recreation area, oriented and laid out to take advantage of the physical characteristics of the site, including existing and new planting. The recreation area should be easily accessible from the two main buildings (NCHM HQ and NWFWC) as well as the conference centre and the restaurant/canteen.

4.18 Waste Disposal Systems

Any building project must take into account the safe and sustainable disposal of waste material that will be generated by the people occupying the buildings. The types of waste generated will also be linked to the nature of the activities for which the buildings are provided.

The biggest challenge will be the safe treatment and disposal of sewage. As the site is very unlikely to be serviced by a public sewer system, arrangements will need to be made for an on-site sanitation system. Such systems often combine the treatment of black waste (toilet effluent) with grey waste (from sinks, washing machines, and the like). Given the number of staff who will be accommodated at the site and the challenging nature of the terrain (which makes it difficult to construct adequate soakage pits/percolation areas for the output of standard septic tanks), a commercial wastewater treatment system will most likely be required. These systems treat the sewage within closed tanks and use a combination of mechanical agitation and biological processes to break down the waste matter and deliver output which can conform to the appropriate health and safety standards in relation to biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS) and levels of e-coli.

It will be imperative to have a separate drainage system for rainwater (including runoff from roofs and the like) to ensure that rainwater cannot enter the wastewater system and overload the system during episodes of heavy rain.

For more general waste, it would be useful to have a range of waste receptacles so that individuals could deposit waste in one of four containers.

1. Organic matter such as food waste etc.
2. Recyclable materials such as paper, cardboard, plastic etc.
3. Glass
4. Other waste, which typically will go to either landfill or incineration.

Given the proximity of the proposed site to the national agriculture and food research and development centre, it is possible that they may use the organic waste to make compost. For the other categories of waste, a joint approach between the two government-owned centres to organising and funding appropriate recycling or disposal would most likely provide the most economical and environmentally sustainable solution.

There will be certain other waste disposal/recycling issues on a smaller scale (such as the safe and appropriate treatment of waste oil from vehicles) which will require more specialist and bespoke solutions.

5. Layout of the Building Blocks

It is, of course, not possible to provide a detailed plan for the layout of the buildings without an accurate survey of the site, and in particular its contours. The detailed layout will be the task of the architect commissioned to design the buildings and the campus and will need to take into account also such considerations as where the access roads will be. However some early proposals can flow from an overview of the different buildings, their functions, sizes, and footprints.

Appendix 1 provides an indicative guide of the sizes of the individual rooms that will be required. Adding up the total area of the rooms and making allowance for corridors and other circulation spaces allows a first-order approximation to be made of the building sizes. Then, depending on the number of floors in each building, the footprint can be arrived at. Table 2 provides indicative figures for the sizes and footprints of the different buildings.

The conference hall, while only one storey, will need to have a high roof so that the large space inside has an appropriate relationship between the horizontal and vertical dimensions. Thus, there are three 'large' buildings (HQ, NWFWC, and conference hall) and three lower-profile buildings (laboratories, stores/garage, and canteen) which together form the heart of the new NCHM campus. The staff accommodation and creche should ideally be located at a distance from the office/technical buildings, to allow for reasonable privacy. The communications mast and adjoining buildings and the generator/power supply area, should be located as far as possible from the office / technical buildings and the residential accommodation to minimise the impact of noise etc.

A possible configuration would be for the larger buildings to be positioned around three sides of a rectangle, forming a semi-enclosed green space between the buildings which ideally would have a southerly aspect. This arrangement would also facilitate the provision of covered walkways or similar paths linking the buildings.

The laboratories and the stores/garages could be located behind the central building, perhaps in an

Table 2: Estimated total area and footprints of building

Building	Total Area (m^2)	Floors	Footprint (m^2)
Headquarters	1,134	2	567
National Weather and Flood Warning Centre	592	2	296
Conference hall	415	1	415
Laboratories	279	1	279
Stores and garages	261	1	261
Canteen/restaurant	114	1	114
Staff accommodation	935	3	312
Creche/Child-minding	60	1	60
Communications/Power supply	47	1	47

'L' shape, forming a second courtyard which could provide some natural enclosure and shelter.

The canteen might be located adjacent to the conference hall (indeed it might be incorporated into it in some manner). The canteen should take full advantage of the panoramic views over the valley to the east and south, to provide a pleasant and relaxing environment for staff to enjoy during their time away from their desks.

For the staff accommodation projections, it is assumed that all the residential units (estimated as nine in the calculations) will be provided in one physical building. If a different arrangement—such as a courtyard-style development—is preferred, then the area required will be substantially greater. The assumption is that this building can rise to three stories (which is typical in Thimphu) but if two stories are preferred, the footprint will also need to be greater than indicated.

Adding all the building footprints together brings a total of approximately 2,500 m^2. To this should be added another 500 m^2 for access and connecting footpaths, giving 3,000 m^2 in all.

The NCHM has indicated that it wishes to reserve 1 acre (0.4 ha) for a solar field. This would take up 4,000 m^2.

Providing space for a synoptic observatory and allowing for a possible auto-launcher for balloon ascents would take up approximately 800 m^2.

Surface car parking could consume a lot of space. Based on providing parking facilities for approximately 70 cars and one bus, together with access roads, up to 7,000 m^2 would be required. The site layout should be such that car parking is located close to the entrance, to minimise the length of the internal roadway.

Adding everything together it seems that, of the 20,000 m^2 of the site, up to three-quarters of the total area, or 15,000 m^2 in all, could be taken up with the buildings, car parking, solar field, and weather observatory. Not included in these figures is the area for the wastewater treatment plant, but these are frequently located below the surface where possible.

The space requirement that could be reduced most easily is that for car parking, either by designing for fewer cars (may be possible if coordinated bus transport to the site from central Thimphu is arranged) or by building a two- or three-story parking garage.

6. General Comments

As has been mentioned, the design team will have the freedom to propose different solutions to the overall accommodation needs of the new NCHM campus. When a detailed site survey has been prepared and allowance made for the necessary services to be installed, the overall layout of the buildings on the 2 ha site can then be considered, attempting to balance the practical and logistical needs with the particulars of the site (aspect, slope, etc.) to provide a harmonious assembly of structures capable of accommodating the many diverse needs outlined above. Only then will it be possible to proceed to the detailed design of each building.

It is important that the buildings are designed with resilience in mind and protected as much as possible from natural hazards such as flooding, and landslides and safety measures incorporated to better resist earth tremors, and lightning. The work of the NCHM is especially important during periods of natural hazard and the operations must be able to continue uninterrupted through these challenges.

In general, the buildings should be designed to be as energy efficient as possible, making use of natural heating and ventilation where this is possible. The Operations and Data Centre areas will certainly require climate control/air conditioning given the nature of their use; other areas may not need this to the same extent. The accommodation needs, as above, do not specify any details around items like plant rooms and circulation spaces (corridors, staircases, etc.) as these will be determined by the design decisions taken by the relevant architects and engineers.

It is likely that the development of this campus will not take place in one phase but will be divided among several phases so that the buildings can be erected as budgetary conditions allow. Nevertheless, it is important that a 'master plan' for the campus should be developed as the first design task, to be followed by the detailed design of the buildings to be constructed in Phase 1. These are likely to include the NWFWC, the HQ building, and the accommodation units for staff, together with the necessary facilities for supplying water, power, and communications.

Appendix 1 - Room and Building Sizes

Room Description	No. of Persons	Floor Area	ICT Etc.	Comments
HQ Building - Priority One				
Entrance hall/Reception area	1	6 m x 8 m	Cat 6 points	1 desk, some informal seating
Director's Office	1	4 m x 6 m	Cat 6 points	Director's desk, separate meeting table, projector/screen
Director's Administrator	1	4 m x 3 m	Cat 6 points	Opening into Director's Office as well as corridor
Library/Reading room	6	6 m x 8 m	WiFi preferred	Good natural lighting needed
Climatological archive	2	5 m x 8 m	Cat 6 points	Needs temperature and humidity control plus suitable shelving
Chief's Office (four of these required)	1	4 m x 6 m	Cat 6 points	One desk; separate meeting table
Open plan office spaces for up to 60 persons	60	540 m^2	Cat 6 points	Space for up to 60 desks, divided informally into spaces for 6 to 8 people. This can be housed on different floors or as a series of separate spaces.
Meeting room/Boardroom	15	4 m x 10 m	WiFi preferred	Projector/screen with teleconference facilities
Meeting room	10	4 m x 8 m	WiFi preferred	Projector/screen with teleconference facilities
Meeting room	6	4 m x 6 m	WiFi preferred	Projector/screen
Meeting room	4	4 m x 3 m	WiFi preferred	Projector/screen
Toilet/washing facilities		4 m x 3.5 m		One each, male and female; Suitable for circa 60 persons
Cleaner's rooms		3 m x 2 m		One per floor, with sluice sink and space for cleaning equipment
Storage rooms		3 m x 6 m		One per floor
Total Floor Area (to include 15% extra for corridors etc)		**1,134 m^2**		
Number of floors		2		
Building footprint		**567 m^2**		
National Weather and Flood Warning Centre - Priority One				
Operational Forecast Room	6	12 m x 12 m	Multiple Cat 6 points at each desk	Needs a high ceiling—at least 3.5m. Needs hard-wearing desks, fittings, and surfaces as it will be occupied 24/7.
Studio/Presentation Room	2	5 m x 6 m	Cat 6 points; possibly also video connections	Needs a high ceiling (for studio lighting). Needs to be soundproof, with no natural light. Full teleconference facilities.

continues

Room Description	No. of Persons	Floor Area	ICT Etc.	Comments
National Weather and Flood Warning Centre – Priority One (cont.)				
Education Space	30 children plus 4 adults	6 m x 10 m		Projector/screen
Data Centre	2	8 m x 10 m	Main comms hub. Main internet connection	A raised floor will be required and a generous ceiling height. Needs a high level of cooling and air handling/ filtering. Needs controlled access.
Open plan office space for 8 persons	8	72 m²	Cat 6 points	Space for eight desks/working areas
Meeting room (one or two required)	6–8	4 m x 6 m	WiFi preferred	Projector/screen
Kitchen facilities	4	3 m x 4 m	WiFi preferred	Some kitchen fittings such as sink, fridge, and microwave plus some food lockers would be required.
Toilet/washing facilities		3 m x 4 m		Suitable for circa 15 persons; perhaps separate toilet facilities for visiting school groups
Cleaner's rooms		3 m x 3 m		One per floor, with sluice sink and space for cleaning equipment
Storage rooms		3 m x 6 m		One per floor
Total Floor Area (to include 15% extra for corridors etc)		**592 m²**		
Number of floors		2		
Building footprint		**296 m²**		

Conference Hall – Priority Two				
Main conference hall	150	12 m x 24 m	WiFi preferred	Projector and screen. Room should be easily divisible into two or three separate spaces.
Conference hall foyer	100	12 m x 6 m	WiFi preferred	
Toilets/washing facilities		3 m x 4 m		Suitable for circa 20 persons; separate male and female facilities required
Total Floor Area (to include 8% extra for corridors etc)		**415 m²**		
Number of floors		1		
Building footprint		**415 m²**		

Laboratories – Priority One				
Maintenance and Calibration Laboratory	10	9 m x 14 m	Cat 6 points	Ceiling heights of 3.5m
Sediment and Water Quality Laboratory	6	9 m x 14 m	Cat 6 points	Ceiling heights of 3.5m
Toilets/washing facilities		2 m x 3 m		Suitable for circa 4 persons
Total Floor Area (to include 8% extra for corridors etc)		**279 m²**		
Number of floors		1		
Building footprint		**279 m²**		

Room Description	No. of Persons	Floor Area	ICT Etc.	Comments
Stores and Garages – Priority One				
Stores		10 m x 15 m	Cat 6 points	
Storekeepers' office	3	4 m x 6 m	Cat 6 points	
Toilet/washing facilities		2 m x 2 m		Suitable for 1 person
Car garage and workshop	2 vehicles	6 m x 8 m		Generous ceiling height plus service pit or hydraulic jack etc.
Kitchen	4	3 m x 4 m		Some kitchen fittings such as sink, fridge, microwave plus food lockers would be required.
Toilet/washing facilities		2 m x 2 m		Suitable for circa 2 persons.
Total Floor Area (to include 8% extra for corridors etc)		**261 m²**		
Number of floors		1		
Building footprint		**261 m²**		
Canteen / Restaurant – Priority Two				
Canteen dining area	40	5 m x 12 m	WiFi preferred	Ceiling height of 3 m minimum
Canteen kitchen	6	5 m x 6 m		Assumes a fully professional catering kitchen
Toilet/washing facilities – Guests		3 m x 4 m		Suitable for around 4 persons
Toilet/washing facilities – Kitchen staff		2 m x 2 m		Suitable for 1 person
Total Floor Area (to include 8% extra for corridors etc)		**114 m²**		
Number of floors		1		
Building footprint		**114 m²**		
Staff Accommodation – Priority One				
Two-bedroom apartment/house (four required)	3 or 4	75 m²		Staff accommodation should follow the guidelines and standards established by the National Housing Development Corporation.
Three-bedroom apartment/house (five required)	4 to 6	110 m²		
Total Floor Area (4 x 2-bed, 5 x 3-bed; 10% added for stairs and so on)		**935 m²**		
Number of floors		3		
Building footprint		**312 m²**		
Creche / Child-minding – Priority Two				
Space for creche/child-minding	20 small children plus 4 adults	7 m x 8 m	None	Integral toilet/washroom and simple kitchen facilities will be needed.
Total Floor Area		**60 m²**		
Number of floors		1		
Building footprint		**60 m²**		

Room Description	No. of Persons	Floor Area	ICT Etc.	Comments
Communications / Power Supply Area – Priority One				
Electricity transformer building		3 m x 3 m		
Back-up generator and oil storage		4 m x 5 m		
Communications tower/ancillary building		3 m x 6 m		
Total Floor Area		**47 m²**		
Number of floors		1		
Building footprint		**47 m²**		

Agricultural landscape in Eastern Bhutan. Photo: UlyssePixel.

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