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SCHOOL DESIGN GUIDELINES

2020

Version 1

SCHOOL PLANNING & BUILDING DIVISION
DIRECTORATE OF SERVICES
MINISTRY OF EDUCATION
ROYAL GOVERNMENT OF BHUTAN
JANUARY 2020

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THIMPHU

Published by:

School Planning and Building Division (SPBD) (spbd@moe.gov.bt)

Directorate of Services

Ministry of Education

Royal Government of Bhutan

Telephone:+975-2-325142,+975-2-333354

The guideline is developed with views, recommendations and research of the SPBD office to improve the school infrastructure design. Every effort has been made to ensure accurate and correct information are captured. Any decrepancy must be brought to the notice of the SPBD office for clarification or correction. SPBD will not bear any liability for errors arising due to their misinterpretation or when it is applied out of context.

Edition: Version 1 January 2020

ACKNOWLEDGEMENT

The Division on behalf of the Ministry of Education would like to offer our deep gratitude and appreciation to the Bhutan Foundation for their financial support and ARUP consultant (UK office) for the development of the guidelines.

Further, a special thanks to Tshering Choden (Architect), for her contribution in the guidelines as well as liasing with the consultants.

Lastly, a deep appreciation and gratitude to all the SPBD officials for their cooperation and contribution towards the development of the guidelines.

SPBDs' Vision:

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> **"To become a leading technical agency in the country that is looked upon by everyone for its professionalism and standards of work"**

SPBDs' Mission:

> **"To secure a place of learning for every Bhutanese child"**

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Royal Government of Bhutan
Ministry of Education

SECRETARY

Rethinking Education

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FOREWORD

The School Planning & Building Division, Directorate of Services, Ministry of Education is pleased to bring out "School Design Guideline" for the School Projects to benefit all architects, engineers and builders while designing and implementing any new Schools under Dzongkhags and Thromdes level.

With the rapid growing of the construction technology in this 21st century, it has become mandatory to build a sustainable and safety infrastructure to habitat all children seeking education in a secured structure. The Engineers and the Architects in the construction professions today are faced with increased challenges in School construction projects in terms of designing seismic resilient structure, disabled friendly structure, preservation of traditional architecture façade and execution of high-quality structures.

In the past, SPBD developed many manuals for the School Projects to maintain safety of the structures after it is been constructed. However, due to lack of user-friendly education at the School level, most of the structures are either in dilapidated condition or requires major maintenance which entails incurring huge expenditure. Therefore, this guideline primarily focuses on the proper planning, selection of new construction sites, take accounts of the disaster resilient features, designing of safe RCC structures and maintenance at the later stage. It also clearly outlines the different stages involved in administrative and planning process. The document comprehensively covers different aspects of a building construction viz. architecture, civil, electrical, plumbing and sewer components. It is also intended to guide the professionals to control the material quality and workmanship by specifying selection of approved branded materials, various tests to be carried out and measures to be taken at construction site. References are also made to relevant codes and standards developed by the Bhutan Standard Bureau and Ministry of Works and Human Settlement. This document further provides directives and guidance for supervising and monitoring professionals.

I am optimistic that this document prepared with the support of Bhutan Foundation and in-house consultation by our SPBD experienced professionals will have positive impact for safe and user-friendly infrastructure for all times to come.

Finally, on behalf of the Ministry of Education, sincerely hope that this guideline will form the basic principles for all Dzongkhags and Thromdes while designing school infrastructure in the days to come.

"Let us secure a safe place of learning for School Children".

Tashi Delek!

(Karma Yeshey)

Secretary

Preface

For last many years, SPBD was the custodian of the Designs of Schools and implementation of the Projects as well. However, with the decentralization policy under 12 FYP, Dzongkhags, Thromdes and Local Government are empowered to initiate all construction activities and accordingly, the GNHC has disbursed the Funding to individual Dzongkhag & Thromde. At this juncture, this has become very crucial for SPBD to immediately initiate the School Design Guidelines so that it becomes a standard norm or streamline development of designs for School Projects.

This context of the Guidelines shall become the guiding principles to provide clear and concise Design procedures and methods that can help Architects & Engineers at the Dzongkhag & Thromde level to build School infrastructure with highest standard quality.

We are sure that with the extensive use of this document and feedback from the users, further revisions and improvement will follow.

The very comprehensive Design Guidelines is initiated and developed by the School Planning & Building Division, Directorate of Services towards holistic approach for School Designs Projects under any of the Dzongkhags and Thromdes in the Country.

(Lalit Kumar Gurung)
Chief Engineer, SPBD

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List of Acronyms

ACH	Air Changes per Hour
ARC	Avoid, Reduce, Control
ASCE	American Society of Civil Engineers
ASHRAE	American Society of Heating, Refrigeration and Air-Conditioning Engineers
BSRIA	Building Services Research and Information Association
CCTV	Closed-Circuit Television
CIBSE	Chartered Institution of Building Services Engineers
DEO	Dzongkhag (District) Education Officer
DRM	Disaster Risk Management
EWS	Early Warning Systems
HVAC	Heating, Ventilation and Air Conditioning
HWS	Hot Water System
ICT	Information and Communications Technology
IDF	Intensity – Duration – Frequency
IWM	Integrated Water Management
IS Code	Indian Standard Code
LAN	Campus data network
LPS	Lightning Protection System
LV	Low Voltage
MEP	Mechanical, Electrical and Plumbing (Engineering)
MHM	Menstrual Hygiene Management
MoAF	Ministry of Agriculture and Forests
MoEA	Ministry of Economic Affairs
MoHCA	Ministry of Home and Cultural Affairs
MoE	Ministry of Education
MoWHS	Ministry of Works and Human Settlement
MPH	Multi-Purpose Hall
MV	Medium Voltage
NEC	National Environment Commission
NBC	National Building Code
NRC	Noise Reduction Coefficient
NUDC	National Urban Development Corporation
QA	Quality Assurance
RDS	Room Data Sheet

SCS	Structured cabling system
SDP	Sub Distribution Panel
SMC	School Management Committee
SPBD	School Planning and Building Division
SWM	Surface Water Management
WASH	Water, Sanitation and Hygiene
WEDC	Water Engineering and Development Centre
UPS	Uninterruptible Power Supply
VOC	Volatile Organic Compound

1 Introduction

1.1 Purpose of the Guidelines

The School Design Guidelines are to be used as a benchmark by all who are involved in the planning and design of school infrastructure facilities.

Aim:

1. *To provide guidelines for planning and design of schools that provide safer, sustainable, inclusive, maintainable, affordable and appropriate teaching and learning environments.*
2. *Create consistency for the different implementation pathways by:*
    a. *Identifying the key activities to be addressed through planning and design stages*
    b. *Defining minimum performance standards*
    c. *Referencing and highlighting relevant codes and standards to be used*

1.2 Scope of the Guidelines

The Implementation Stages for school infrastructure include; Planning, Design, Construction and Operation & Maintenance.

At each stage there are a variety of activities (Figure 1) and responsible stakeholders. These Guidelines address the activities under the Planning and Design stages for school infrastructure facilities serving classes Pre-Primary to class XII.

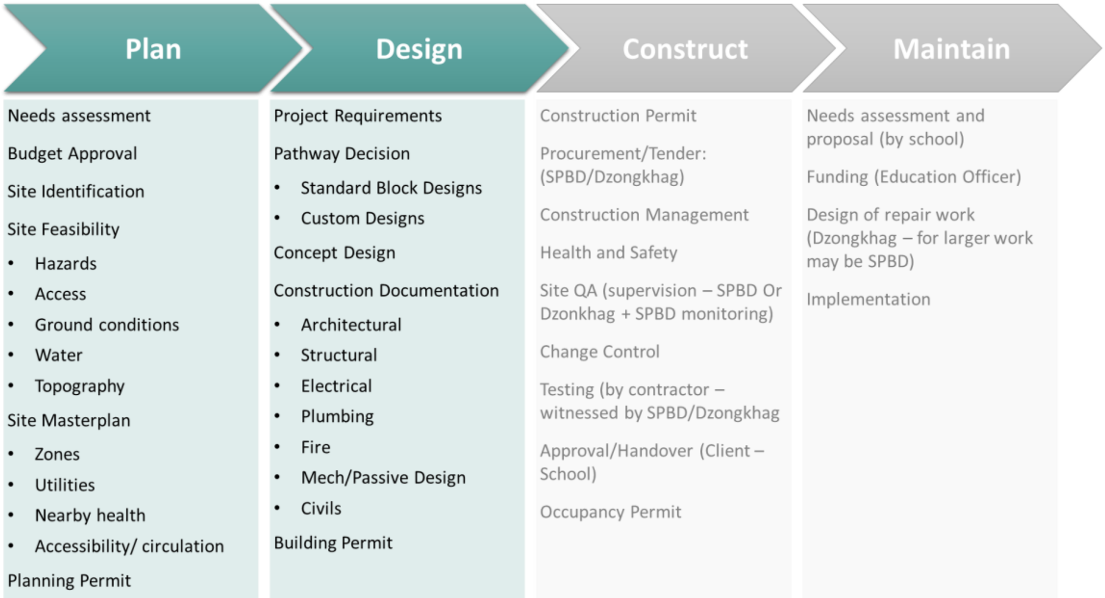


Figure 1 The four stages of infrastructure implementation and associated activities

1.3 Users of the Guidelines and their Roles

The Guidelines will have different users each of whom will take on a different role in the planning and design process. These users are noted below (Table 1) along with their expected roles. For chapter specific primary and secondary readership, please refer to Section 2, How to Read this Document.

It should be noted that different people may take on the planning and design role in different projects depending on the specific circumstances of that project.

Table 1 Guideline Users & Roles

User	Expected Role
SPBD	• Review and approval of school plans and designs by others • Planning and overseeing design of Schools (where local capacity in the Dzongkhags/Thromdes does not exist).
MoWHS/Thromdes	• Issuing Planning and Building Permits

Dzongkhags/Thromdes Engineering Teams	• Planning and Designing Schools in order to obtain a Planning and Building Permit
Private Sector Consultants/ Design teams (implementing Private Schools)	• Planning and Designing Schools in order to obtain a Planning and Building Permit
School Principals, Dzongkhag/Thromde Education Offices	• Understanding key issues and criteria to inform proposals for school development, including development of project briefs for new school infrastructure facilities.

1.4 Background

The School Planning and Building Division (SPBD) was started in the year 1986 as a small unit with the mandate to look after the maintenance of school buildings. Over the years, the roles and responsibilities grew to meet the rising demand of increasing population of school children. Hence, it became a full-fledged division under the Ministry of Education, responsible for designing, constructing and monitoring the construction of school facilities.

However, for the 12^{th} Five Year Plan, in line with the decentralization policy of the government and to empower the local governments, all school design and construction works should be taken up by the respective Dzongkhags/Thromdes where capacity is available. The SPBD shall function as a compact and efficient team to provide technical support to them. The main roles and responsibilities of the SPBD shall be to develop standard drawings and estimates and to monitor the school construction works undertaken by any agencies/parties.

The Guidelines were conceived as a means to ensure that, irrespective of who is responsible for planning or designing school projects, a common standard is applied so that the resulting school facilities deliver a consistent quality teaching and learning environment.

1.5 Review and updates to the Guidelines

These Guidelines will be reviewed periodically to update them with further information and clarifications. For example, these updates may be in response to comments and feedback from users, to account for emerging technologies, or to incorporate the requirements of new policies and initiatives.

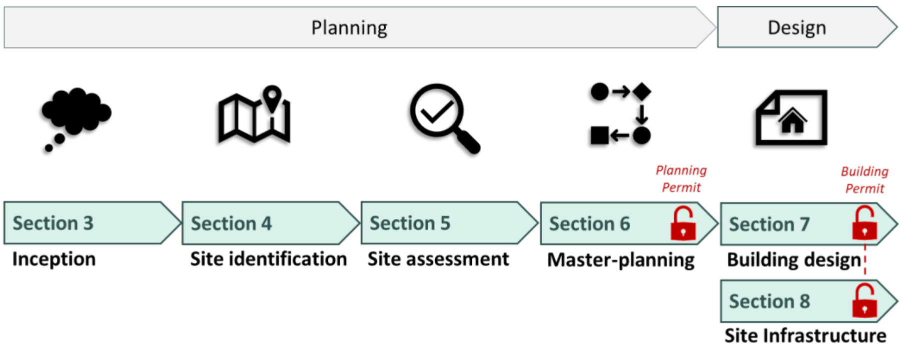
Genuine users are highly encouraged to drop in comments and feedback at the SPBD office or by email (chiefspbd@moe.gov.bt).

2 How to Read this Document

These Guidelines should be used as a supplementary document to the latest Bhutan Building Regulations [1] and Code [2] in place (2018 versions current at time of writing) and adhere to all the latest rules and regulations of building by-laws of each Dzongkhag/Thromde as well as the environmental preservation norms of the country.

It should also be used in conjunction with other relevant guidelines, such as the *Bhutanese Architecture Guidelines 2014* [3], *Bhutan Green Building Design Guidelines 2013* [4], *Guideline for Differently Abled Friendly Construction 2017* [5] etc. Relevant additional reference documents are noted by chapter and in the Bibliography.

The Guidelines explain the sequential activities that comprise the planning and design process (Figure 2). The objectives and guiding principles for each activity are provided, along with criteria that define the standards and performance to be achieved. Users should refer to the section addressing the activities related to their role and the project stage.



Primary Readership	Education Officers/School Principals	Design Team*
Secondary Readership	Design Team*	Education Officer/School Principals

**Design team refers to either Dzongkhag/Thromde Engineering Team, the SPBD or an independent consultant designing a private school, whoever is undertaking the design of the school.*

Figure 2 Guidelines Structure

Section use notes

At the start of each section there is box like the one below containing a description of the ***purpose*** and ***user*** to clarify how the information provided should be applied in the implementation process.

Purpose	
User	

3 Inception

Purpose	Whether a new school or an expansion of an existing school, the needs and requirements of the proposed project should be considered and documented at the Inception Stage. This ensures that as the project moves through the implementation process, all stakeholders are clear on the parameters of the design and that all the constraints are considered at the start of the project reducing the risk of delays on site or redesign work being required.
User	This should be developed by the Education Officer within the Dzongkhag/Thromde in consultation with other stakeholders (including the Principal for existing schools).

Things to consider when conducting a Needs Assessment include:

Topic	Key Information Required
Purpose	What is the desired outcome of the project? What will the space be used for within the school? Are there any secondary uses (out of class time or by the community etc.)
Users	Who and how many people (staff/students) will be using the new facilities? Do they have any special requirements, such as disabled access or assisted learning needs?
Cost	What is the allocated budget (if known at this stage) for the works? How will budget approval be obtained and by/from whom?
Timing	Are there any specific deadlines by which the project must be completed (e.g. in time for the exam period or during the school holidays)?

Missing information	What information is still to be determined? When/how will this be obtained?
Site and Location	Is the desired location of the new building(s) known already? Is there an existing masterplan and does it need amending? (see Section 4 – Site Identification)
Additional needs	Are there any other specific requirements for the facility – e.g. storage provisions, flexibility in use of the space? Is any temporary space required during construction?
Key contacts	Note any key stakeholders – Education Officers, School Management Committee (SMC), School Principal, any focal person within the school for the construction works.

4 Site Identification

Purpose	The purpose of this section is to ensure that basic suitability of sites can be assessed during the site selection process prior to the engagement of the SPBD and/or other technical specialists. Considering the aspects covered in this section prior to detailed technical site assessment could avoid time and cost being spent planning works on highly exposed sites or sites with fundamental flaws.
User	This section is aimed at those involved with the initial site selection for a school or for the selection of a plot within an existing site for expansion projects. It is envisaged that for new sites the users will be the Education Officers from the Dzongkhags or Thromdes, possibly in collaboration with the local community. For existing school sites the users are likely to be the School Principal and/or the Education Officers.

Site selection is the process of examining multiple options and assessing their relative advantages and disadvantages. Site selection comes after the Needs Assessment is completed. If you select a site before the needs assessment, you may compromise on key design aspects due to site limitations.

A good site selection process should include the following outcomes:

- The school site is a community focal point and benefits the entire community
- The school site takes full advantage of existing resources
- The school site is easily and safely accessible

Those involved in identifying potential school sites should learn about the neighborhoods of the potential sites, walk through the area and consult with residents to better understand whether the site is a viable option and whether a school is welcome. It is recommended to identify at least three potential site options for the location of the school. With multiple site options, it is possible to rank project priorities, for example, cost, location, and size. Exploring more than one site option also makes clear to lenders and other funders that there is a clear commitment to building the best project possible. Analyzing alternative site plans allows comparison selected criteria and design features in a practical rather than an abstract way.

When a new school site is required, the Dzongkhag/Thromde should set up a committee comprising of community representatives that carry the accountability for selecting potential sites.

For existing school expansion, the Dzongkhag/Thromde should set up a School Management Committee (SMC) comprising of Principals, Parents and community representatives that carry the accountability for selecting potential sites.

It is suggested that the committee takes these steps during the site selection process:

A. Review of the Needs Assessment and Educational program

Make sure that all the committee members are familiarized with the Needs Assessment and the educational program for the site that clearly explains the activities that will take place in and outside the school buildings, both on the school grounds and off campus.

B. Agree a site selection criterion based on technical requirements

Set up a list of site selection criteria based on technical requirements. These criteria in addition to the educational program form a set of "standards" which potential sites can be evaluated against. A detailed list of criteria and questions that cover all potential concerns for each site should be developed as part of this step.

A list of recommended criteria is given below. A list of guiding questions for each suggested criteria have been attached in Appendix A.

Recommended criteria for school site selection:

- Safety and Security
- Exposure to natural hazards
- Location
- Size and proportions of the site
- Topography and soils
- Accessibility
- Utilities / Public services / Drainage
- Environment
- Availability and legal issues/ land ownership
- Cost
- Public acceptance

C. Site evaluations

The committee is responsible for choosing a site that is considered the best location for a new school or expansion of an existing school. Each potential site should be analyzed and evaluated thoroughly based on the selection criteria. The committee shall also seek support from architect, landscape architects and/or engineers to help them with the evaluation and selection procedure.

A suggested scoring checklist has been included in Appendix B.

If any of the selection criteria do not meet the suggested minimum level the site should be re-assessed to see if it is feasible for a school or not.

D. Prioritization and site selection

This step shall focus on comparing and ranking all potential sites assessed above, then taking the final decision on which site should be acquired.

It is expected that the acquisition price may be one of the key criteria considered. However, it is recommended that when comparing the land costs, the total cost is calculated including the development, construction and operation and maintenance of the selected site. Mitigation of site-specific constraints such as civil engineering works to mitigate against natural hazards, landscaping and levelling of the site and other measures can be expensive and therefore these must be included in the overall cost of site in consideration of the budget.

5 Site Assessment

Purpose	The purpose of the Site Assessment is to ensure the technical suitability of the site identified for the school. The assessment will look at the main aspects of the site which are important to the design of the school and verify that it is fit for purpose. It will also identify where there are site constraints which will need to be considered in the Masterplanning of the site and/or in the design of the buildings.
User	The site assessment should be done by an appropriately qualified technical consultant(s) with expertise in the technical disciplines being assessed. It is envisaged that this will be done by either the SPBD or the Dzongkhag/Thromde engineering teams depending on local capacity and expertise available.

5.1 Topographical site survey

The topographical survey should be undertaken to the appropriate standards outlined here by qualified surveyors. The topographic map should include, as minimum, details such as: contours (of at least 1m contour interval), spot height elevations, structures and principal features (e.g. wells, boundary fences, walls), water courses (rivers, streams, ponds).

Any type of structure, whether temporary or permanent within the site should be noted with their condition and usability.

If the site has an approach road, water supply, drainage system and electric lines, their location should be noted. If they are not available within the site, then their closest source or point should be identified.

Any electrical transmission line passing though the site must be carefully noted. It is not viable to relocate transmission lines over 33KV, therefore careful planning must be done to avoid any structures below the line.

The design team should be made aware of any nearby potential hazards such as water courses (rivers, streams, lakes), landslides/ steep unstabilised slopes, flood, falling boulders, huge weak trees, ground water seepage, steep cliff, avalanche zones.

5.2 Hazard Assessment

Hazard assessment is an important step in Disaster Risk Management (DRM), to identify site specific hazards and inform mitigation strategies and measures. The three components of risk: hazard, exposure and vulnerability, are shown in Figure 3 along with the relevant section of the Guideline. The hazard assessment identifies the key hazards which will affect a specific school.

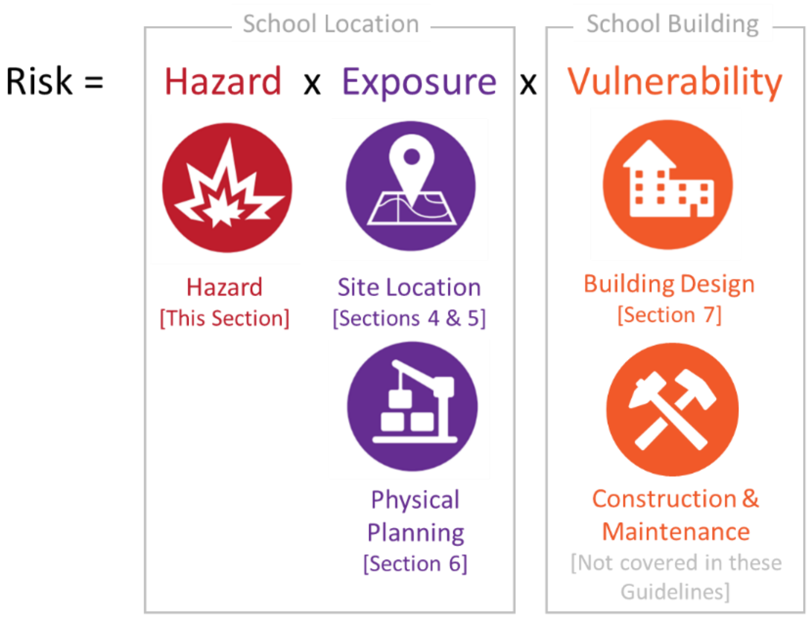


Figure 3 The Components of Risk

(Adapted from the Roadmap for Safer Schools [6])

Mitigation strategies and measures to reduce risk of schools to the hazards they are exposed to can be implemented at different stages of project, with important activities including:

- mitigation of hazard by avoidance at site selection stage
- reducing exposure of the school to hazards through physical planning of the site and providing civil engineering mitigation works
- reducing vulnerability of the buildings through good design and quality workmanship and quality materials during construction
- mitigating residual risk by preparing and implementing a disaster management plan for each school

Further details on Disaster Management can be found via the Ministry of Education Disaster Management Unit: https://sites.google.com/a/moe.gov.bt/disasterunit/

5.2.1 Hazard Identification

Bhutan is subject to a wide range of geological and hydro-meteorological hazards, including (not limited to):

- **Earthquake** (ground shaking, liquefaction, earthquake induced landslide)
- **Flooding** (river flood, groundwater flooding, pluvial storm water flooding, glacial lake outburst, flash flood, cloud burst)
- **Landslide** (rockfall, earth flow mudflow)
- **Avalanche**
- **Wind**
- **Wildfire**
- **Lightning**

The hazard assessment should be carried out by a suitably qualified technical consultant with expertise in the analysis of the specific hazards being addressed. It should aim to quantify the intensity and probability of occurrence of the selected hazards identified.

Hazard information can be found from a variety of sources including:

- Catalogues of previous hazard events including a description of the event and the damage sustained
- Hazard Maps including global hazard information
- Soil and geological information
- Topographic and hydrological information

This information may not be available from the Ministry of Education directly, rather collaboration with other agencies will be required. Potential sources of information include:

- Department of Disaster Management, Ministry of Home and Cultural Affairs (MoHCA)
- National Soils Services Centre, Ministry of Agriculture and Forests (MoAF)
- Ministry of Home and Cultural Affairs (MoHCA)
- Department of Geology and Mines, Ministry of Economic Affairs (MoEA)
- The Department of Forest and Park Services (MoAF)

- National Environment Commission (NEC)

A list of additional (but not exhaustive) sources and specific report is provided in Appendix C.

DRM strategies should be cognizant of the impacts of climate change that are making some natural hazard events both more frequent and potentially of higher impact e.g. flood design flows and levels for some river catchments may be higher than previously modelled or codified for.

5.2.2 Mitigation

Early Warning Systems (EWS) have proven to be effective in reducing loss of life for most hazards, but not in reducing risk to physical assets. The emphasis on whether to reduce exposure or vulnerability of schools depends on the type of hazards most prevalent in that location. Sites prone to landslides or avalanches should be avoided, although in some cases civil engineering measures can be taken to stabilise slopes and, likewise, to reduce flood risk (see Section 8).

- In areas prone to high winds (typhoons, cyclones, hurricanes) the orientation of buildings can significantly reduce the level of exposure,
- It is impossible to mitigate the exposure of a school due to earthquakes other than locating buildings away from fault lines, therefore mitigation must be to the vulnerability of the building and the design to considered seismic loading.
- The design and construction of buildings can significantly reduce vulnerability due to high winds, flooding and earthquakes.

5.3 Access Assessment

Distance to the local population will often be a primary factor in site selection for schools in addition to consideration of access conditions. Access includes both access to and egress from the site (e.g. medical evacuation).

Vehicle and pedestrian access should consider access for children, staff, deliveries and access for service and emergency vehicles (ambulance, fire engine, police). Access to and within the site should be inclusive for a broad range of population including those with disabilities or less able e.g. elderly people.

Consideration should include whether there is more than one access road and, if so, which may be considered the primary access. Factors outside the school property boundary can be of high importance, such as bridges and highways. Capacity and condition of highways, bridges and other similar key access constraints should be considered during assessment. Whilst improvements to these may not be the direct responsibility of the school, the school can be an important stakeholder and priorities for access condition can be considered at both local and national level, especially with regard to the provision of access to critical infrastructure.

5.4 Ground Conditions Assessment

Geology, soils, hydrology and hydrogeology (groundwater) conditions at site and local area are important considerations that can impact siting and building design (especially foundation design and structural design) and operation (school use) and can directly contribute to the risk of schools to natural hazards.

The spatial distribution and variation in rock and soil properties, groundwater and hydrogeology are key controls on ground conditions and should be assessed to inform potential ground related hazards (e.g. subsidence, differential settlement, structural damage, flooding, landslide etc.). Ground conditions should be assessed both within the site and beyond the site boundaries e.g. with considerations of drainage catchment areas and upslope or downslope ground conditions and land cover (e.g. vegetation and land-use).

It is therefore important that an assessment of ground conditions should be undertaken by suitably qualified engineer to ensure that site hazards are identified, and that sufficient information is collected in order to undertake the foundation and seismic design of the structures. An outline of a site investigation methodology is provided in Appendix D.

5.5 Site (Civil) Infrastructure Assessment

An assessment of the existence and current condition of the infrastructure within the selected site and its vicinity will need to be carried out to identify risks and suggest mitigation measures and opportunities that will be considered during the development of the masterplan.

It is suggested that the following areas and topics should be addressed:

Flood risk and surface water drainage

- Existing local surface water management strategies and key stakeholders for the catchment and/or sub-catchment that the site is located in.
- Potential sources of flood risk and flooding areas within the site and its vicinity.

- Current surface water directions and flows of the site.
- Existing surface water drainage networks in the vicinity and their capacity.
- Rainfall information and other hydrological information such as river/lake levels, and rainfall. (Intensity-Duration-Frequency curves).
- Existing climate change forecasts reports (where available).
- Site permeability and infiltration potential of the site (refer to Ground Conditions section).

Water resources, water supply

- Existing local water supply distribution strategies and key stakeholders.
- Current water supply practices in the area.
- Existing sources of water available near the site and their capacity/frequency of availability (e.g. municipal supply, groundwater, river/lake, rainwater harvesting).
- Water quality of the different water sources.

Sanitation

- Existing local sanitation strategies and key stakeholders.
- Existing wastewater networks in the vicinity and their capacity.
- Existing wastewater treatment plants in the vicinity and their capacity.
- Current records of any water-borne/hygiene disease outbreaks.
- Alternative sanitation strategies and treatment methods practiced in the area and/or suggested by the authorities and feasible for the site.

Solid waste

- Existing local solid waste management strategies and key stakeholders.
- Existing location of waste collection and waste disposal points in the vicinity.
- Alternative solid waste management methods practiced in the area and/or suggested by authorities and feasible for the site.

Power, energy and renewables

- Existing local power supply strategies and key stakeholders.
- Existing Medium Voltage (MV) or Low Voltage (LV) power lines available near or within the site and their capacity.

- Existing MV/LV transformers / substations near or within the site and their capacity.
- Potential for developing renewable energy within the site (e.g. irradiation levels for solar power, or river flows for micro-hydropower).

Information Communication and Technology (ICT)

- Existing local ICT strategies and key stakeholders.
- Existing telephone or internet/data lines in the vicinity (e.g. copper, or fibre optic).
- Current mobile/cellular phone coverage on-site.

Environmental and ecological

- Existing local environmental strategies and key stakeholders.
- Existing social, environmental or ecological constraints that may impact the development of the school.

Transport & access

- Existing local mobility strategies and key stakeholders.
- Existing main roads/highways near the site and their condition and estimated traffic flows.
- Existing secondary/local roads near the site and their condition and estimated traffic flows.
- Existing pedestrian and/or bicycle routes near the site and their condition.
- Current access gradients.

Emergency Services

- Current accessibility/coverage of emergency services such as medical care, police, fire and rescue.

In order to obtain the risks and opportunities linked to the areas above described a series of activities are recommended:

- Site walkovers to get familiarized with the site and identify any potential major issues.
- Identification of relevant authorities responsible for each of the utilities and services described above.

- Start consultation processes and set up meetings with each of the relevant authorities to share the project needs and obtain any relevant information related to existing services and current capacity of them.
- Desk review of information currently available for the site to assess existing services.
- Obtain agreement with each of the relevant authorities about the utilities and services required having enough capacity to accommodate the expected needs of the school or agree a feasible alternative.
- Identify the repercussion of new connection to utilities or off-line services and get agreement from relevant authorities or developers.

5.6 Environmental Conditions

Existing vegetation cover, wind direction and sun path should be observed to enable the design team to use the natural features of the site to design advantage.

5.7 Preservation

All good views, vistas, historic sites, monuments and landmark places must be incorporated in the site plan and respected through the design development.

6 Masterplanning

Purpose	This section covers the design aspects of the next stage in the implementation process, which is to develop a Masterplan of the school site. This should indicate all the facilities to be constructed, including consideration of phased implementation and allowance for future needs. It should incorporate the findings from the Site Assessment including the location of existing buildings, site hazards and required mitigation identified, ground conditions, topography and location of incoming services to the site. It should also respond to the needs identified in the Inception Stage in terms of facility requirements and constraints of the project.
User	The masterplan should be developed by the Design Team for the project and will require both Architectural and Engineering input.

6.1 Masterplan Key Design Considerations

The masterplan should strive to achieve a good balance between building structures and open space as well as functional and aesthetic requirements of a school campus. It will define the outline into which the detailed design of the buildings will fit, ensuring sufficient space is allowed for open space, outdoor learning and site infrastructure.

The design of schools and learning environments should maximise the potential for learning, both in structured settings such as the classroom as well as in other settings such as external and play areas, promoting intellectual, creative, social and physical growth. Flexibility should be considered in the design of the buildings in order to facilitate a number of different classroom configurations, with different seating layouts which support both the curricular and extracurricular activities of the school.

Allowance for break-out spaces for teaching or learning by smaller groups should be considered. The scaling of spaces and the integration of nature should be considered in order to create spaces that are harmonious and suitable for children. Working with the existing school teachers and parents in workshops, to understand their needs is to be encouraged, and these findings can help inform the detailed design of the schools for the future.

6.1.1 Site Boundary

The masterplan should consider how the school will interact with the surrounding community and natural features. The location and orientation of the buildings can influence whether the school has open interface with its surroundings or operates in a closed, segregated manner.

This also relates to site security – whether there are hard boundaries and divisions (fences etc.) or routes for communities to readily access the school grounds. A balance is necessary to create a warm, welcoming learning environment but maintain the ability to secure and protect school assets from abuse or theft.

6.1.2 Spatial quality

The scale and proportion of the building should be appropriate to the users. They should not be huge and intimidating nor tiny and insignificant.

Planning should aim to create spaces that lift the spirits of the students and not depress and demoralize them. The school should have a welcoming and lively air about it.

Careful thought and consideration should be given on how the shape, mass and the height of the buildings will impact or play with the adjacent structure or spaces around them.

Flexibility should be considered in the spatial configuration, in order that the design can facilitate future needs, where possible. The design should maximise natural daylighting and views in order to promote wellbeing.

6.1.3 Location & Orientation of Buildings

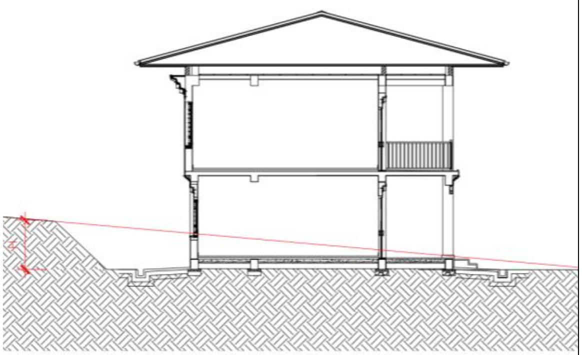
It is expected that Dzongkhags/Thromdes will come up with a custom design which is best suited to their needs and sites.

A number of factors must be considered when locating and orientating the building to respond to the site constraints and opportunities.

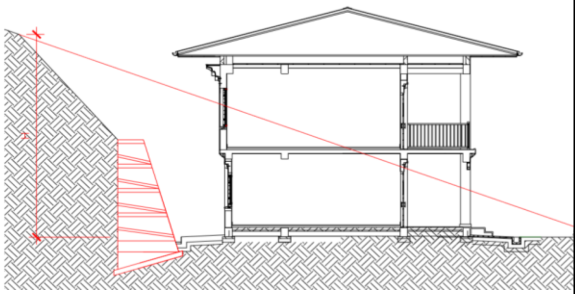
6.1.3.1 Topography

The choice of topographic setting should also be considered in relation to ground conditions (Section 5.4). In mountain areas frequently (though not always) hill spurs and ridges can be preferred sites with regards to mitigating exposure to and impact of natural hazards.

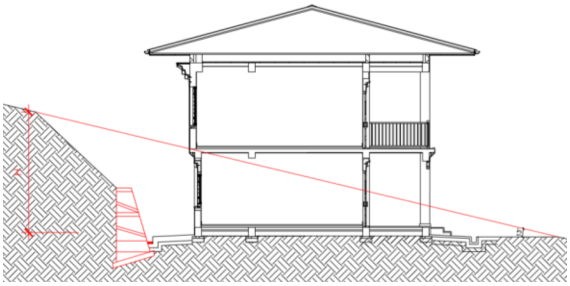
Due to the geographical nature of Bhutan many school sites are located on slopes. If the building locations are not carefully planned, it can lead to high construction costs due to huge volumes of earth cutting and retaining structures. However, such costs can be considerably reduced by opting for site location that requires minimum cutting as indicated in the following illustrations (Figure 4):



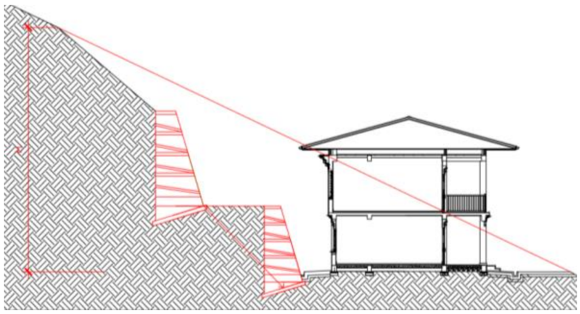
(a) When the ground slope is less than 5º it is cut to fit the building and no retaining wall is required.



(b) When the ground slope is between 10-15º huge retaining wall is not required. If the soil is not loose or marshy the heights of these walls can be half the height of the cut. The cut surface can be stabilised with vegetation cover.



(c) When the ground slope is between 15-20º the height of the retaining wall should be approximately 2/3 of the cut height. The cut surface should be stabilised with vegetation cover.



(d) When the ground slope is greater than 20º the cut becomes too deep and hence such cuts are not recommended. However if it cannot be avoided than double retaining wall of RRM or RCC walls must be considered. The active resultant force of the upper retaining wall should fall on the middle of the lower retaining wall foundation.

Figure 4 Approximation of requirements for earth cutting and retaining walls

Buildings should be placed with least disturbance to the natural land profile with minimum cutting. For the same reason it is also economical to place linear buildings length wise along the contours (Figure 5).

(a) Locate the building along the contours to minimise cutting

(b) Locating the building across the contours will entail huge earth cutting

Figure 5 Influence of contours on preferred building orientation

6.1.3.2 Orienting for Passive Performance

The aim shall be to limit the building’s energy demands through passive design. This approach utilizes natural ventilation to control air quality and cooling, solar heating and daylighting to reduce the use of electricity for lighting.

The potential performance of the passive design is greatly determined by the orientation of the building on a particular site. This should be developed with consideration of prevailing winds (which can influence natural ventilation) and the sun’s path (which influences the extent of solar gains and daylight).

Wind

Building siting to minimize loading from wind is also important:

- Orient the shortest length of the building towards the strong wind.
- Avoid placing huge windows and openings in the strong wind direction
- Place trees to divert the wind direction, but they should not be too close (minimum of tree height*1.25 from building) to avoid falling onto the buildings (Figure 6).

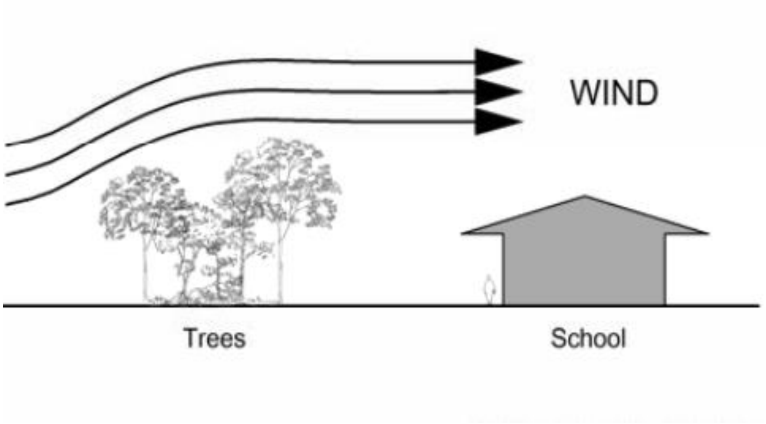


Figure 6 Wind-breaker diagram

Sun-path

The building can be orientated to maximise or minimize solar gain. Which orientation is desirable will depend on the level of heating or cooling needed. The orientation can also influence the level of daylighting available.

The sun path for Paro (Figure 7) shows that during the summer months the sun is high in the sky for the hours when the solar heat intensity is at its greatest; whereas during winter the sun remains low in the sky even at midday (reaching a maximum altitude of around 40deg at midday in December).

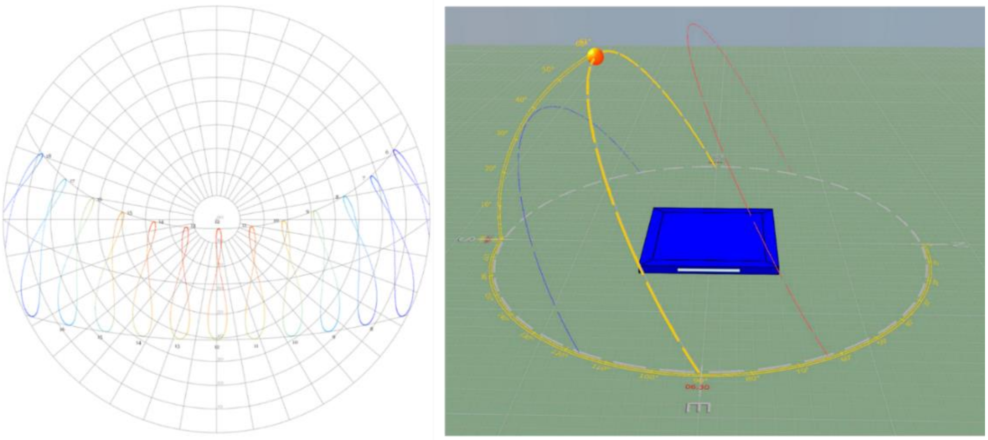


Figure 7 Paro Sun-path Diagrams

This shows that south and east orientations will receive the most direct sun when the heat gains are highest. Whereas north orientations will receive little (or no) direct sun and west orientations will receive less intense direct sun.

The preferred building orientation will therefore depend on the need for heating during winter (and/or limiting heat gains during summer) - which in turn will depend on the climatic zone the building is located in.

Bhutan has mainly three climatic zones which are: **Alpine, Temperate** and **Sub-Tropical.** These zones are broadly in the north, central and southern regions respectively (Figure 8).

	Alpine	Extremely cold winter	Cold summer
	Temperate	Cold winter	Warm summer
	Sub-Tropical	Moderte winter	Hot & humid monsoon season

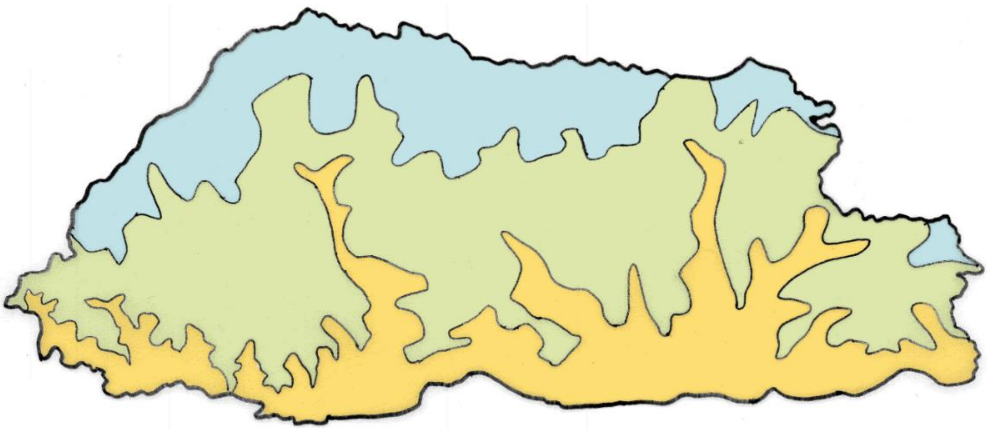


Figure 8 The three primary climatic zones

The following principles can be used to help optimize the building orientation according to its climatic zone.

Note: For actual building design, the micro climate of the particular site must be considered in detail.

Orientation in Alpine zones

These regions have temperate/cool summers and extremely cold winters; therefore direct sunlight is required all year round (during school term) to naturally heat the inside of the buildings. So, the best orientation is to face the longer length of the building towards south-east to receive maximum solar heating. It is also useful to plant trees in the path of the prevailing cold winds to divert them away from the occupied spaces (Figure 9).

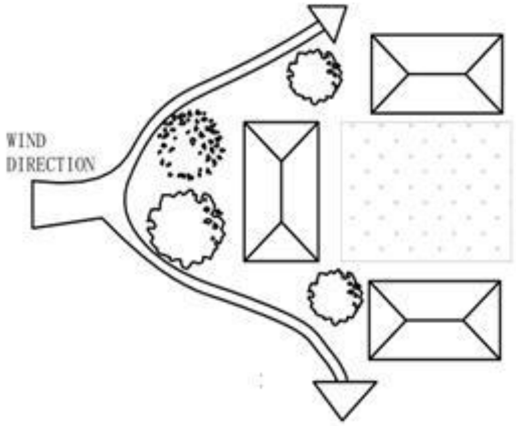


Figure 9 Using trees to divert the wind direction

Orientation in Temperate zones

In this zone summers are warm to hot and winters are cold. Similar to the Alpine zone, the building should be orientated to utilise solar heating; however care will be needed to ensure sufficient shading during summer. Planting deciduous trees around the building may help prevent the direct summer sun from entering the building and allow sun penetration during cooler winters (Figure 10).

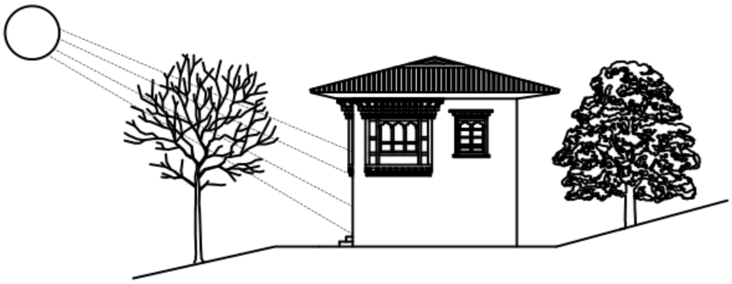
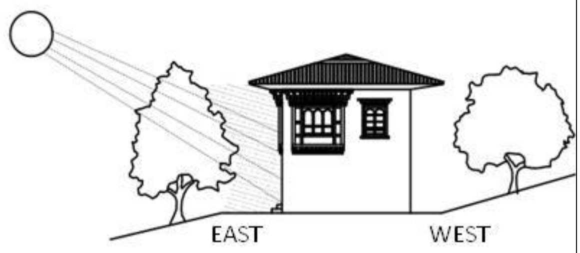


Figure 10 East & South facing buildings in the Temperate zone

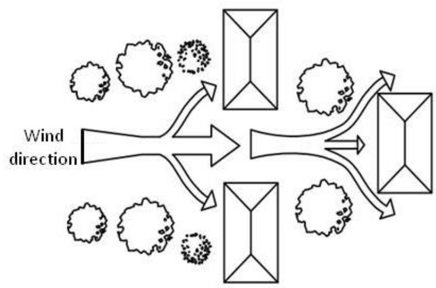
Using deciduous trees allow winter sun to heat the building whilst providing shade during summer

Orientation in Sub-Tropical zones

In this zone, as it is very hot during the summer and moderately warm in winters, therefore it is not desirable to have too much direct sunlight into the rooms. Hence, buildings should be designed to face north and west to avoid direct sunlight. If facing east and south are unavoidable, then evergreen trees can be planted in order to prevent direct sunlight from entering the building (Figure 11.a). The other good solution is to have over-hang balcony to provide shade on the east and south side. Further, buildings should be orientated in such a way as to channel the prevailing winds to cool the interiors below (Figure 11.b).



(a) Using trees to shade the building from direct solar heat



(b) Using trees to channel wind through buildings for cooling

Figure 11 East-West facing buildings in the Sub-Tropical Zone

Shading

In some cases, other site constraints may limit the ability to orientate the building optimally according to the sun path. Additionally, there can be contradictory requirements throughout the year as limiting solar gains may be desirable in summer whereas it may be beneficial to maximise them in winter. Shading solutions can help balance these conflicting requirements.

Shading can be in the form of components added to the building or making use of natural sources of shade such as trees. During masterplanning – the opportunity for beneficial shading (or avoiding detrimental shading) from natural sources should be considered.

With natural sources – care must be taken where there could be a risk of a change of condition – e.g. trees may fall down. However, there can also be a benefit from natural transitions – deciduous trees provide more shade in summer (when they are leafy) and less in winter (when they are bare).

The design of building-mounted shades is discussed further under Building Design.

Noise and air pollution

Sources of noise and air pollution should be identified and assessed to determine the implications for siting the building.

The aim should be to locate the buildings at sufficient distance from pollution sources such that:

- Background noise levels are limited to 45db.
- Natural ventilation openings are clear from sources of pollution [20-30m is ideal. Depending on the severity/toxicity of the pollution, 10m may be an acceptable minimum].

If a school location cannot be avoided near a highway or other noise producing elements, planting trees and shrubs in between can reduce noise pollution considerably (Figure 12).

The design of schools should segregate vehicles away from the school campus, in order to mitigate against pollution and create a safe campus. Pedestrian friendly campuses should be encouraged.

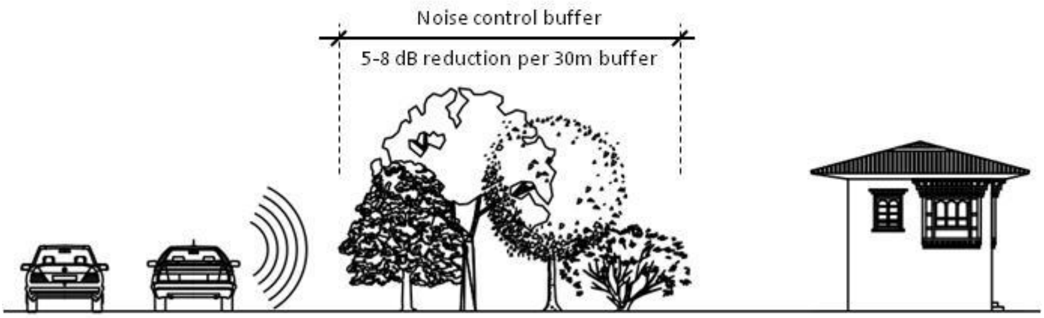


Figure 12 Using trees to reduce noise

6.1.4 Zoning, layout and adjacencies

In order to enhance to the efficiency of the school campus, the facilities provided in the campus should be located in such a way that they function in harmonious and cohesive manner. Careful thought should be given on how and when the facilities are used. Generally, classrooms, staff-rooms administrative offices, libraries, laboratories are grouped as academic zones. Similarly, the play area, basketball court, volley ball court, football field and multipurpose halls are grouped as sports/recreational zones. Finally, the residential zone consists of two kinds, one comprising of the hostels, warden/matron quarter and dining hall for students and the other of staff quarters provided within the campus.

The sports/recreational zone should be placed between the student's residential zone and the academic zone so that they can be used during breaks in between class periods and also after school for evening recreation.

As the recreational groups generate lot of noise, it is desirable to locate them at safe distance from academic area to mitigate disturbance and distraction during class hours.

If the hostels cater to younger students for (PP-VI), it is sensible to place the staff quarters in close proximity to the hostels to provide passive vigilance. However, for older students, it is a better option to keep a reasonable distance between them to allow for privacy for both students and teachers alike.

The spaces and areas which are frequented by the general community such as administrative and multipurpose halls should be located closer to the entrance of the campus for easy access.

The zoning plan should illustrate how all these facilities and zones are organized (e.g. Figure 13).

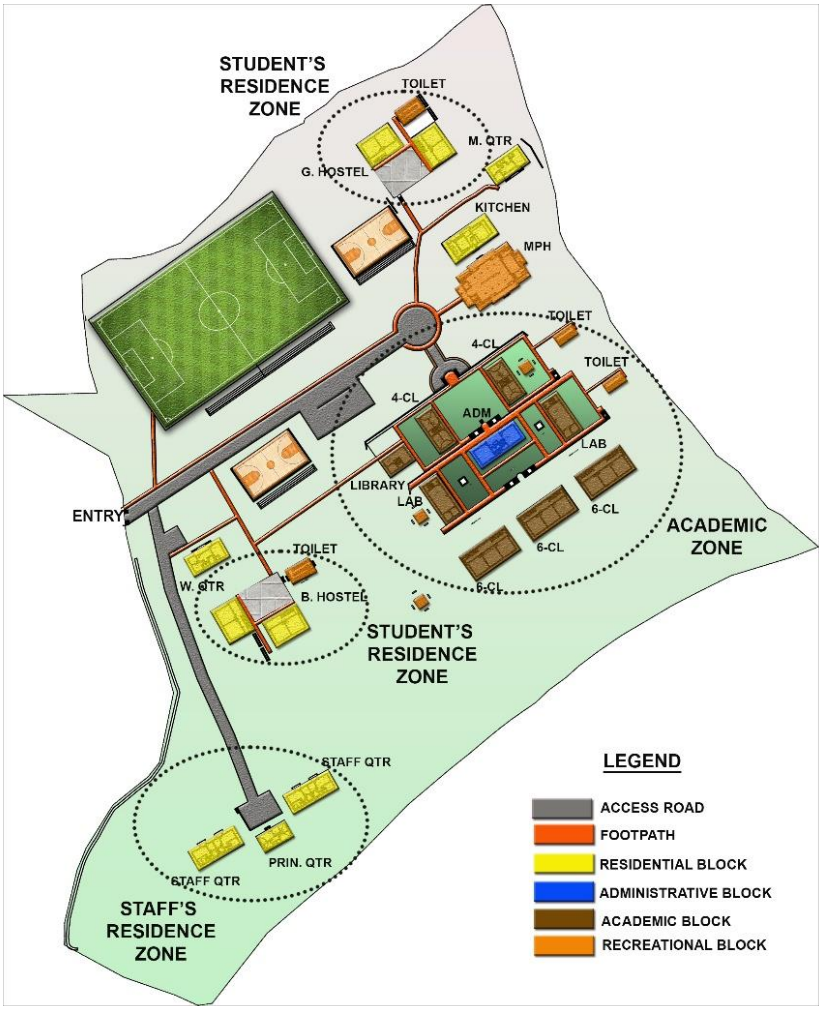


Figure 13 Example zoning plan

6.1.5 Environmental conservation and landscape

A beautiful green campus is essential to provide amicable learning environment. Natural vegetation cover, especially trees, should be conserved as much as possible and should be incorporated to enhance the landscape of the campus.

If there is a natural stream through the site, care must be given to positively integrate it with the school landscape and also tap upon it for non-potable use.

Such streams must be protected and maintained well and should not pose any health and accidental threats to the users.

It is best to use the locally grown plants for landscaping purpose.

6.1.6 Open Space and Agricultural Area

Apart from the specified play area, it is also important to provide some open space in the campus. Open space can include landscape areas such as flower gardens, Plantation areas, lawns and even vegetable gardens. The total proportion of open space to be provided at each school will be a balance between the functionality required and the constraints of the site. An indicative target is to maintain about 25 % of the site as open space.

Open space may also be part of a strategy to mitigate against risks such as flooding or mud slides. If a risk of mud slides is identified – mitigation measures may include building a walled enclosure and/or establishing a no-build zone.

It can be provided with benches and gazebos for informal seating.

Agricultural gardens must be promoted to learn, practice and encourage growing our own food.

6.1.7 Surface water management

Appropriate and adequate surface water management is essential for good school masterplanning design. Good surface water management has a direct impact on the health and wellbeing of people and the environment. If both water quality and quantity are properly considered, well designed surface water management solutions can address a variety of closely linked vulnerabilities (i.e. flood risk, erosion and landslides, pollution and vectors & diseases) and can also provide wider benefits such as livability and inclusion.

Surface water management involves reducing the risks of flooding and ponding of water originated from runoff from the land, small watercourses, pipes and groundwater following periods of heavy rainfall/precipitation. This water should be assessed by both its water quantity (too little or too much water) and water quality (the chemical, physical and biologic properties).

Pollution of surface water is frequent. Good surface water management allows water that lands on the ground to be used if the water quality is adequate, helping to preserve water resources.

Water quality can also be improved for the benefit of humans and the local ecosystem. In this guidance, rainwater and spilt water are considered to be the two main categories of surface water sources, defined as follows:

- Rainwater: Precipitation of any product of the condensation of atmospheric water vapour that falls under gravity this includes rain and snow.
- Spilt water: Clean/treated water that might be spilt on the site. (i.e. water that is spilt at a tapstand, or by a water truck).

It is important that surface water management should not include greywater and sewage or blackwater. Greywater is the water that has been used for washing, bathing, laundry or cooking etc. and is contaminated but, unlike sewage (or black water), contains very little or no faecal matter or solid waste. Sewage or black water is water which contains faecal matter. This is highly contaminated water and needs to be managed separately using different measures. The management of both types of water are covered under the utilities and services section.

The surface water management strategy of the school masterplan should be developed by a civil engineer with experience in this area, and in constant coordination with the masterplan and landscape architects.

Assessment

Prior to commencing design of the surface water management strategy, a good understanding of the site is needed. Site assessment information should be clearly recorded as assumptions will be made from this information (e.g. infiltration rates and vegetation choices).

Where possible, a site walkover is an essential activity to start a site assessment, giving a clearer understanding of the site and identifying/verifying information that will be part of the site assessment.

A suggested list of information that should be collected is shown below. Some of this information may have been already gathered in previous stages or by other disciplines. In order to avoid duplications and improve efficiencies, communication across the planning team is very important and strongly recommended:

- <u>National, regional or local guidance:</u> Currently there is no national regulation or guidelines in relation to surface water management. Where it exists at the regional and local level, guidance should be reviewed and compared against the advice given in these guidelines.
    - Government guidance and regulations including environmental regulations, local advice and standards.
    - Local catchment / integrated water management (IWM) plans, flood authorities and flood maps.

- <u>Sources of surface water:</u> Find the location, quantity and quality of the following sources:
    - Rainfall data, glacier melt, snowmelt, groundwater/springs and other natural sources at the site and those upstream.
    - The extent of typical flooding on flood plains. Existing catchments, runoff and drainage systems. Understand the human/social impacts of previous flood events including water levels and damage extent.
    - Existing sources of water pollution (e.g. latrine overflow).
    - Potable water spills – including locations of tapstands.

- <u>Discharge locations:</u> Find the current locations where surface water from the site is currently being discharge as:
    - Local drainage network: Who owns, operates and maintains local sewerage and water treatment infrastructure. Are there opportunities to use this? Where is it located and how big is the network?
    - Watercourses: rivers, streams, lakes etc. (including information on their size and fluctuation during the year). Is it possible to discharge into existing watercourses? Is approval required from a management authority? Is the proposed school going to increase the discharge flow into the watercourse? Will discharge from the school increase the flood risk in the river, downstream of the school?
    - Infiltration areas/Groundwater.
    - Detention / Attenuation / Evaporation ponds.

    In addition, consider the following questions when thinking about discharge locations:

    - Can discharge be avoided through localized storage and water re-use locally?
    - How does surface water discharging from the site impact downstream areas (e.g. increased flooding or reduced water resources for irrigation)?

- Key surveys: The following resources might be useful for the design of the surface water management strategy:
  - Topographical surveys or mapping of the catchment upstream of the site to understand the potential flow path of surface water to the site.
  - Topographical surveys of the site to understand localize drainage flow paths on the site.
  - Geological maps including ground infiltration characteristics.
  - Groundwater/aquifer/hydrogeological information.
  - Water sources and local waterbody surveys (rivers, lakes etc.).
  - Hazard maps, historical flood and landslide information including watermarks or trash lines and frequency.
  - Historic, existing and proposed drainage infrastructure.
  - Historic, existing and proposed land use changes within the catchment upstream of the school – including impacts on ground/soil conditions.
  - Wastewater

- Disease, vectors and pests: It is important to understand if and how diseases, vectors and pests that impact humans are affected by surface water. It should also be considered how these might vary due to seasonal or extreme weather events.

Rainfall

Understanding the climate and the pattern of rainfall on a site will support appropriate preparation for storm events. This should be carefully considered to ensure that it does not lead to a significant over or under-sizing of the surface water management components. Selection of the right Intensity Duration Frequency (IDF) curves is important for drainage design, as they allow design of infrastructure for different hazard level.

As rainfall data can be difficult to get or may require time, it is suggested that information gathering starts at the masterplanning stage and then is further developed in the design phase.

Water quality

When designing the surface water management strategy, it is important to identify potential sources of contamination and predict the expected water qualities that will be generated by the different sources of surface water.

Rainwater is likely to be unpolluted, but it is important to identify uses that may pollute it after contact with surfaces as carparks, washing areas, animal feeding areas, etc.

Different water qualities should be linked to different surface water management techniques.

Initial strategy / Influencing site selection and school masterplan

All the information collected should be used to start designing the surface water management strategy and influence the design of the school masterplan. Highlight which areas may be low risk and which areas are a higher risk to plan different uses within the site.

As part of that initial strategy the following should be identified:

- Definition of different types of surfaces and runoff coefficients;
- Total amount of areas by type of surface;
- Sources of surface water, estimated quantitates and qualities, including potential sources upstream of the site;
- Natural drainage flow paths and propose drainage paths;
- Potential surface water management techniques to be used;
- Potential sources of surface water contamination and estimated surface water qualities; and
- Potential outflows locations to be used and current capacity.

6.1.8 Utilities & Services

During the masterplanning stage there are two primary objectives with respect to utilities and services:

(1) Confirm availability of supplies by estimating demands and confirming with the relevant authorities if there is available capacity in the local network (and if there is not – then identify the steps required to secure the supply).
(2) Inform the masterplan layouts by proposing the utilities strategy which should include locations of connection points (where the services come into the school site) and the likely sizes and routes of main distribution.

For a school masterplan the following utilities and services are considered the most relevant:

- Water supply
- Sanitation and hygiene
- Solid waste
- Energy supply
- ICT

The utilities and services strategy of the school masterplan should be done by a civil engineer with experience in utility coordination and in constant coordination with the masterplan and landscape architects as well as with the relevant Implementing Authority for each service/utility.

Water Supply

When developing the water supply section of the masterplan the following aspects should be covered: water sources, water quality, water demand and storage, water facilities and distribution networks.

Water sources

An assessment of the available water sources in the site and its vicinity should be carried out including the potential yield and water quality. Some of the potential water sources expected in a school are:

- Municipal water network: in urban areas it is likely that a potable network will be available in proximity to the school site, in which case this should be the preferred source of water for the school. According to the Bhutan drinking water quality standard of 2016, water supply from a municipal water network should be treated and safe to drink, however, this needs to be confirmed with the water supply authority.
- Groundwater: In the absence of a municipal water network, groundwater may be an alternative water supply. Groundwater may be obtained from springs or pumped from underground. The reliability of water yield and quality should be assessed through a hydrogeological investigation to confirm if this could be a suitable source of water for the school. In the case of springs, special consideration should be given to protection against external contamination risks.

- Surface water: in the form of streams, rivers, ponds or lakes if present close to the school site. Water quality and potential contamination risks are important considerations with this type of source. Seasonal variation in quality and quantity must be also considered.
- Rainwater: Even in the presence of a municipal water network or a spring, alternative water sources such as rainwater should be considered for uses other than drinking (e.g. irrigation, washing, animals). Collecting rainwater from either an existing roof structure or a ground catchment area can provide a useful supplementary source of water even if it is not used as the main supply and can have a significant benefit in terms of surface water drainage or flood risk management.

Water demand and storage

Sufficient water should be available at all times for drinking and personal hygiene, and for food preparation, cleaning and laundry as applicable. This amount of water should be stored in one or more water tanks.

The location of the water tanks shall be planned at this stage. The following aspects shall be considered when planning the location of the tanks:

- Topography: Where possible, storage should be provided at a higher level than all water use points, so that supply can be maintained during a power outage. If possible tanks should be located on the ground.
- Security: Tanks shall be placed in a safe place and security measures shall be considered in order to minimise the risk of vandalism and contamination.
- Accessibility: Tanks should be accessible for construction as well as for operation and maintenance.
- Geotechnical: Bearing strength, potential settlements and landslides should be taken into account. The construction of foundations may be considered.
- Buried, ground-bearing or tower: a specific comparison should be done in each case to decide which is the preferred option.

Water facilities and distribution networks

From the water storage tanks, water should be distributed to all the different buildings with water supply requirements and any additional water supply point (i.e. tapstands, handwashing points, irrigation, cleaning taps).

Depending on the location of the tanks and the pressure required at each supply point, the network may be planned as a gravity or pumped network. In case of being a pumped network, space should be allowed for water pumps.

An initial distribution network shall be planned with preferred materials and estimated diameters. If possible, the water supply network should be designed as a ring/looped network, where the main pipeline is provided around the periphery of the site, with distribution lines from this main, connecting to each supply point. A looped network will provide consistent water pressure around the site.

Sanitation

The ultimate goal for sanitation interventions is to protect public health. Within a school masterplan the sanitation section shall define the capture and containment of the sanitation service chain. The hygiene strategy is recommended to be developed at the design stage (Figure 14).

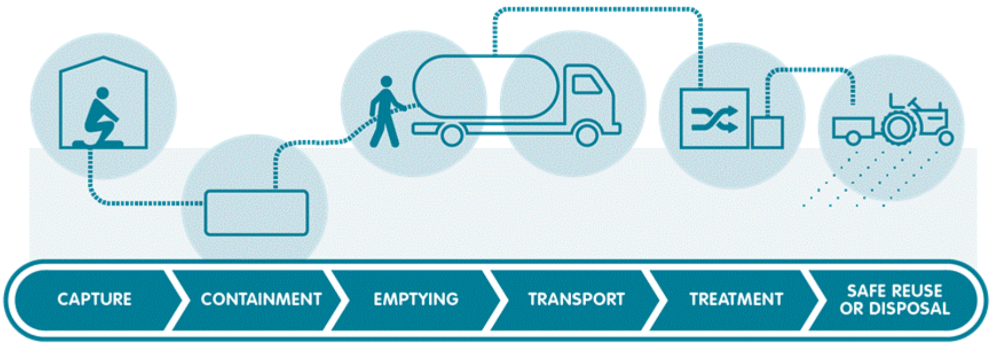


Figure 14 Components of a sanitation and hygiene strategy [7]

Capture

The most important tasks at this stage are identifying the **location** and preferred **type** of toilets, and the effluent collection/disposal strategy.

- Location: Toilets should be easily accessible to all, including staff and children with disabilities. In principle, toilets should be as close as possible to classrooms and playing areas, to ensure that they can be used conveniently and safely. Ideally toilet blocks should not be more than 30 m from all users. Access routes must be open and clear and the facilities in audible and visible proximity to the community, in the event that immediate assistance is needed.

When locating toilet blocks it is important to ensure accessibility during all weather conditions, including after heavy rains or flooding. Sufficient lighting is needed for children who use facilities at night (in boarding schools). The location should also allow for security to reduce the risk of vandalism, particularly when communal WASH facilities are being installed. Toilet facilities should be situated apart from other producers of odours and flies such as garbage dumps, cattle or animal pens. Such placement discourages people from using them.

Toilets with leach-pits must be located downstream from any spring and at least 20-30 metres from wells and water sources to avoid pollution of water sources.

- Type of toilet: The type of toilet should be selected based on a series of factors: method of anal cleansing, water availability, affordability, demand for re-use of faecal waste. Appendix E provides a guide to sanitation selection developed by the Water Engineering and Development Centre (WEDC) and commonly used in the sector. As water is generally available for sanitation in schools, when a minimum of 10 litres of water per flush is available, the recommended options are toilets with connections to sewerage (if accessible) or toilets connected to a septic tank.

  As most visits to a school toilet are for urinating only the provision of urinals should be considered as this can have many advantages, such as reducing the volume deposited in septic tanks, reduction of smells and higher potential for using faecal matter from septic tanks. When providing urinals attention has to be paid to the local acceptability, in particular for girls, where its design deserves serious consideration. The discharge from urinals can be either connected to the sewerage network/septic tank, or it can be diverted into a separated closed tank or container, where it can be treated by storage (time itself leads to pathogen kill) and reused in agriculture. Alternatively, it can also be connected into a separated soak pit.

Containment / Connection to network

Depending on the type of toilet selected, different type of containments will need to be planned. In the context of toilets in schools, the most likely case is that wet toilets will be used, and these will be connected to the sewerage network or connected to a septic tank.

- Connection to sewerage: If there is a sewerage network accessible to the site its location and depth should be determined to assess potential means of connecting into it. When possible, the preferred approach is to connect the toilets by gravity, however, pumping solutions can also be considered.

- Septic Tank: Septic tanks are suitable for conditions where the wastewater can drain away and be absorbed into the soil without contaminating groundwater where it is extracted. Sealed solid waste storage is an option if the soil is unsuitable or the water table is too high. Cesspits are another option.
    - Location: An initial location of the tank should be planned at this stage, considering that it should be downhill from the source of sewage and at least 15m from the nearest water supply and avoid flood prone areas.
    - Connection: A series of connections will need to be planned from all the site toilets to the tank, including the staff toilets within the buildings.

Solid waste management

A solid waste management strategy shall be planned at this stage covering the waste generation, segregation and collection within the site.

The Waste Prevention and Management Regulation (2012) states that '*The heads of educational and training institutions shall include waste management as part of their co-curricular activities and encourage use of filter water and discourage use of packaged foods and drinks in the schools and training institutes.'*

In many occasions this may lead to a "zero waste" policy for students, however, a solid waste management strategy will be needed for other sources of waste such as from classrooms and offices, waste from cleaning open areas and gardening, and from kitchens and toilets.

The solid waste management strategy should align with the following duties:

- safely store and dispose of waste at a designated site or deliver it to a designated waste collector
- waste is handled in a manner which does not endanger any person or the environment
- comply and cooperate with waste segregation, reduction, reuse and recycling standards and initiatives as required under the 2012 Regulation
- cooperate with monitoring and implementing agencies or its authorized service provider for the purpose of implementing this regulation

Power supply

A safe and constant power supply shall be provided to the school at all times. Within the school masterplan, the power supply section shall define the energy and power demand including opportunities for reducing energy demand, alternative sources of energy, power connection options and on-site distribution network.

For the purpose of the masterplan and initial engagement with the Electricity Authority, a preliminary demand estimate is required. This should be generated by producing a table of all the different uses and areas, including site lighting and security, and calculating the estimated daily average and peak energy demand.

Opportunities to reduce consumption and/or utilise alternative energy sources should be considered at this stage.

Alternative sources of energy may be desirable for two reasons – improving sustainability and improving resilience.

In the context of Bhutan, the sustainability driver may be lower given that the grid supply is generated by hydropower. However, there may still be cases where local generation from renewables has sustainability advantages – for example in remote locations where a grid connection may require consumption of substantial energy and materials.

In terms of resilience, and alternative energy source can reduce/remove the school's reliance on the grid supply such that in the event of short- or long-term grid failure the school may continue to operate.

Examples of potential alternative energy sources are:

- Solar energy
- On-site wind generation
- Anaerobic digestion & biogas
- Biomass and biofuel
- Micro-hydro
- Back-up generator

Wherever possible energy demand reduction should be prioritised. Whilst provision of alternative energy sources can be beneficial they can also have substantial space and cost implications. If an alternative energy source is planned – this should include consideration of operating and maintenance which might require agreement with an appropriate specialist organisation.

Power connection options

Based on the average and peak power demand estimation, and with consideration of any alternate power supply strategy, agreement for the power supply should be established with the Electricity Authority along with identification of the best connection points.

Generally, the new school site will be connected into an existing Low Voltage network in the area.

In the case of an LV network not existing in the area, or not having enough capacity, a connection to the Medium Voltage network will be required. In this case, an MV/LV transformer substation will be required within the school site and space for this should be identified in the masterplan. The size of an MV/LV substation may vary depending on whether it is built onsite or prefabricated. But in either case a minimum plot of 6 meters by 6 meters should typically be planned.

On-site distribution network

A site network will be needed to distribute power to all the different power demands from buildings and public space (lighting, CCTV, water pumps etc).

On large sites, it may be worth considering a ring network to provide diverse supply routes and improve resilience against failures.

Information and Communications Technology (ICT)

Technology has a fundamental role in the delivery of education, and this will increase even more in the future. Ideally, secure, reliable and effective connectivity to fixed and mobile networks should be planned and future-proofed to support advances in technology. A strategy should be developed to ensure demand for ICT and telecommunication services can be supported over the lifetime of the school.

The ICT section of the masterplan should cover:

- External connectivity infrastructure
- Site-wide distribution infrastructure
- ICT spaces and cable pathways
- ICT Systems such as:
    - Structured Cabling System (SCS)
    - Campus data network (LAN)

- Wireless LAN (Wi-Fi)
- Satellite TV Distribution

6.1.9 Access & Circulation

The access and circulation strategy should enable the effective and efficient movement of staff, students and visitors to, from and within the site across all modes of transportation.

The development of the access and circulation strategy is also a good opportunity to develop and promote a sustainable transport strategy that reduces reliance on private car usage through the promotion of cycling and walking.

Within a school masterplan the access and circulation section shall define the local road connectivity and the internal circulation strategy (e.g. Figure 15)..

The masterplan strategy should consider internal and external circulation for pedestrians including consideration of weather protection. Maximising external circulation can minimise costs and create generous landscaped spaces and pedestrian friendly routes.

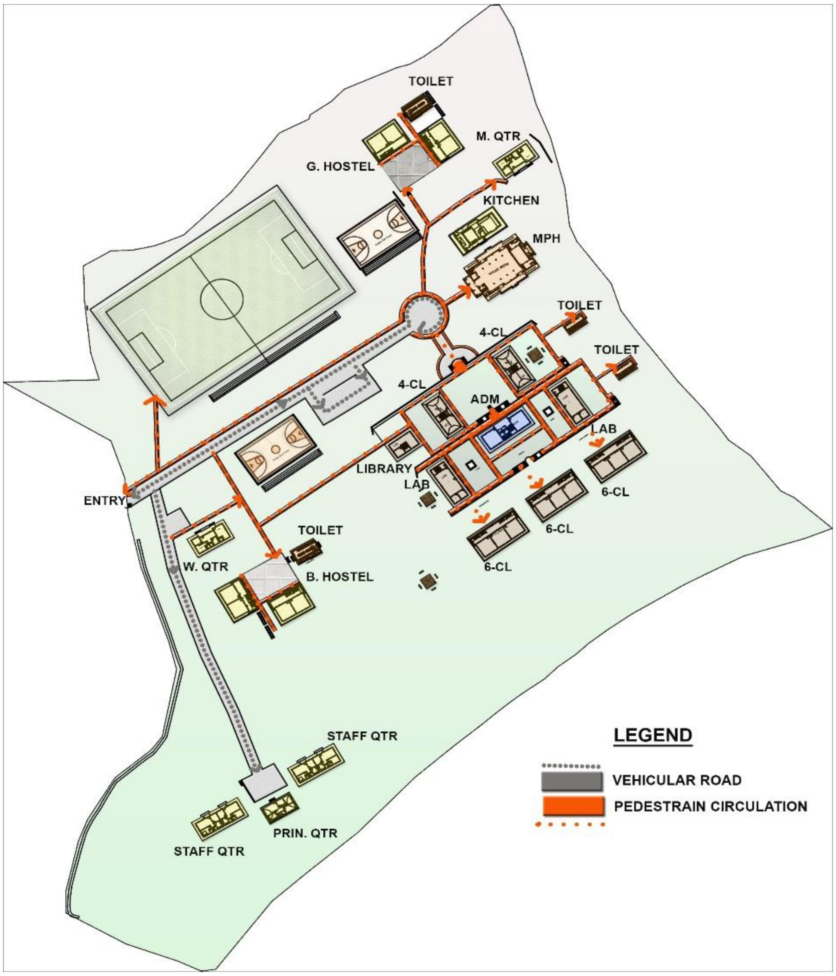


Figure 15 Example Site Circulation Plan

Local road connectivity

Communications should be established with the relevant local authority to identify and agree which local road(s) in the vicinity will be the most appropriate for the design of the school access connection.

To better assess if the affected roads nearby the school have enough capacity, the amount of access and departure movements divided by means of transport and estimated times should be forecast at this stage.

Based on the traffic forecasts, a series of road access will need to be planned to accommodate the travel demands across all modes (car, bus, bicycle, walking).

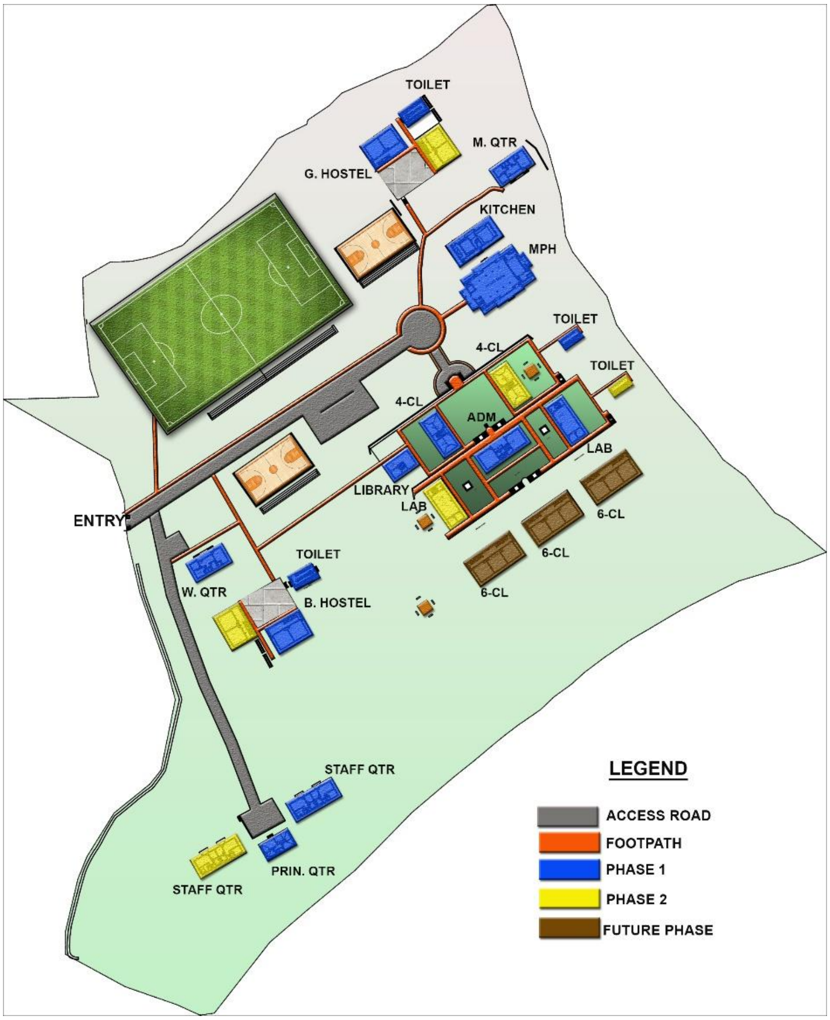
Internal circulation strategy

Internal parking areas and site roads should be planned to provide access to the different areas to be developed on the site.

Road geometry and pavement design should consider expected usage, topography and geology.

6.2 Phasing

The masterplan should consider the strategy for incremental development of the school site. This relates to both the gradual construction of the immediate project (e.g. if there are multiple buildings planned for construction over a number of years), and also potential future expansion. This should be captured in a Site Phasing Plan (e.g. **Error! Reference source not found.**).



6.2.1 Assessment of Existing Sites for Expansion of Facilities

If the project is an expansion of an existing site, then it is still important to reconsider the points in Section 4 and 5 to see if any of the existing masterplanning elements noted need to be upgraded to match the demands of the new layout. Examples of changes to be considered might include:

- Assessment of land to be used for construction for hazards particularly landslides and flooding – was there a reason this area was not built on previously?
- Do new buildings disrupt previous evacuation planning, and will this need to be reconsidered?
- Understanding what other buildings may be required in the future to ensure that new buildings are placed as strategically as possible to allow space for further expansion. Does the site zoning need to be updated?
- Increased power demand due to a change of use from a classroom to an IT laboratory or due to increased number of buildings or hostels. Is a new power line from the grid required?
- A need for more toilets due to increased number of students or need for further menstrual health management facilities due to increased proportion of girls?
- Increased water demand due to increased student numbers or increased numbers of boarding students.
- Revised surface water drainage strategy needed as new buildings disrupt the current run off pathways.
- Need for a new traffic management strategy at the school entrance if change from boarding to non-boarding school.

A key point to consider is that the masterplan should consider future needs and potential as well as immediate requirements. If the masterplan only considers the affordable construction of the first phase, then the opportunity can be missed for developing an integration solution for the future.

6.3 Planning Permit

The Building Regulations 2018 includes the application form for a Planning Permit and the process set out in this document should be followed. Along with the completed application form the following documents must be submitted to the local government:

i. Copy of the latest Lag Thram/ Land Ownership Certificate/User Right Certificate
ii. Copy of Planning Certificate (only in planned areas)
iii. 2 sets (A3/A4) site plan showing the (one set referral to the other agencies): a. The boundaries and dimensions of the plot, set-back lines and the access road b. Levels of the plot, and the location of drains, septic tank and soak pit or sewer lines c. Location and dimensions of existing buildings, trees and car parking spaces.
iv. Certificate of the designer.

7 Building Design

Purpose	Once the masterplan has established the location and orientation of the various blocks, design development can commence for the individual buildings. This section provides guidance specific to the various technical disciplines involved in the detailed design of the structures and site facilities.
User	The design team should refer to the sections respective to their discipline but should also cross reference other sections for coordination. All designers should read and adhere to the guidance on **Safe by Design** under section 7.2.

7.1 Project Requirements ('The Brief')

The design team should ensure that the project requirements are well defined and understood. This may require engagement with the school (for expansions/renovation), local authority and/or community to ascertain what the priorities and challenges are.

This exercise can build on the original needs assessment (Section 3) to develop a more detailed brief. Ideally this would include review and development of **Room Data Sheets (RDS)**. A sample RDS is provided in Appendix F along with some general descriptions for different types of space/facilities (the latter may assist in the completion of more RDS). Depending on the level of capability and capacity of the school or authority – the RDS completion may require some leadership and initiative by the design team; but in those circumstances the RDS can be submitted to the school/authority for review and confirmation.

The Ministry of Education Disaster Management Unit provides a useful guidance document that details the most common hazards found on school premises together with guidance on the mitigation of these hazards [8] [9].

7.2 Safe by Design

During the design stage, all measures that can be practicably employed to remove or reduce risks should be considered. These can be risks during construction or during use of the building and the designer should think about what the specific risks on their project or site might be. These should be recorded in risk register.

The acronym ARC can be used to identify measure to manage risks [10]:

A	Avoid	*where reasonably practicable design out the hazard or substitute it for something less harmful*
R	Reduce	*lessen the effects of the hazards through lowering exposure time, number of people exposed etc.*
C	Control	*introduce measure to further manage the risk. Examples of controls will look at methods such as providing management procedures, operation and maintenance strategies, specialist training etc.*

All risks that cannot be entirely avoided should remain active on the risk register and key risks during construction should be noted on the drawings. Where reliance is being made on operation and maintenance strategies, it must be well communicated to the school management what these strategies are so they can be employed in the day-to-day running of the school after the construction is completed.

The measures adopted will depend on the specific hazard and situation however some examples of this might be:

- Ensuring there is safe access to components which may require replacement or maintenance over the lifetime of the building (e.g. external light fixtures, windows, overhead water tanks etc.)
- Removal of harmful materials in the specification such as lead-based paint or varnishes with a high VOC content.
- Ensuring that structural elements are sized to reduce the risk of injury from manual handling.

7.3 Architecture

Purpose	The design of the schools should be carried out using all reasonable skill and care, based on relevant national and local codes and international best practice. The buildings should be functional and should also provide moments of delight. They should enable the learning experience and a range of teaching methods.
User	The architectural design should seek to resolve form and function to create buildings which meet the needs of the users whilst also complementing and enhancing the local environment. The architects will need to work closely with the engineers to create a holistic design that efficiently addresses constraints and requirements in a coordinated and cohesive solution.

7.3.1 Design composition

All the buildings within the campus should conform to their local building authority norms, for example the allowable height, allowable percentage coverage, zoning regulations, mandatory setback and so on. The internal clear height of the buildings should be 3.0m generally to the underside of ceilings, with 2.7m locally below beams and in toilet and shower areas. The height of halls however should be determined by the requirements for sports activities and the environmental design.

The individual building design can vary to suit their use and purpose but at the same time there should be common elements that unite them with consistency and harmony.

The buildings should blend in harmoniously with the surrounding architectural structures. They should contribute to enhance the aesthetic appeal of the local architecture.

Whether the campus is based on a joined series of buildings, or separated buildings linked via landscaping will need to be assessed as one of the key masterplanning decisions. This decision needs to be made in relation to all design disciplines including fire.

7.3.2 Building performance and sustainability

The suitability of the environment provided by the building is characterized by performance in terms of noise levels, lighting levels, air quality and thermal control.

A key objective is to control the environmental conditions through passive solutions. This has implications for the configuration of the building in terms of the fabric performance, glazing arrangement and provision of ventilation openings.

The design features which address each aspect of the passive solution are interrelated and therefore must be evaluated in a coordinated, integrated approach (e.g. glazing size/location has implications for both daylighting and solar gains).

Designing for passive performance will limit the extent of energy consuming systems required but is unlikely to completely mitigate the need for those systems. For example, daylighting may not meet 100% of the lighting requirements throughout the day so electric lighting is still required. Therefore once the limits of the passive design performance have been identified the next step is to consider how any remaining systems can be designed for maximum efficiency. The final step is then to evaluate clean, green ways to supply the residual energy requirements.

The design principles for each of these aspects are described as follows:

Acoustics	Acoustic attenuation between spaces should be considered as well as suitable acoustic absorption. This is essential to meet best practice for education environments.
Daylighting	Naturally lit spaces should be provided throughout. The extent of glazing, the depth of plans and the spacing between buildings must all be considered in order to maximise daylight and views to the outside, whilst also mitigating glare.
Ventilation	Natural ventilation should be prioritised over mechanical systems to minimise costs and create a sustainable campus. A mixture of single sided ventilation, cross ventilation and high-level ventilation utilising the stack effect can be adopted. The areas of opening windows required will need to be assessed based on a specific building design.
Thermal Comfort (including shading design)	The thermal performance of walls and roof should be considered as well as the thermal mass of materials. The design must avoid condensation and the degradation of materials. A strategy to avoid glare must be developed, considering roof overhangs, trees, blinds and curtains as

	well as the suitable orientation of buildings and their glazed facades.
Low Energy and Renewable technology	The application of renewable technology should be considered, to minimise the carbon footprint of the school and running costs. Technologies that can be considered include Trombe walls, photo voltaic panels, solar water panels, solar cookers and ground source heat pumps. An assessment of the appropriate nature of each technology will need to be made on a case by case basis, given the site and budget. The design should allow for these technologies to be introduced over time. This strategy can allow for a progressive de-carbonising of the school and provide for learning opportunities.

7.3.3 Materials

Materials selection should be carefully considered. The design should enhance and promote a sense of local identity as well as embracing appropriate technology and aim to support sustainable economic development (e.g. engineered timber). The process for selecting materials should include consideration of:

- Environmental (thermal and acoustic) performance
- Structural performance
- Availability and affordability
- Sustainability
- Health and Safety
- Durability and maintenance (for design life)
- Aesthetics

Safety issues relate to performance in a disaster scenario (fire, earthquake, flood, wind) and suitability for day-to-day activities and users (child-safe).

For considerations relating to designing for thermal performance refer to Section 7.5, and acoustic performance refer to Section 7.3.4.

The list of options may vary by location but some considerations for different building elements are provided below.

Cladding (external covering of the façade)

- Heavy and potentially brittle cladding such as bricks or precast concrete shall not be located where students may congregate or adjacent to access and egress paths, except at low level.

- Brick cladding is a robust durable system that has many advantages for school buildings when considered over the whole building life, but it may not be suitable for all locations, with consideration of geotechnical conditions, seismic load and falling hazard. There are also challenges with the sustainability of bricks as they are imported.
- Rabsay wall and other masonry infill walls are to be properly anchored to the RCC structural frame.

Partitions (internal walls / divisions)

- Partitions shall be protected from damage either by limiting seismic drift of the primary structure to less than the drift, which causes onset of damage for the partitions, or
- By providing seismic protection to the partitions (such as sliding head restraints). See Section 7.4.7 for more details.
- The thickness (width) of the partition wall, if constructed using masonry brick, is to be provided at a minimum of the width of the brick

Ceilings (upper interior surface of the room)

- Even if full suspended ceilings are not necessary, acoustic panels may be required.
- In general, ceilings must be laterally secured and designers must consider deformation compatibility in the detailing of edges and junctions with structural elements.
- The ceiling systems should preferably be made using fire resistant materials (in compliance with the building code as a minimum and aligned to the school fire strategy).
- Ceilings (or acoustic panels) should be carefully detailed to avoid falling in an earthquake.

7.3.4 Acoustics

Each room or space in school building must be designed and constructed to have good acoustic conditions appropriate for their intended use.

As teaching in schools require clear communication between teacher and students, quality of acoustic material in the classrooms play a crucial role in learning environment.

Table 2 provides noise level criteria for different types of space.

Table 2 Recommended Noise Level Criteria by space type

Space	Noise (L_{Aeq}, 3mins dB) *	
	New Build	**Refurb**
Art Room	40	45
Biology/Chemistry/Physics Lab or Prep rooms	40	45
Circulation space	45	50
Classroom	35	40
Computer Lab	35	40
Conference Hall	35	40
Dining room	45	50
Examination Centre	35	40
Examiner accommodation**	35dB daytime, 30dB night-time	
Health Room (or Councillor Room)	40	45
Hostels (bedrooms)**	35dB daytime, 30dB night-time	
Kitchen	50	55
Library / Media Centre	40	45
Multipurpose Hall	35	40
Music Room	35	40
Office and staffrooms	40	45

**Generally based on Building Bulletin 93* [11].
*** Based on BS8233* [12]

Noise penetration into the classrooms from playground and traffic must be mitigated as much as possible. Sources of external noise will have been identified during masterplanning and where possible the building location would have been adjusted to mitigate proximity to excessive background noise. The building design will then need to incorporate features to mitigate any residual external noise, in addition to managing noise transfer from internal sources.

Noise producing and noise sensitive places should be planned, designed and detailed to minimize interference between them.

Large rooms where excessive noise is produced should have ceiling treated with acoustical materials which have noise reduction coefficient, NRC of not less than 0.70.

Some other simple methods of improving acoustic quality in the classrooms are by using double glazed windows with timber frames rather than single glass with steel frames.

7.3.5 Inclusive Design (Universal Access)

The design must ensure that all facilities are accessible and usable to all regardless of gender, age and special needs.

Ideally all floors of a building should be made accessible to differently abled users, however if that is not possible due to economic reasons or otherwise, at least the ground floor must be accessible to the physically challenged.

Generally, at least one toilet for each gender must be designed to meet the needs of the differently abled users with adequate wide doors. This is an absolute minimum and the design team should review its suitability according to the number of students and school layout.

To improve accessibility, efforts must be made to link the different courtyard levels by ramps. The recommended ramp gradient is 1:20 (to climb a height of 1 meter, the ramp length required is 20 meters) with a maximum allowable gradient of 1:12. The surface of the ramp must be slip resistant, especially when wet. Proper handrails for the ramps should be provided.

Drains should be properly covered, and footpaths should be laid with proper gradients by avoiding steps and blockades at doorways.

7.3.6 Building Security and Access

The security of the school premises is an important component in rendering a school safe for its users.

To provide passive natural surveillance is an integral design idea. Creating dark and dingy spaces should be entirely avoided. Doors to all the rooms except toilets should be provided with viewing panel to provide surveillance against harassment and abuse.

CCTV provision should be considered for areas that cannot be monitored by passive surveillance and/or for its role as a visible deterrent.

To achieve building security, number of entry points should be limited; however the need for efficient egress during emergency should not be compromised.

Security bars maybe used for the Ground floor windows to prevent vandalism and upper floors to avoid accidents.

Security measures should create safe environment for students and staff while discouraging unauthorized member of the public to loiter around.

7.3.7 Design Criteria for Standard Facilities

Appendix F contains room data sheet and guidance notes for the requirements of different room types.

Appendix G contains example accommodation schedules for primary and secondary schools. The schedules are intended to demonstrate just some of the ways that space can be allocated within the recommended zones of net and non-net area. Many others are possible. Some of the recommended spaces may be shared between infant, junior, middle and higher schools if the campuses are co-located. In particular, the administrative offices and multi-purpose halls.

7.4 Structural Design

Purpose	This section sets out the design criteria for the structural design of school buildings. It is to be read in conjunction with the relevant building codes which set out the specific design procedures. The requirements provided in the Bhutan Building Code and corresponding IS Codes are to be viewed as the minimum standard and any increase to performance standards provided in this design guideline should be deemed to take precedence.
User	The structural section of the guidelines is designed to be read by a qualified Structural Engineer, and it has been assumed that the reader is already well versed in structural principles and design procedures.

7.4.1 Relevant Codes

Existing reference codes and guidelines to be read in conjunction to these guidelines are as follows:

- IS 456:2000 – Code of practice for Plain and Reinforced Concrete
- IS 875 (Part 1 to 5):2000 – Design Loads (Other than earthquake) for Buildings and Structures
- IS 1893 (Part 1):2002 – Criteria for Earthquake Resistant Design of Structures
- IS 4326:2013 – Earthquake Resistant Design & Construction of Buildings
- IS 13920:2016 – Ductile Detailing of RC Structures subjected to Seismic Forces
- NUDC/002/1985 – Manual for Timber Engineering Design, RGoB
- IS 800:2007 – Code of practice for General construction in Steel

7.4.2 Loading

Dead Loads

The following bulk unit weights for materials should be considered:

Table 3 Bulk unit weights for various materials

Material	Load (kN/m^3)
Reinforced Cement Concrete	25
Plain Cement Concrete	23.5

Brick Masonry	22
Stone Masonry	26.5
Timber	*Refer to IS 875 for specific value*
Structural Steel	78.5
CGI (or PPGI) Sheet	0.2kN/m^2

For further reference to unit weights of other materials including finishes, refer IS 875 Part 1- Dead Loads

Live Loads

Table 4 Live loads by room use

Room Use	Area Load (kN/m^2)	Point Load (kN) [13]
Kitchens, Classrooms, Lecture rooms, Staircases & Corridors	3.0	4.5
Bedrooms, Dormitories, Toilets & Bathrooms	2.0	2.0
Offices, Lounges & Staff rooms	2.5	2.7
Dining halls, Cafeteria & Restaurants	4.0	3.0
Gyms and auditorium (including multi-purpose halls)	5.0	3.6
Storerooms and libraries	5.0	4.5
Inaccessible roofs	0.75	0.9
Accessible roofs	1.5	1.7
Line load along balustrades and parapets in areas of large capacity such as assembly hall [14]	2.25 kN/m	
Line load along balustrades and parapets in all other areas	0.75 kN/m	

For further references refer to IS 875 Part 2 Imposed Loads [14]

Wind Loading

The calculations for the wind load are considered using a wind speed or velocity of min. 44m/s or a Basic wind pressure of 1.5 KN/m^2 for school buildings up to 2 storeys in height [15]. For others, calculations are made with reference to IS 875 (Part 3 Wind Load) [15]. It is recommended that a proper wind test be conducted for any irregularities.

Snow Loading

Snow loading must be considered in areas which experience snow fall. The following bulk snow weight should be considered:

- Fresh snow: 1.8 KN/m^3
- Compacted snow: 5.0 KN/m^3

Further information on the design for snow loading can be found in IS 875 Part 4 [16].

Seismic Loading

Refer to Section 7.4.4 on seismic design criteria.

7.4.3 Loading Combinations

In order to ensure that the structure is designed to act within the elastic zone of the structural behaviour function, a limit state approach should be adopted. This is a design approach in which factors are added to the loads in various combinations thereby ensuring the elements do not surpass the elastic limit and will behave in the same way over time under continuous loading.

The following load combinations should be considered for reinforced concrete design:

Load Combinations for Reinforced Concrete Structures
1.5* (Dead Load + Imposed Load) + 1.0 * (Wind Load **OR** Snow Load)
1.2 * (Dead Load + Imposed Load ± Wind Load **OR** Snow Load)
0.9 * (Dead Load) + 1.5 * (Wind Load) *[where DL favorably offsets WL]*
1.5 * (Dead Load + Seismic Load)
1.2 * (Dead Load + Imposed Loads ± Seismic Load)
0.9 * (Dead Load) + 1.5 * (Seismic Loads)
Note: *The table above has been adapted from IS 456:2000, IS 875 (Part 5):1987 and IS 1893 (Part 1):2002 and applies to the ultimate limit state design of reinforced concrete only. For other loading combinations including for serviceability limit state and other structural materials, please refer to the relevant IS codes.*

7.4.4 Seismic Design Criteria

The follow basic principles in design for good seismic performance should be considered [17]:

- Structural simplicity.
- Uniformity, symmetry and redundancy.
- Bi-directional resistance and stiffness.
- Torsional resistance and stiffness about the vertical axis.
- Adequate performance of the floor slabs at each storey level when acting as diaphragms to distribute seismic actions.
- Adequate foundations.

Seismic Design to be undertaken as per IS 1893 (Part 1):2002 [18]. The following design factors should be considered:

Table 5 Factors for Seismic Design
(Derived from IS 1893 (Part 1):2002 [18] *- see original document for referenced figures & tables)*

Factor	Value
Seismic Zone (as per Fig 1)	V
Zone Factor, Z (as per Table 2)	0.36
Importance Factor, I (as per Table 6)	1.5
Response Reduction Factor (as per Table 7*): ➢ Ordinary RC moment-resisting frame (OMRF) ➢ Special RC moment-resisting frame (SMRF)**	 3.0 5.0
Soil Type – to be chosen based on site investigation (see Section 5.4) ➢ Rock or Hard Soil (N>30) ➢ Medium Soil (30>N>10 and poorly graded soils with N>15) ➢ Soft Soils (N<10)	 I II III
** For other structural typologies including steel framed buildings and RC buildings with shear walls, refer to Table 7 in IS 1893 (Part 1):2002* ***A Special Moment-Resisting Frame is a moment-resisting frame specially detailed to provide ductile behaviour and comply with the requirements given in IS 4326 or IS 13920 or SP6(6)*	

Performance Objectives in Seismic Design

The above design criteria provide design advice to the Indian Standard which considers the design of a building based on the hazard assessment they have adopted. It states:

"It is not intended in this standard to lay down regulation so that no structure shall suffer any damage during earthquake of all magnitudes. It has been endeavoured to ensure that, as far as possible, structures are able to respond, without structural damage to shocks of moderate intensities and without total collapse to shocks of heavy intensities."

In the design of certain school buildings some consideration could be made to whether the building would be used by the wider community in the event of a disaster. This may be, for example, the use of a Multi-Purpose Hall as emergency shelter or an aid distribution centre. For these purposes, the designer may want to consider a higher performance objective that than set out in the Indian Standard to ensure that these key buildings are able to be used safely in the immediate days following an earthquake.

The following performance objectives provided by the ASCE 41-06 standard *Seismic Rehabilitation of Existing Buildings* [19] are amongst the most commonly used performance objectives in practice:

- **Collapse Prevention:** Structures meeting this target level only may incur significant hazard to life safety resulting from failure of non-structural components. A significant loss of life is avoided as the structure does not collapse. Direct and indirect economic losses due to considerable damage are expected;

- **Life Safety:** Structures meeting this target level and the previous one may experience significant structural and non-structural damage. Repairs may be required before re-occupancy and in some cases this may not be economically feasible. The risk of loss of life is generally low;
- **Immediate Occupancy:** Structures meeting this target level and the previous ones may expect minimal structural damage and some damage to non-structural components. It is generally safe to re-occupy the structure after the earthquake, but the loss of non-structural systems may not allow the continuity of the business operation; and
- **Operational:** Structures meeting this target level and the previous ones may expect minimal or no damage to their structural and non-structural components. The structure may be suitable to continue with its normal operation after the earthquake.

A graphical representation of the performance objectives can be seen in Figure 16. The three diagonal lines represent the performance objectives for different groups of structures. Structures that satisfy the Basic Objective are basic residential or commercial structures, while structures that require a higher level of protection such as hospitals, fire stations, data centres, key manufacturing facilities, are all represented by the Essential Objective. The Safety Critical Objective is appropriate for hazardous facilities such as large dams and nuclear power plants.

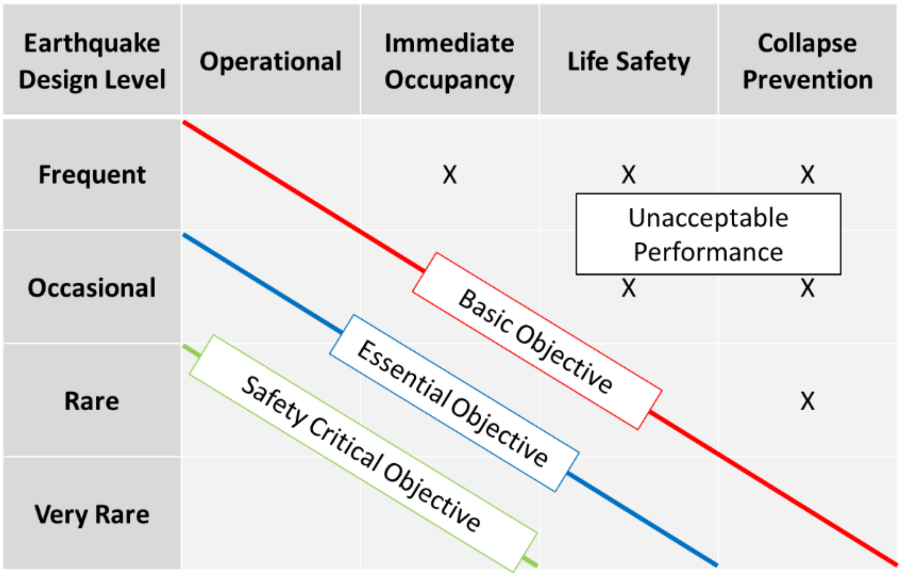


Figure 16 Multi-level seismic performance objectives
(adapted from Vision 2000 Committee, 1995)

This performance based seismic design approach is not covered in this design guidance and its applicability should be considered on a case-by-case basis by the designer. For further detail on the definition of performance objectives and their application please refer to Appendix H.

7.4.5 Building Layout

Plan regularity

Plan regularity of the buildings is key to ensuring good performance of the building under wind and seismic loading. Irregular shapes such as those shown in Figure 17[1], plus T, H or E shaped buildings and long thin buildings should be avoided. Where these occur, seismic joints should be introduced in order to improve the regularity of each building element, see section below for further information.

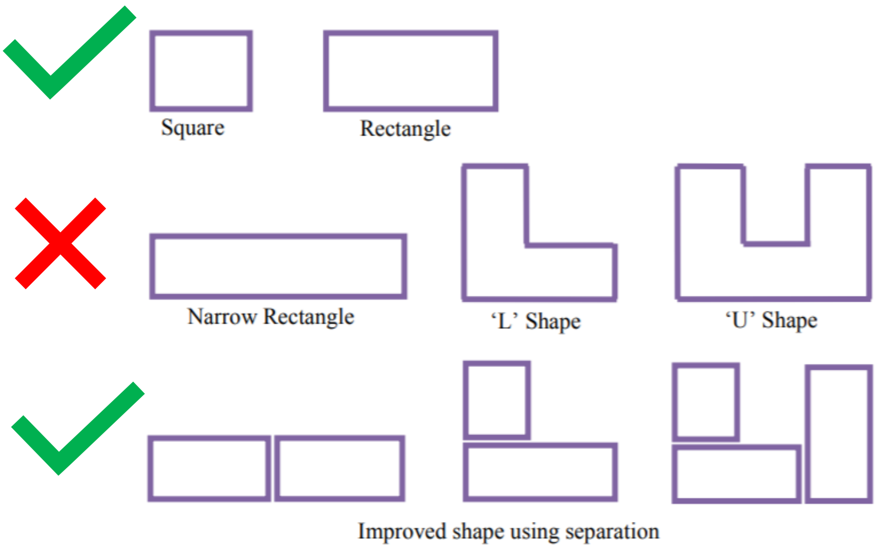


Figure 17 Examples of building shapes for good or poor plan regularity

Structural Joints

Structural joints should be provided in order to improve regularity on the floor plate and are used to both control movement and shrinkage and also to control seismic

[1] https://www.undp.org/content/dam/bhutan/docs/climate-change-adaptation-porfolio/TrainingMaterials.pdf

performance. The maximum aspect rations for each section between joint types is shown in Figure 18.

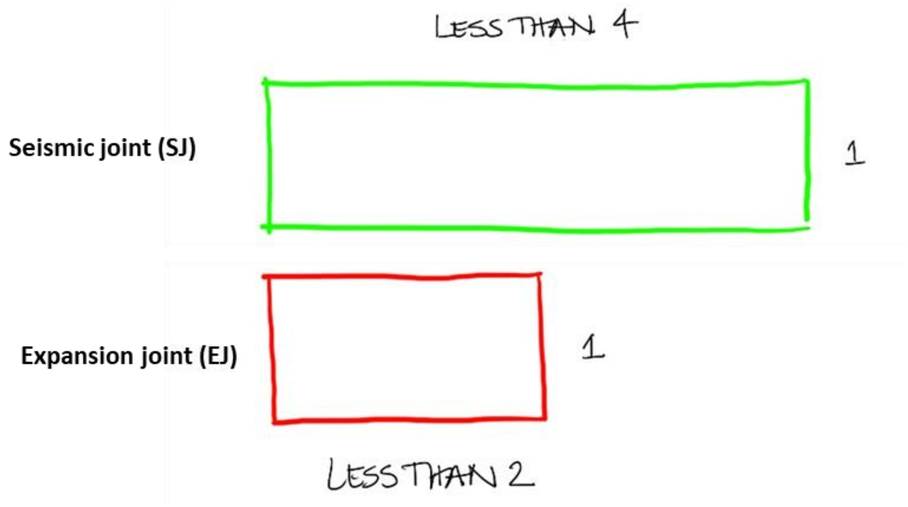


Figure 18 Maximum aspect rations between joint types [20]

Example layouts of seismic and shrinkage joints are shown in Figure 19:

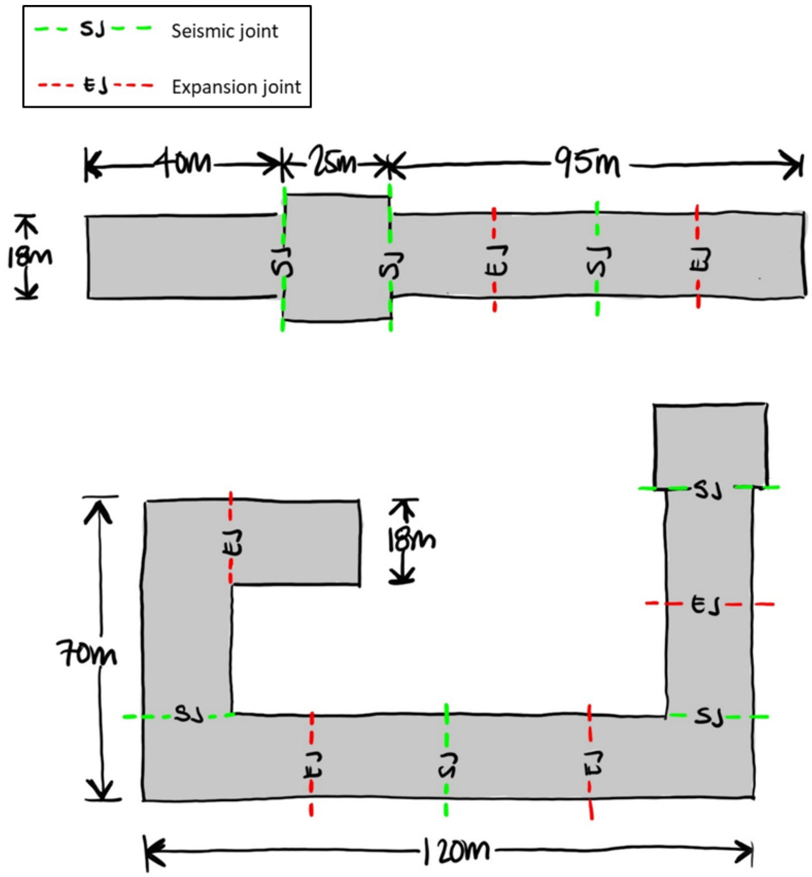


Figure 19 Example layouts of seismic and shrinks age joints [21]

Vertical regularity

Buildings should be designed to provide a regular stiffness over each storey. This means the shape of the building vertically should be approximately uniform (refer to Figure 20) and there shouldn't be floors which have a substantive difference in stiffness from the others (often called a soft storey).

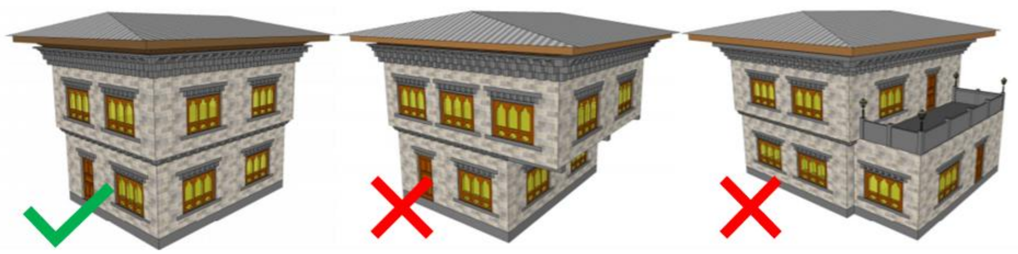


Figure 20 Examples of good and poor vertical regularity [22]

The presence of soft storey may occur, for example the lower floors are to provide larger, more open classroom spaces or require a large floor to ceiling height, as shown in Figure 21.

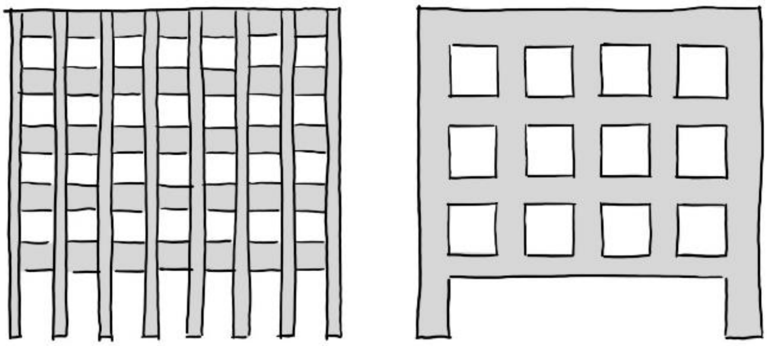


Figure 21 Examples of configurations with a soft storey [23]

7.4.6 Foundation Design

Suitable foundation design is of critical importance in the structural design of the building.

The design of the foundations is to be based on the geotechnical information which has been obtained from the site investigation (see Section 5.4) as this will determine the suitability of the soil for different foundation types, the bearing capacity of the soil and ground water information.

An approximation of the bearing capacity can be made from the N-value obtained in the ground investigation in the absence of any other information on the bearing capacity of the soil.

Table 6 provides a summary of the advantages and disadvantages of different types of foundation:

Table 6 Foundation Options Summary

Foundation Type	Advantages	Disadvantages

Pad foundations	Cost effective and easy to design Requires minimal excavation	May require the design of ground beams to avoid differential settlement. May not be suitable in areas with low bearing capacity May not be suitable on liquefiable soil (or additional vertical support needed) May not be suitable if there is high groundwater
Strip footings	Good under loading bearing walls in order to spread loads Cost effective and easy to design Requires minimal excavation	Must be well tied in order to avoid differential settlement. May not be suitable on liquefiable soil (or additional vertical support needed)988
Raft foundation (continuous mat)	Good in areas with variable soil types in order to spread load and reduce differential settlement	Expensive – requires a lot of material and excavation.
Piled foundation	Allows for construction in areas which have poor strata of soil Minimal earthworks or excavations required Good if there is high groundwater	Expensive as requires specialist equipment Not all sites will have suitable access for a piling rig

It is not recommended to mix different types of footing design in one building.

Required design checks for foundation design:

- Vertical load bearing capacity
- Capacity against sliding in horizontal loading including seismic load cases
- Capacity against overturning in horizontal loading including seismic load cases
- Where reinforced concrete is being used, ensure that sufficient concrete cover to the reinforcement is provided where the outside of the concrete is in contact with the ground.

Shallow foundations (including pad and strip footings) should be a minimum of 1500mm in depth and must bear onto hard, stable and undisturbed strata.

It is recommended to cast a mat of 50mm sand and cement blinding under foundations.

7.4.7 Superstructure Design

Stability Systems

The structure must be stable in two orthogonal directions. The position of the structural joints (as noted in Section 7.4.5) must be considered and each section of the structure must be independently stable.

The purpose of a stability system is to transfer lateral loads across the structure and/or into the foundations and this can be achieved through a number of different methods:

Braced Frame	Cross bracing (typically in steel frames) or shear walls (in RC and/or masonry) are provided within the frame which carry lateral forces as resultant axial loads within the elements
Moment Frame	All connections between members are “fixed” and stability is provided through frame action. Lateral loads are transferred as moments across connections and the supports are designed as pinned.
Vertical Cantilever	The base of the supports is designed as fixed with lateral loads transferred as moments at the base into the foundations.
Loadbearing walls	In loadbearing masonry structures, the structural walls also provide the stability system in a similar manner to shear walls.

Stability members should be located as regularly as possible on plan in both directions to avoid creating eccentricity in the position of the shear centre. If this cannot be avoided, the stability members will also need to be designed to resist the torsional forces induced by the eccentricity as well.

Columns and Beams

Columns and beams must be designed to withstand both the axial and bending forces determined as part of the structural load calculations. It's important that the stability system is well understood (see section on Stability System above) as this will add loads to some or all of the elements in addition to the gravity loading, particularly in wind and seismic loading cases.

Connections between them must similarly be designed to reflect the type of connection which has been assumed in the stability design (i.e. fixed or pinned).

Floor Structure

The floor structure must be able to span to support the dead and imposed floor loading. It will also typically be providing diaphragm action within the frame (unless horizontal bracing is also provided) and therefore must be able to distribute the lateral loads to the stability elements.

Walls

Walls can be designed as either load bearing or non-load bearing elements.

Load bearing walls should be designed as part of the frame similarly to the columns and beams with consideration to the loads the elements will be required to resist and what type of connection has been assumed with adjacent elements.

Non-load bearing walls must also be considered as part of the design. They should be tied into the surrounding columns and beams in order to ensure they effectively transmit lateral loads into the structure. This is particularly important in high winds or in an earthquake, as failure of non-load bearing walls can cause significant injury to occupants and damage to other structural elements.

If non-load bearing walls are constructed in a stiff material (e.g. masonry or ply and stud construction) will also provide stiffness to the frame which should be considered. This stiffness should either be modelled as part of the structural design so that this stiffness is accounted for in the calculations or the connection with the frame should be detailed in a way that prevents the stiffness of the wall being transferred to the frame (see Figure 22).

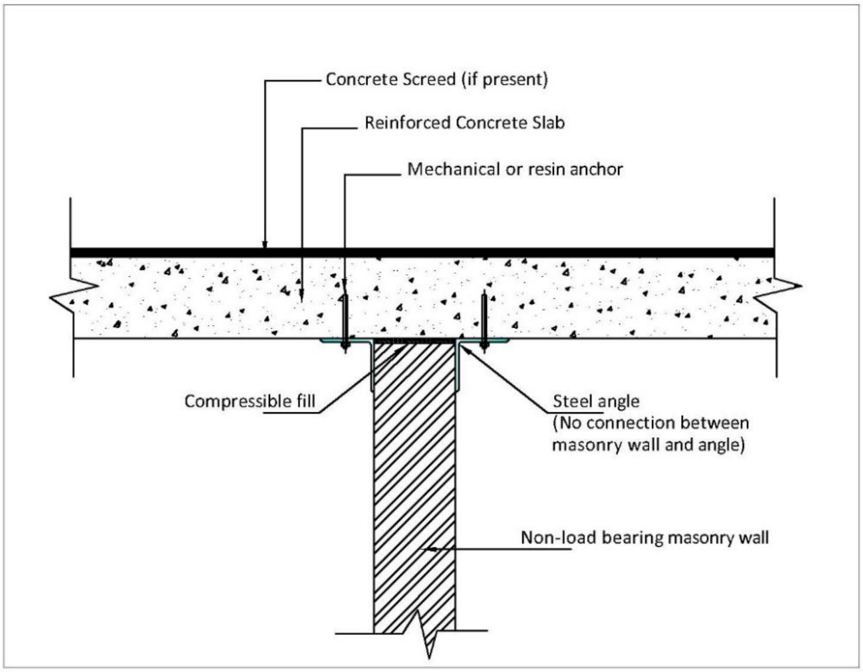


Figure 22 Head connection to non-loadbearing masonry wall

If this is not considered as part of the structural design, the walls will attract load due to their stiffness for which they have not been designed and create alternative lateral load transfer mechanisms which were not the intention of the designer. In extreme loading cases, this can cause failures not just of the wall but other structural elements. For example, a masonry infill wall providing stiffness within a ductile RC frame could cause shear failure of both the wall and adjacent RC column rather than the desired behaviour of development of flexural hinges in the RC frame as was the design intent.

Roof Design

To achieve safer earthquake and strong wind resistance, roof structures and their components should be well connected to walls and columns. Details such as J-hooks to attach the roof to the purlins are recommended (see Figure 23).

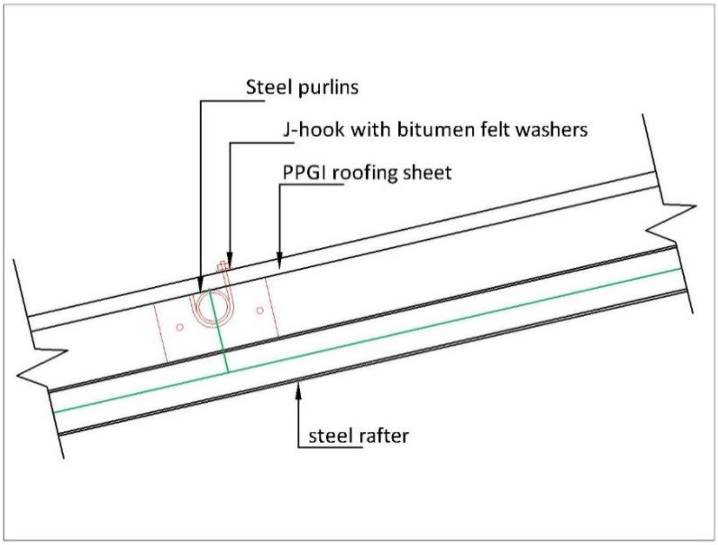


Figure 23 J-hook connection typical detail for roofing

For timber roof elements such as rafters or purlins, screwed connections between elements is also recommended rather than nailed connections in order to improve robustness against uplift wind action.

7.4.8 Structural Materials

Selection of a material for the structural frame should be based on a number of factors including but not limited to:

- Structural Performance
- Availability
- Cost
- Sustainability (including embodied carbon)
- Maintainability

A summary of the main aspects of each material is given below:

Reinforced Concrete	
Advantages	Good performance in seismic conditions if correctly detailed Design guidance and software is widely available and IS code covers its design Robust material Good thermal mass if left exposed Fire protection can be detailed within the concrete
Disadvantages	Reinforcement maybe subject to corrosion if not well protected leading to spalling and potentially loss of capacity Requires high degree of control on site during construction to ensure quality workmanship Chemical reaction involved in the production of cement produces carbon emissions
Minimum Material Properties	Concrete: M20 Reinforcing bars: TMT Fe500
Load-Bearing Masonry: Including Concrete block, Bricks or Stone	
Advantages	Locally available in most areas, particularly those with poor access. Well understood construction methodology and practiced workmanship No requirement for infill walls in addition to structure
Disadvantages	Can perform poorly under seismic loading if not well detailed Not typically suitable for design of buildings > 2 storeys Lack of flexibility once built
Minimum Material Properties	Min compressive strength of masonry units = 5N/mm^2 Min compressive strength of mortar = 5N/mm^2

Timber	
Advantages	Naturally available and sustainable if sourced from responsibly maintained stock Reflective of traditional construction in Bhutan for roof elements Can be naturally insulating Low embodied carbon
Disadvantages	Often imported in Bhutan due to restrictions on forestry for timber production. Not typically suitable or practical for design of multi-storey structures
Minimum Material Properties	To be updated in future with standard values based on Bhutan timber data
Engineered Timber	
Advantages	Much higher structural performance achievable than standard timber Smaller sections of wood can be used in the production of elements reducing wastage in timber manufacture.
Disadvantages	Not well used in Bhutan and design standards do not exist yet Requires specialist knowledge on design and detailing, especially Expensive currently as only one source available – may reduce if uptake and production increases and economies of scale can be achieved.
Minimum Material Properties	To be updated in future with standard values based on Bhutan glulam data

Structural Steel Sections	
Advantages	Lightweight structure reducing foundation requirements Quick to erect on-site compared to RC frames Inherent ductility in material
Disadvantages	Requires additional fire protection materials May required on site welding which is not well controlled Requires fabrication of elements (usually off site)
Minimum Material Properties	*$Fy = 435\ N/mm^2$*

7.4.9 Design for Fire Safety

It is recommended that at least a 1 hour (60mins) fire rating is provided for the structure of schools (recommendation per *Building Bulletin 100: Design for fire safety in schools* [24]).

Reinforced Concrete

In order to maintain structural integrity of the reinforced concrete frame for a suitable period during a fire, sufficient concrete cover should be allowed for in the detailing of the structural elements (Table 7).

Note that these are the minimum dimensions for fire only and may be exceeded by dimensions required for strength, corrosion protection or other design requirements in which case these design criteria must take precedence.

Table 7 Minimum Dimensions and Cover Requirements (Based on BS 8110-1 [25])

Structural Element Type	**Requirement** (all dimensions in mm)	**Fire Resistance Time**			
		1 hour (60 mins)	**1.5 Hours** (90 mins)	**2.0 Hours** (120 mins)	**3.0 Hours** (180 mins)
Columns	Minimum Column Width	200	250	300	400
	Cover*	20	20	25	25
Walls	Minimum Wall Thickness	120	140	160	200
	Cover	20	20	25	25
Beams	Minimum Beam Width	200	200	200	240
	Cover: Simply Supported	20	20	40	60
	Cover: Continuous	20	20	30	40
Slabs with plain soffits	Minimum Slab Thickness	95	110	125	150
	Cover: Simply Supported	20	25	35	45
	Cover: Continuous	20	20	25	35

**Cover required to all reinforcement including links. If cover >35mm, special detailing is required to reduce the risk of spalling*

Timber

Timber elements must be sized in order to allow for the wood to char in the event of a fire and retain sufficient structural capacity. Charring rates vary depending on the type of wood but most timber is accepted to have a charring rate of 20mm in 30 mins and 40mm in 60 mins [26] but this should be confirmed based on the type of wood before the structure can be considered to have been “engineered” for fire.

Steel

Steel elements have very little inherent fire protection and therefore additional fire protection must be provided either through cladding or intumescent paint.

Cladding and finishes

Consideration to the flammability of the other elements of the structure should be considered. See Section 7.8 for further details. All insulation products shall be non-combustible such as mineral wool as opposed to polystyrene.

7.4.10 Non-structural Elements

In addition to the appropriate design of the structure, the consideration of non-structural elements is also an important component of providing a safer building environment in schools as these elements can fall or become dislodged in earthquakes or high winds, injuring the building occupants.

The performance of these non-structural systems (including drainage, water supply, communications infrastructure, mechanical and electrical plant and equipment, cladding and secondary structural elements such as ceiling systems and partitions) has been one of the major determining factors in the post-earthquake operability of buildings, regardless of structural damage.

This is not covered as part of this guidance however please refer to separate guidance provided by the Ministry of Education on this: *Manual on Non-Structural (Falling Hazards) Mitigation for Schools* (available from: https://drive.google.com/file/d/1f_luvxxsaQnBSjdCdfiJyvMF21ZG5S89/view).

7.5 Environmental Engineering

Purpose	Environmental Engineering provides guidance on designing for healthy, comfortable conditions in the internal spaces; creating an environment conducive to learning through the control air quality, temperature and possibly humidity according to the space, activity and climatic circumstances. The aim shall be to achieve this through passive design measures wherever possible, limiting or eliminating mechanical systems. Where mechanical systems are deemed necessary, they shall be designed to mitigate associated energy consumption (e.g. by selecting efficient equipment) and with consideration of safe operation and maintenance.
User	The architect should use the guidance in this section to maximise the passive performance of the buildings. Where mechanical services are required a qualified engineer should use the guidance in this section to design appropriate systems.

7.5.1 Environmental Performance Criteria

Air quality

Spaces shall be designed to achieve minimum outdoor air requirements (Table 8). Wherever possible this shall be done through natural ventilation (see Section 7.5.4 for guidance on sizing natural ventilation openings which should typically be sufficient for meeting this requirement unless mechanical ventilation is mandated under Section 7.5.5).

Table 8 Minimum outdoor air requirements

Room Type	Minimum Ventilation Rate [See notes]
Classroom (general); medical rooms	2.3 l/s/m2 or 8 l/s/p – whichever is greater
Office	10 l/s/p
Laboratory & preparation room	> 70 m^2 → 4 l/s/m^2 37-70m^2 → 11.42 – (0.106xArea) l/s/m^2 < 37 m^2 → 7.5 l/s/m^2
Chemistry Store room	2 air changes per hour, 24 hours per day

Art Classroom	2.5 $l/s/m^2$
Toilets, showers	7.5 $l/s/m^2$
Table Notes 1. Source: BB101 [27] 2. Table rates apply to spaces 2.7m or higher. For spaces below this height the equivalent rate can be calculated by converting the value to air changes per hour (based on height of 2.7m) and applying to the actual room volume.	

Thermal Comfort

Spaces shall be designed to maintain a comfortable (and safe) temperature throughout the year. Suitable design temperatures should give consideration of the local climate in recognition that perceived comfort is relative to the local conditions and time of year (e.g. suitable design temperatures may vary from winter to summer to allow for different levels of clothing). Typically, design temperatures would be in the range of 18-24 ^{o}C.

For naturally ventilated spaces, thermal control should be achieved by following the guidance under Section 7.5.3. It should be recognized that natural ventilation does not provide close control of internal temperature. Therefore the design temperature is an indicative target and allowance is made for some variation according to the external temperature on a given day. Notwithstanding, it is anticipated that internal temperatures should not exceed 32^{o}C; and temperatures greater than 28^{o}C should not be experienced for prolonged periods of the day.

Climate Change

Designers should consider the effect of climate change by referring to both current and projected future climate conditions when developing their design solutions.

7.5.2 Passive vs Active Solutions

Wherever possible, passive solutions should be favored over mechanical systems. Table 9 summarises the passive and active (mechanical) solutions that can be considered.

Table 9 Passive vs Active solutions

Design Criteria	Passive Solution	Active Solution

Air Quality (control of contaminants/pollution and odours)	Natural ventilation	Mechanical ventilation
Thermal comfort during summer (cooling)	Natural Ventilation	Air Conditioning
Thermal comfort during winter (heating)	Beneficial Solar Gain	Heating system (electric, hot water etc.)

The following sections will describe in more detail the design approach for each solution.

7.5.3 Natural Ventilation & Passive cooling

Natural ventilation can serve two purposes: control of air quality and control of thermal comfort in summer. The latter generally requires a greater ventilation rate (the exception may be spaces such as kitchens where the process requirement is the overriding factor).

Natural ventilation has an inherent limitation in cooling capacity associated with the outdoor air temperature. Therefore a critical component of maximizing the feasibility of achieving sufficient cooling without mechanical systems is to minimize heat gains (and therefore the cooling demand).

Rule of thumb:	Limit heat gains to 30-40W/m^2 to enable adequate cooling through natural ventilation (Reference: CIBSE AM10 [28])

Internal Heat Gains

The designer should assess the internal heat gains and base design development on calculated loads where applicable. The following values (Table 10) can be assumed for concept development:

Table 10 Internal heat gains

Load Type	Value	Reference
Occupants*	70 W per person (sensible) 55 W per person (latent)	BB101 [27]

Lighting	8 W/m^2	BB101 [27]
Small Power	5 Wm^2	Estimate based on assumption of very limited local plug loads.
ICT	25 W/m^2	BB101 [27]
**Clarification on Occupant Loads – Sensible and Latent gains* *Sensible gains released from a person relate to the discharge of heat from the skin surface to the surrounding atmosphere. Latent gains from a person relate to heat transfer through the process of respiration and sweating. For a simple calculation for a typical naturally ventilated classroom, the latent gains can be ignored.*		

Example formula to calculate heat gain using benchmark values above (assumes all the loads listed in Table 10 are present – which may not be the case for ICT):

Heat Gain (W) = [Number of occupants x 70] + [Floor area x (8+5+25)].

External Heat Gains (and losses)

Envelope (Fabric) Gains

Envelope gains refers to the transfer of heat through the building fabric (the materials that compose the walls, window, floors and roof). The rate of heat transfer will depend on the thermal performance of the fabric, which is quantified by the U-value (W/m^2K). The total U-value for a given construction will depend on the performance of the component parts and should be calculated by the architect.

The heat transfer through the fabric is calculated with the following formula:

$$\mathbf{Q_{Env} = UAdT}$$

Where

Q_{Env} = Envelope Gains (or loss) (W)*

*U = total U-value for construction (W/m^2K)***

A = area of fabric (i.e. wall, window, roof or floor) (m^2)

dT = internal/external temperature difference (^oC)

**note heat will transfer from the warmer to cooler side of the fabric so when it is warmer outside there will be a heat gain to the space, and when it is cooler outside there will be a heat loss.*

***this must be calculated according to the construction build-up.*

Infiltration

Infiltration is the transfer of air through the building fabric due to permeability of the envelope construction. This uncontrolled air exchange can result in heat loss during winter – therefore designing for airtightness will be important for schools in the Alpine zone.

Solar Gain

Solar gain will often be the greatest heat gain to a space and therefore measures to reduce this can greatly impact the feasibility of achieving comfortable conditions through passive means.

Factors to consider are:

- Window sizing – limiting the size of windows may reduce solar gains; but it also limits daylighting (and therefore increases the need for artificial lighting and associated energy consumption). So a compromise must be made.
- Window orientation – maximizing north and west facing glazing and minimizing east and south facing glazing can help balance beneficial daylighting with minimizing direct solar gains in climates where cooling is the predominant concern. Where solar heating is desirable – south and east facing glazing is preferred (see also the guidance on orientating the building according to the sun path and climatic zone, under Masterplanning).
- Shading – careful design of shading can block direct solar gains whilst maintaining daylighting and views. It also helps control glare.
- Glazing specification – Specification of low G-value glass will limit transmission of direct solar gains

Shading Design

Window external shading devices achieve their primary function firstly by blocking direct solar irradiation.

The design of building-mounted shades should be calculated with reference to the sun's altitude and azimuth. For southern facades horizontal shades are most effective as the sun will tend to be higher in the sky when acting on this face of the building. Angling the shade can address times of year when the sun is lower in the sky (Figure 24). On east and west facades, the sun will often be at more of an angle to the façade, which can mean vertical shades are more effective than horizontal. Again, angling the shade can further optimize its performance.

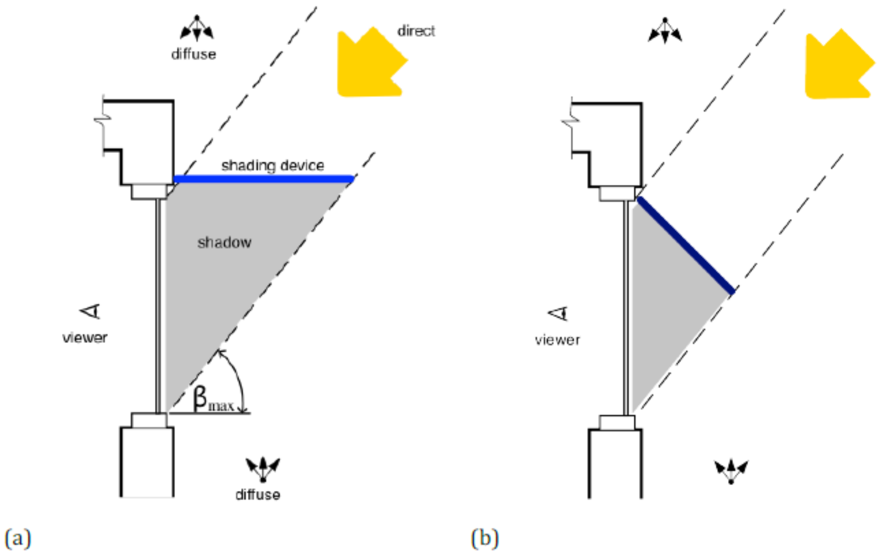


Figure 24 Simple horizontal and angled shading

Brise-soleil consist of multiple blade like shading elements. The combination of blades can be seen to create a set of similar triangles with the same effect as a simple projection (Figure 25a). Blades can also be tilted (Figure 25b).

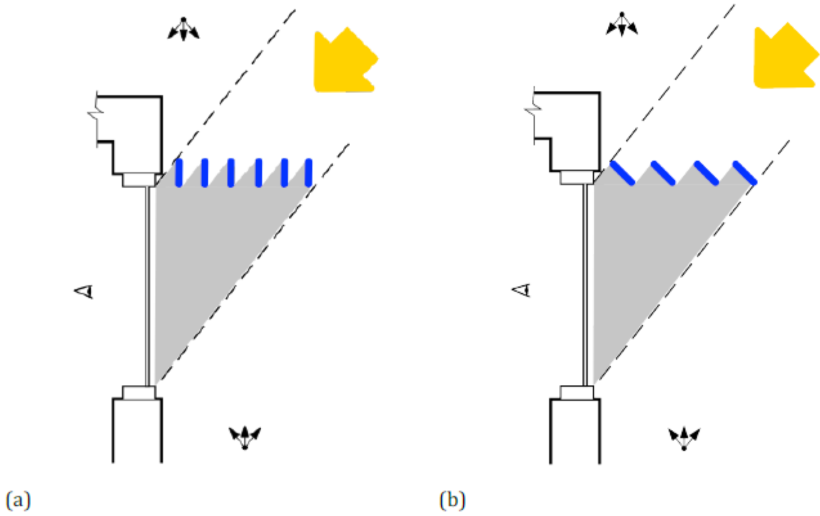


Figure 25 Brise-soleil shading

It is also possible to integrate shading with other components of the buildings (Figure 26)

Figure 26 Photo voltaic panel installation where the panels also provide shading to glazing

7.5.4 Natural ventilation openings

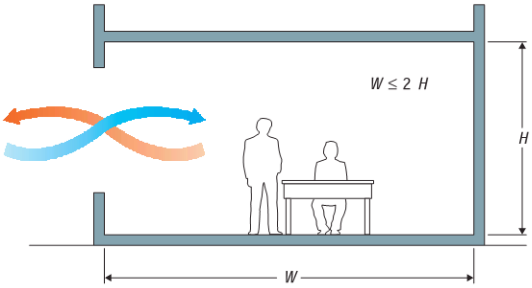
The performance of natural ventilation is determined by the size and location of the openings.

There are three modes of natural ventilation which can be considered:

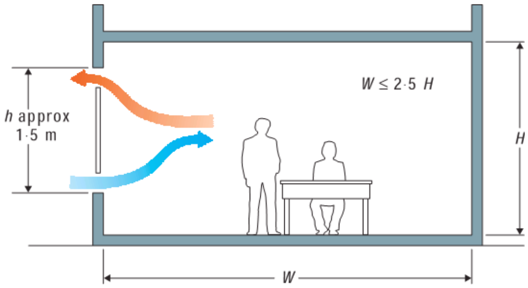
- Single sided (openings on one side of the room)
- Double sided (openings on multiple, ideally opposing, sides of the room)

- Stack effect (high- and low-level openings that take advantage of the buoyancy of warmer air to drive ventilation.

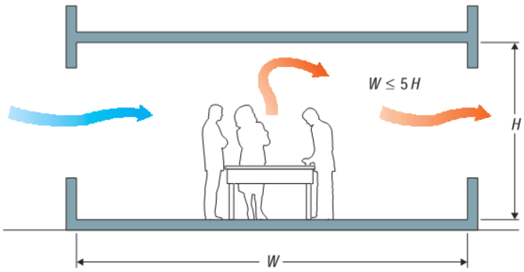
The following diagrams (Figure 27) illustrate the limiting room sizes for which each mode of natural ventilation is effective:



(a) Single sided with single opening



(b) Single sided with double opening



(c) Cross ventilation

Figure 27 Room size limits for different modes of natural ventilation [28]

Where possible, the prevailing wind conditions of the site should be considered so that openings are located to benefit from this natural driving force.

<u>Night purge (or night cooling)</u>

In warmer climates where it is difficult to achieve sufficient cooling with natural ventilation during the day it is possible to make use of cooler night time temperatures to 'precool' the building (or 'purge' the heat gains from the day).

To do this – ventilation openings must be provided which are suitable to be left open at night without creating a security risk (or risk from vermin). This is typically done by adding smaller ventilation openings along the tops of window frames, which may be closable louvres rather than glazing. It is likely that these will require manual opening and closing (because this would be more cost effective and practical than introducing the complexity of automated openings) so school staff must be assigned responsibility for managing the vent opening/closing and provided with training on when to do so.

7.5.5 Mechanical Ventilation

There may be some spaces where natural ventilation is inadequate to control either air quality and/or thermal. In these cases mechanical ventilation may be provided. This may take a number of forms as follows:

Table 11 Types and applications of mechanical ventilation

Type of mechanical ventilation	Applications & considerations
Wall fans	Most suited to low flow rate requirements for a small space. The necessary opening in the wall can be a source of uncontrolled heat loss unless provided with a means to close when not in use. These fans can also be noisy. Can be simple system – switched on only when necessary.
Ceiling fans	Suited to low flow rate requirements and provide air movement local to the demand. Similar to wall fans these can be simply controlled by occupants as required. Positions must coordinate with lighting to avoid light flicker and shading effect. Can be less effective in tall spaces but for lower ceilings safety must be considered – ensuring there is no risk of occupants accidentally colliding with the fan (e.g. in dorm rooms with bunk beds).
Ducted system	Can be more suitable for larger volumes and controlling location of extract points local to the heat/pollution source. Can be more expensive to install and maintain. May include controls that ensure the fan operates.
Fume Hoods and extract canopies	Used for process specific ventilation – chemistry experiments and cooking. Likely to be proprietary equipment with specialist specification and design. Will need to ensure training is provided on maintenance and spare parts will be available.

Spaces where the need for mechanical ventilation should be carefully considered include:

- **Toilets** – these can (and should) be naturally ventilated generally but mechanical ventilation may be required if it is not viable to provide adequate openings (e.g. due to location or size of the facility). Care should be taken to ensure exhaust points are separated from any ventilation openings on nearby buildings.
- **Kitchens** – proper design of chimneys and make-up air pathways may mitigate the need for mechanical ventilation. But this must be carefully evaluated to ensure a safe hygienic environment is maintained. If mechanical ventilation is provided then care should be taken to consider the fire risk associated with grease and fat collecting in ductwork – which must be mitigated through good cleaning practices and adequate provision of firefighting equipment (extinguishers, blankets) and/or integral suppression systems.
- **Laboratories** – ventilation must be provided for chemical experiments. This may be in the form of a fume hood and/or mechanical ventilation to the room.

7.5.6 Mechanical Cooling and Heating

Where thermal comfort cannot be achieved through passive measures it may be necessary to provide cooling and/or heating.

Generally, it is anticipated that mechanical cooling should not be necessary for most space types. A possible exception would be rooms with high equipment loads – such as an ICT classroom – in schools located in very warm climate. The simplest system for cooling an individual space such as this would be the provision of and split system. If there is uncertainty about the need for cooling (which may be the case as the performance of natural ventilation is difficult to predict without computational modelling, and similarly the level of use of equipment and adaptability of the occupants will be variable) it is recommended that a strategy is made for retrofitting air conditioning rather than installing it immediately. This means identifying where the indoor and outdoor unit will be sited (taking advantage of the opportunity to find an unobtrusive location for the outdoor unit), planning a route for the pipework and ensuring an electrical supply can be readily provided. The conditions in the space can then be observed in operation before deciding whether the air conditioning should be added.

These systems are available with proprietary controls which can implement time routines and/or allow local occupant control as required – this should be decided during specification and procurement.

For schools in the alpine climate, heating may be unavoidable. However, there are examples of successful passive solar heating in similar climatic conditions, so similarly to the air conditioning provision, it is suggested that a strategy is made for retrofitting heating if required. This would conventionally be wall mounted electric heaters and therefore allowance should be made in the floor space plan and distribution of electrical points.

7.6 Electrical Engineering

Purpose	This section outlines the core components of the building electrical systems which are typical for all schools, provides design criteria that should form the basis of system sizing and equipment selection; and guidance on how to configure systems for energy efficiency.
User	The principle user of this section will be the electrical engineer. The section will also be used by those reviewing designs for compliance checks. Other members of the design team may also refer to this section for coordination purposes.

7.6.1 Principles of electrical design

The electrical systems shall be designed in accordance with the rules and regulations of all local codes and ordinances, and other authorities having jurisdiction. In conjunction with this, the Bhutan Electricity Authority's guidelines should be followed while designing the electrical system.

The principal considerations in the design of the electrical systems will include:

- Safety of students, staff, visitors and property
- Reliability and continuity
- Flexibility and provisions for expansion
- Operation and maintenance
- Energy conservation, demand and control
- Initial and maintained costs
- Future expansion– such that retrofit and renovation can be carried out without a detrimental impact on the quality of the installation.

7.6.2 Demand calculation

At the early stages of design, the following allowances can be made for offices and classrooms power densities:

- Lighting – 14 VA/m^2
- Receptacles – 25 VA/m^2
- Space Heating – 100 VA/m^2

Note: All of the above values are notional allowances for concept design and should be checked against detailed design. The inclusion of the space heating allowance may be dependent on the school location and room type.

During detailed design the electrical engineer should refer to the Room Data sheets to understand the services required and develop a detailed load calculation based on the developed design. This information can be used to inform the site main sizing.

The demand calculation should include allowances for future expansion.

7.6.3 Power Distribution

This section relates to power distribution *inside* the building; the details of the site infrastructure are covered under Section 8.0.

The building incomer shall be connected to a main switchboard which will consist of an appropriate power circuit breaker, utility current transformer and distribution sections.

Distribution will consist of group or single mounted molded case circuit breakers. Each outgoing way may have metering to allow measurement verification and allow verification of energy conservation measures. A power factor correction cubical will be provided wherever necessary.

Electrical power distribution throughout the building will be via sub-distribution panels (SDPs) and general-purpose power and lighting panel boards. Any large mechanical loads (>40kW) will be fed via dedicated distribution panel board

Three phase distribution incomer to be provided if the connected load exceeds 13KW.

The SDPs will be located outside occupied rooms. Setting out shall be to the architect's specification – typically with the top at least 250mm below ceilings and bottom 1.75m above ffl. The panels shall have a lockable latch flushed to the wall. All metal parts except the insulated conductors shall be earthed.

Surge suppression equipment will be provided on all distribution to minimize disturbances caused by lightning strikes.

Refer to the Room Data Sheets for details of the number and type of power sockets required in each space. Power sockets shall generally be placed at mean height of 450mm from floor in dry areas. Ideally the power sockets should be located proximate to the expected location of utility. However furniture layouts should also be considered, and the power socket location can be adjusted to ensure accessibility. This may include located sockets at the room entrance below the light switches; or below the window seals. In wet areas, sockets are preferred at 1.5m height near the geyser or whatever expected power appliance to secure safety against leakages from splashing of water.

Metering

"you can't manage what you can't measure"

The design should consider a sub-metering strategy which allows accurate monitoring of energy consumption disaggregated by building type. For example, a basic sub-metering strategy could cover the following levels of consumption:

Level 1	**Level 2**
Main power (bulk meter)	Individual unit/ building supply

Ideally meters should be connected to a central control system for automatic monitoring but if this is not viable they should be located in easily accessible positions to facilitate regular manual readings.

Emergency / Standby Power

Standby power will be considered for the following:

- Emergency and exit lighting
- Path of egress lighting from the building to meet code
- Fire alarm control panel and all alarm components
- Limited laboratory equipment such as freezers and refrigerators
- Laboratory exhaust fans and/or fume hoods (including control power).

Local UPS's should be provided for the ICT closets.

7.6.4 Grounding System (Earthing & Bonding)

A grounding system will be provided for the building, in line with the Code, consisting of ground rods and concrete encased electrodes. All grounded busses from main switchboards, transformers and panelboards will be connected at a central ground bus in the main electrical room.

All extraneous conducting metal work within the building will be bonded. A dedicated grounding system may be provided to communication closets.

7.6.5 Lighting

Lighting levels will comply with the Building Code as minimum. Table 12 provides recommended levels in line with international good practice which should form the basis of design with consideration of the following:

- The lighting levels should be reviewed according to project requirements and in coordination with the architect's daylighting strategy.
- Ceiling heights impact the ability to achieve the desired illuminance level.

Where 430 lux or greater is desired, the distance between the work surface and the ceiling height and the presence of shelving or furniture over the work surface must be considered.

Table 12 Recommended* illumination levels

Space Type	Illumination Level (Lux Level)**
Art Room	500
Biology Prep	500
Biology Store	100
Biology Lab	500
Chemistry Lab	500
Chemistry Store	100
Chemistry Prep	500
Circulation space	100
Classroom	300
Computer Lab	300
Conference Hall	500
Dining room	200
Examination Centre	500
Examination Store	100
Examiner accommodation	200
Health Room (or Councillor Room)	300
Hostels	300
Kitchen	500
Library / Media Centre	500
Multipurpose Hall	500
Music Room	300
Office and staffrooms	300
Toilets	100
*The values in this table are indicative of international best practice and should be considered preferred where achievable. Lighting levels in line with the building regulations remain the minimum requirements. **Derived from LG5 [29]	

The architect should provide the electrical engineer with guidance on preferred light fittings and layouts. The electrical engineer should then develop the design to achieve the required lighting levels – coordinating with the architect for agreement on the final configuration.

Light fittings may be ceiling or wall mounted. The ceiling mounted types serve better in respect of providing general illumination. But tropical areas using fans from the ceilings have lights mostly provided on the walls to avoid the shadows of the moving fans on the working surface.

Light switches should generally be located near entrances to every room for convenience of access on entering the space. They are placed at mean height of 1.1m from floor (1m in disabled toilets) and within 300 mm from edge of the wall (for ease of access on entering the room even in pitch darkness).

Lighting Control

It is not anticipated that a complex/expensive lighting control system would be practical or necessary in most schools. However, the designers should consider opportunities to reduce energy consumption such as:

- Zoning lighting such that areas near windows can be switched off while there is sufficient daylight, whilst lighting over deeper plan areas can be switched on as required (Figure 28).
- Dimming switches to allow the artificial lighting level to be reduced to the minimum necessary.
- Training and signage to encourage users to turn off lights when leaving a room (and when there is sufficient daylight).
- Division of circuiting to allow building lights (or appropriate groups of lights) to be switched off at a common point.
- Local occupancy/vacancy sensors on lighting for transient spaces (e.g. toilets).

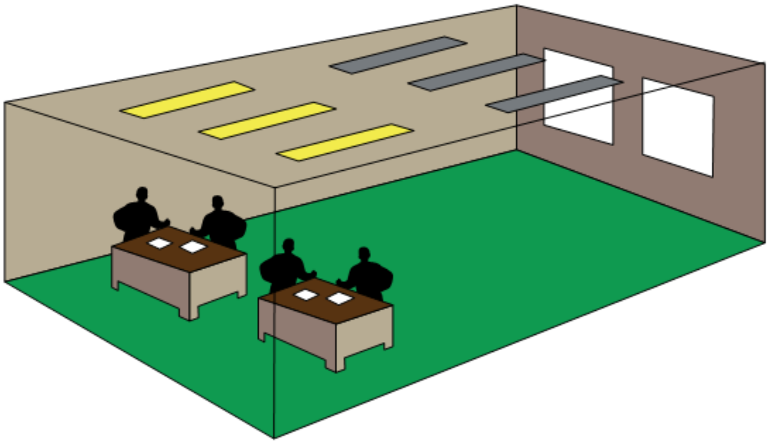


Figure 28 Lighting switching according to location in the room

(from CIBSE TM57 [30])

Daylighting

All teaching spaces and habitable rooms must be designed to have natural daylight as the principle source of lighting. At masterplanning stage the orientation of the building should have been assessed for optimal daylighting – including consideration of any surrounding obstructions (e.g. trees, other buildings) which could overshadow the glazing.

Maximum depths of space for daylighting are comparable to those for classrooms. For a typical 3.0m high classroom the depth should be limited to 7m to allow for daylighting throughout. If the depth of the room increases, in order to maintain daylighting the height of the space may need to increase (to allow for taller glazing) and/or skylights may be required.

The total window opening should not be less than 25% of the floor area for classrooms as illustrated in Figure 29 below.

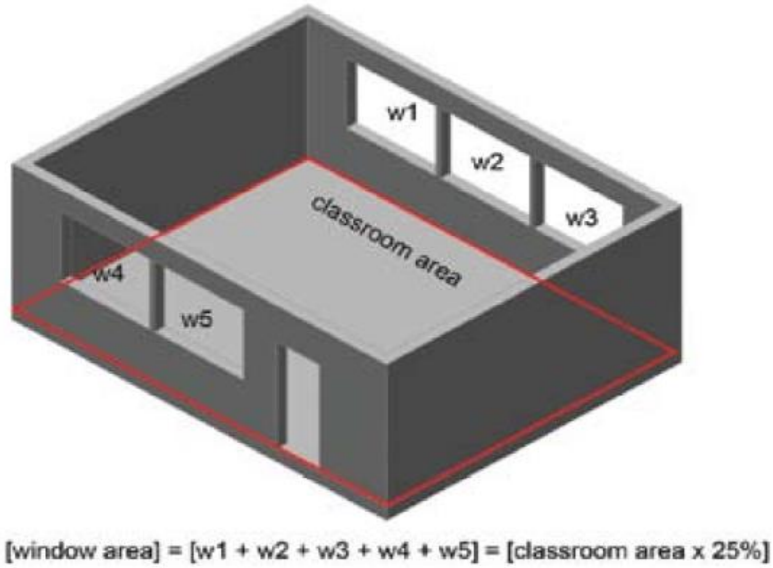


Figure 29 Sizing windows for daylighting

Glare

The lighting design (daylighting and artificial) must also aim to mitigate problems with glare. Considerations include:

- Glazing size/position, particularly the angle of sun ingress relative to working surfaces and also the view of the sky illuminance which can cause discomfort glare.
- Reflectance of interior surfaces (this can mean seeking a compromise between maximizing reflectance to improve lighting efficiency and reducing reflectance to mitigate glare).
- Provision of movable shades to mitigate glare when required and avoid users retrospectively blocking windows with paper etc. These must be designed/specified carefully with respect to coloration and pattern.
- Assessment based on the 'teaching surfaces' relevant for the room – which include the teacher/pupil faces; text; black/white board; wall mounted and/or computer screens (this is an important note as glare is often discussed in terms of the impact on using computer screens however, with the exception of ICT classrooms, these are generally not the primary teaching surface).

7.6.6 Security

Means of securing and protecting the school occupants and assets should be provided. Control of access to the campus through the use of fencing, gates etc. should be balanced with maintaining connectivity with the surrounding community.

Provision of CCTV is increasingly common, particularly in urban schools. An assessment of risk should be conducted specific to the school to determine whether this level of protection is needed.

7.6.7 Lightning Protection System

Assessment and design of the lightning protection system shall be carried out in accordance with the Indian Building Code or as per the regulation from relevant authorities.

A detailed risk assessment shall be carried out (in accordance with BS EN 62305 [31]or suitable equivalent) to determine whether a lightning protection system (LPS) is required.

If installed, the LPS shall be tested annually to check for damage or increases to the electrical resistance.

The LPS should include:

- Air Termination
- Down Conductors
- Earth Termination

7.7 Plumbing Engineering

Purpose	This section outlines the core components of the building plumbing systems which are typical for all schools, provides design criteria that should form the basis of system sizing and equipment selection; and guidance on how to configure systems for maintainability.
User	The principle user of this section will be the those responsible for designing the plumbing services. The section will also be used by those reviewing designs for compliance checks. Other members of the design team may also refer to this section for coordination purposes.

The plumbing installation shall comply with the Bhutan Plumbing code.

7.7.1 Plumbing design criteria.

Typical (according to international standard practice as cited) design criteria for plumbing systems are provided in Table 13. The plumbing systems in schools shall be designed to these values or those provided in the Bhutan Plumbing Code - whichever is the more onerous.

Table 13 Typical Plumbing Design Criteria

Parameter	Value	Source / comment
Outlet flowrates (minimum):	Water closets (WC): 0.1 l/s Wash hand basins 0.1 l/s Sinks 0.1 l/s Sinks (kitchen & cleaners) 0.3 l/s Showers (medium use) 0.1 l/s External taps 0.15 l/s	PESDG low usage unless specified otherwise. Medium usage in public/community areas and kitchen.
Distribution velocity:	Dia 20-50mm 0.75-1.0m/s Dia>50mm 1.25-1.5m/s	BSRIA/CIBSE
HWS system:	Storage	Include secondary return on systems with long runs

HWS generation plant:	Electric geyser / solar thermal / Air Source Heat Pump. Point of Use heaters for remote individual sinks.	Semi storage, quick recovery.
Water distribution temperature:	Cold: 10°C (20°C max.) Hot flow: 60°C Hot return: 55°C	In accordance with ACOP L8 Control of Legionella Guide
HWS outlet temperature:	Pupil and staff outlets including Showers 43°C Kitchen sink 60°C Cleaners sink 60°C	
Mixing valve:	TMV3	To comply with the Thermostatic Mixing Valves Manufacturer's Association (TMVA)
Sanitary ware specification:	Architects specification	

7.7.2 Hot & Cold water distribution

The incoming water mains and any site-wide water storage shall be designed by the civil engineer, who will bring the water service to within 3m of the building.

Each building with a water supply should have a meter. This helps with management and monitoring of the system including identification of excessive consumption which may be due to leaks or mismanagement.

Depending on the pressure supplied from the site mains, all building incomers shall have a pressure reducing valve to limit pressure within the building to 6bar (maximum).

The plumbing engineer shall refer to the room datasheets and/or architect's plans to identify the water uses in the building and calculate the hot and cold water demands.

Distribution routes shall be agreed with the architect; however it is suggested that pipes are kept accessible where possible (either surface mounted or only concealed behind removable surfaces such as ceiling tiles) to enable leak detection and rectification.

Pipework shall be insulated to mitigate heat loss from hot water, freezing of cold water and warming of cold water (as applicable for the climatic location of the school).

Pipework shall be labelled appropriately to indicate the service.

Shut-off valves shall be provided at regular points on the system to enable ease of maintenance.

Water Pipework Testing

The designer shall specify appropriate testing requirements that shall be carried out by the contractor and demonstrated to the resident engineer. These requirements may include:

- *All piping systems shall be tested after completion with all branch piping installed, but before being concealed, insulated or equipment fixtures and fittings set and connected.*
- *Where previously agreed, piping systems may be tested in sections, but a final test shall be made on completion of all work.*
- *Test failures shall be rectified, and the test repeated until a satisfactory result is achieved.*
- *Test procedures shall be in accordance with relevant guidance / standards / codes.*
- *Piping systems shall be tested with cold water and the test pressure maintained for two hours or sufficient to ensure inspection of all joints without further application of pressure and without visible leakage or drop in indicated pressure.*
- *Test pressure shall be not less than 1.5 times working pressure.*
- *Domestic hot and cold water pipework shall be leakage-tested, using potable water only, at 1.5 times the working head maintained for two hours.*
- *Concealed or work to be permanently buried shall be tested at twice working pressure.*

7.7.3 Hot Water generation

For most day-schools cold water will be sufficient however in some cases, particularly for showers in boarding schools, hot water should be provided.

This is typically generated using electric geysers.

Alternatives that could be considered are solar thermal hot water and air source heat pumps. Both of these may be coupled with an electric geyser to provide a back-up source of heating; and are typically provided as packaged systems.

Solar thermal systems require space on the roof for the collector panels. Often, particularly for domestic size systems, the tank is located with the panels.

An air source heat pump system has an outdoor unit that appears similar to a split systems condenser unit. These draw air across tubes containing refrigerant to extract heat from the air which is then transferred to the stored hot water; and the cooled air is exhausted back to atmosphere. So, the unit must be located with a free airflow path.

7.7.4 Foul Drainage

The foul drainage design should follow these principles:

- The above ground foul drainage shall be a vertical system of drainage with soil, waste and vent pipe work.
- The above ground foul drainage system shall be primary ventilated single stack system. The ventilation pipes shall be suitably terminated at roof level.
- All stacks on each floor level and at each change of direction shall be provided with accessible access fitting for future maintenance at the height of 1.2m above the finish floor level.
- Pipework shall not be routed through electrical switch rooms, electrical ducts, or ICT equipment rooms.
- A minimum gradient of 1 in 60 shall be provided for all branch pipes.
- Safety valve discharges from hot water cylinders shall discharge to a suitable drainage location.
- There should be consideration for the use of ring sealed joints to allow the dismantling of pipework for access if required.
- Exposed pipework in occupied areas shall be insulated with mineral wool to reduce the noise of system operation.
- Provisions shall be made to accommodate thermal expansion.
- Concealed pipework shall be tested prior to concealment.
- Drainage from the kitchens will pass through grease interceptors. The operation and maintenance guidance provided to the school should include instruction on cleaning the interceptors.
- For chemistry laboratories the type and volume of chemicals to be discharged shall be assessed. As appropriate a system for collecting and treating drainage from the laboratories shall be installed. Laboratory waste shall not discharge directly into open drainage channels.

Drainage Pipework Testing

The designer shall specify appropriate testing requirements that shall be carried out by the contractor and demonstrated to the resident engineer.

These requirements may include:

- *Pipework shall be clear of debris prior to testing.*
- *A CCTV survey shall be carried out to demonstrate cleanliness.*
- *Tests shall be made with air or water. A further water test shall be made on completion of backfilling and surface reinstatement.*

7.7.5 Rainwater drainage and harvesting

Wherever possible internal rainwater pipes shall be avoided.

Rainwater harvesting systems should be considered to collect water for non-potable uses such as irrigation.

The assessment should identify suitable roofs and calculate the potential collection volume. This should be compared with the various water demands to determine which demands can be offset from the water main.

All water systems should be clearly labelled to identify their suitable application – specifically there must be clear distinction between potable and non-potable supplies.

7.8 Fire Engineering

Purpose	To create a campus of buildings that considers fire safety in relation to regulatory compliance, international best practice and practical use.
User	The design team should refer to this section and ensure their design responds to the requirements.

7.8.1 Code and Minimum requirements

As a minimum, the design shall comply with the requirements of the Bhutan Building Code Part 6 (Fire Safety) and BTS-014. This shall include provision as follows:

- Exits sufficient to permit safe escape in case of fire or other emergency
- Fire doors (rated 30min) along the escape route, particularly at the entrance to stairs
- Escape exits providing continuous means of egress to the exterior
- Existing routes arranged such that they are reached without passing through another occupied space
- Travel distance to exits on each floor shall not exceed 22.5m (requirement for Residential and Institutional buildings per Code)
- Travel distance in a single direction should not exceed 18m
- A suitable fire assembly point is designated, and fire drills are implemented on site
- Buildings constructed predominantly of combustible materials such as timber should not exceed 500 sqm and must be spaced to mitigate fire spread between buildings.

7.8.2 Fire Strategy

A document should be produced (either by a fire engineer or led by the architect) which describes the basis of the approach taken to fire safety and provides parameters for the design and any future expansion to adhere to. This would be based on the code alongside an assessment of the specific conditions at the school in question. For example, if there is no fire service able to reach the school within an appropriate timeframe then an alternative strategy for firefighting might be considered.

The following should be considered:

Means of warning & escape

- Fire detection systems
- Fire alarm system
- Signage and lighting for escape routes

Internal fire spread (lining)

- Fire compartmentation and fire rating of partitions. Note this can be somewhat mitigated with appropriate sub-division into multiple buildings which are suitably separated to prevent risk of fire spread from one building to the next.

Internal fire spread (structure)

- Fire rating of structural components (see Structure Design section)

Egress / Ingress

- Planning routes to ensure maximum travel distances for escape (Figure 30).
- Planning access strategies for emergency services including vehicle access.

Protection & suppression

- Provision of sprinklers (may be applicable to high risk areas or schools remote from emergency services).
- Provision of fire extinguishers at regular spacing throughout the school and training on use.
- Provision of hydrants around the site
- Firefighting tanks (for sprinklers and/or hydrants)

Wildfire

- Assess the risk and adapt design accordingly.

The following facilities in the school may have a higher fire risk and should be designed accordingly with consideration of separation from other facilities and prioritization for fire detection, alarm and suppression strategies:

- Kitchens
- Laboratories
- Spaces with electric heating

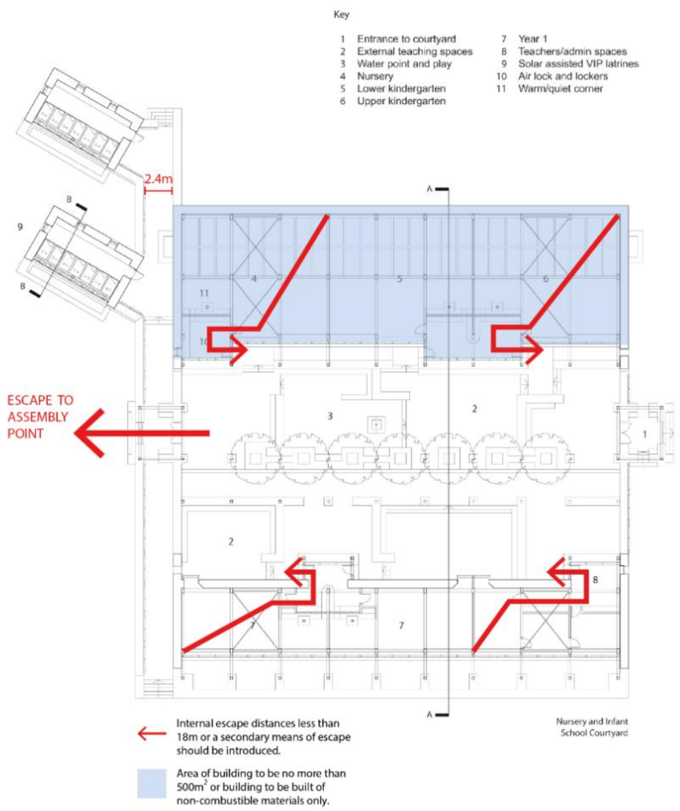


Figure 30 Example Fire escape plan

8 Site Infrastructure Design (Civil Engineering)

Purpose	Design development of the systems identified during masterplanning.
User	A suitably qualified civil engineer should design the site services, in coordination with the relevant members of the design team.

8.1.1 Surface water management

Based on the surface water management (SWM) strategy developed during the site masterplan, a SWM design should be undertaken covering the following aspects: rainfall, catchment assessment & flood protection, environmental conditions, runoff control and discharge and components selection.

Flood protection

An agreement will need to be achieved in relation to the different level of flood protection to be provided to the various facilities within the school. This will have a direct effect on the design of the drainage system and attenuation volumes.

Suggested flood protection return periods are:

- School buildings and key infrastructure: 1 in 100 years
- Parking and playgrounds: 1 in 30 years
- Other areas of lower risk: 1 in 10 years

Surface water drainage/flood protection upstream of the school should also be confirmed.

Environmental conditions

From the rainfall data obtained during the previous stages of the project, mean annual rainfall and Intensity Duration Frequency (IDF) curves information will need to be developed for application in the drainage system design using the Rational Method.

If necessary, seek assistance from a hydrology expert to analyse rainfall data and calculate the intensities for a range of different durations and frequencies (IDF Curves). Sometimes, weather offices have specific approaches to defining IDF curves and the analysis should consider these methods. Digital models can be developed to understand the impact of rainfall events on infrastructure/buildings. When obtaining IDF curves, try to compare a few sources of rainfall data to see whether the data is similar. If the accuracy of the data is uncertain, try to find another local source to compare against.

A suitable **return period** (timeframe between rainfall events of a given magnitude) should be chosen for the different parts of the school masterplan based on the impact caused by failure. National or local guidance should be followed where this exists. Ideally, for the critical parts of the school and buildings, flooding should not occur for a 1 in 100 year period event. Lower return periods (1 in 2, 1 in 5 or 1 in 10 years) should be used for lower-risk areas within the school.

When obtaining rainfall information, it is recommended to find out if the impact of climate change will affect rainfall locally, this may both increase or decrease during the year.

Climate change projections will need to be reviewed and agreed on how this will affect the intensity of the IDF curves. In the absence of any relevant data on climate change, it is recommended to include an additional 20% increase to the rainfall intensity as a precautionary measure.

Sub-catchments

For the purpose of estimating rainfall run-off throughout the site, the site should be divided into sub-catchments based on the natural topography of the site and the school masterplan. The location of catchments should be defined in a drawing estimating the following:

- Area of each sub-catchment.
- The highest and lowest point of the catchment, the length of the catchment and therefore the catchment slope for the calculation of the time of concentration.
- Length of the channel network.
- Catchment impermeability.

Once the location of the different buildings has been confirmed, the layout of each building may also be considered as a sub-catchment. The location and type of outflow connection from the buildings will need to be coordinated with the architects.

Run-off

The peak rainfall run-off for each catchment will be calculated by applying the Modified Rational Method (HR Wallingford, 1981). Specific importance should be given to the selection of the Run-off/ground permeability coefficient (coefficient C). The Run-off coefficient should depend on the slope of the catchment, its permeability and its planned vegetation. A more detailed description of the Modified Rational Method has been explained in Appendix I.

Suggested techniques

As a fundamental principle, surface water should be managed as close to the source as possible and reduce the impact downstream as much as possible. There are a series of surface water management techniques that can achieve these goals:

- Prevent: To avoid or reduce a source of surface water for example through changing behaviours, facilities location or increasing vegetation in a catchment.
- Treat: To improve water quality for example by trapping silts or using vegetation to improve water quality.
- Use: To reuse water from the system for another purpose (e.g. cleaning or irrigation dependent on water quality).
- Store: Accumulate surface water in a place whereit is safely held/stopped for a period of time (e.g. a pond).
- Slow: To reduce the velocity of surface water as it moves, for example by using check dams.
- Infiltrate: A process where water on the ground surface enters the soil (e.g. through a soakaway).
- Convey: To transport water from one place to another, usually in a channel or pipe.

How to use and combine these techniques will depend on the site and its conditions. However a decision tree for choosing surface water management techniques has been suggested below (Figure 31) trying to set some general principles.

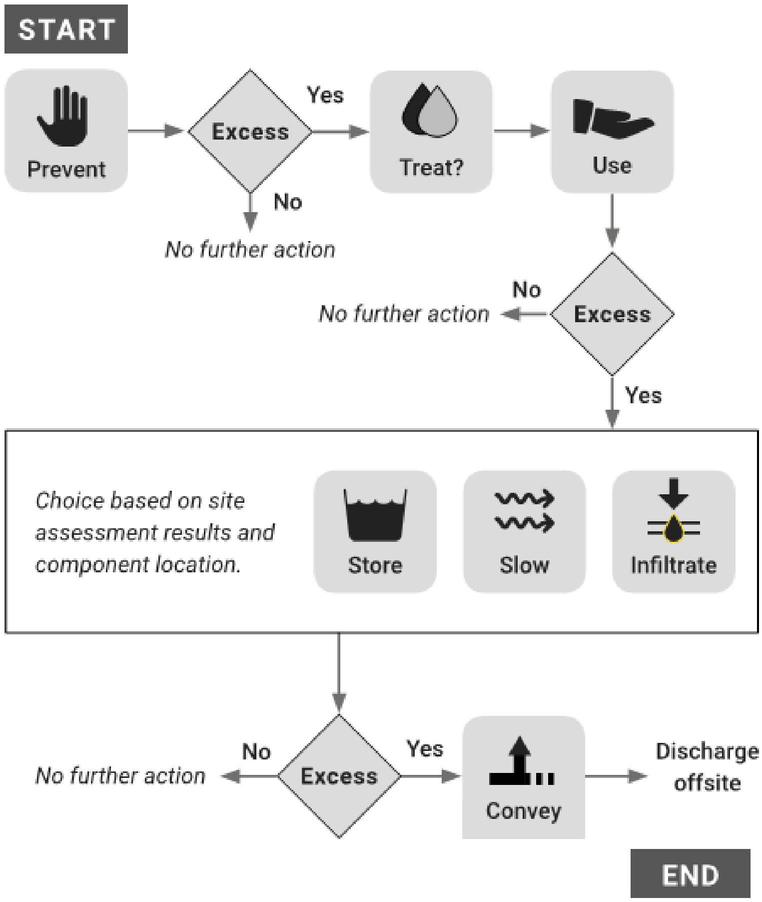


Figure 31 Decision Tree for Selecting Surface Water Management Techniques

Components selection

As highlighted in the masterplan section, the surface water management system should minimize vulnerabilities and maximise opportunities.

During the masterplan stage, a series of strategies should have been defined to manage surface water.

At this stage, a range of techniques and components should be defined and combined to manage runoff across the site. Table 14 shows techniques and which component could be used in its design:

Table 14 Surface Water Management - Prevention and mitigation techniques

Note: ✓ = Yes ~ = can design component to function in this way

		Prevention and mitigation techniques	Prevent	Treat	Use	Infiltrate	Slow	Store	Convey
COMPONENTS	I	Changing behaviours	✓		✓				
	II	Changing surfaces	✓	✓	✓	~	✓	~	
	III	Rainwater harvesting and tanks		~	✓			~	
	IV	Soakaways & infiltration devices		~		✓	~		
	V	Dry basins (incl. retention basins)		~	~	~	✓	✓	
	VI	Ponds & wetlands		✓	~	~	✓	✓	
	VII	Channels (swales & lined channels)		~	~	~	~	~	✓
	VIII	Berms and plinths	✓						✓
	IX	Check dams		~		~	✓	~	
	X	Silt and grease traps		✓					
	XI	Culverts and pipes				~		~	✓

Conveyance

In the case of a series of conveyance structures being required, these will be designed as a gravity drainage network connecting the different catchments outlets and combining them into the agreed discharge points.

The most appropriate material for the drainage network will be agreed on. The design of the surface water drainage network will be done considering the material specifications selected. The final design should include layouts, long sections, dimensions, manholes required and their location, details and performance specifications, to allow correct construction and maintenance.

Some of the most typical conveyance systems used for surface water management are buried pipes, channels & rills and swales.

- **Buried pipes:** Traditionally, surface water in the urban context is managed by a series of connected buried pipes normally made of concrete and designed for being impermeable.
    - Advantages: can provide big capacity, more unlikely to be filled with litter, don't require space above ground.
    - Disadvantages: higher cost, doesn't provide infiltration, doesn't provide retention, lack of integration with the environment.

- **Channels and rills:** Canals and rills are open surface water channels with hard edges. They are simply channels that water flows along whereby they can have a variety of cross sections to suit the landscape, including the use of planting to provide both enhanced visual appeal and water treatment.
    - Advantages: Effective in water & pollution treatment, can be visually appealing in urban landscapes, they have amenity value, easy to construct, good for biodiversity, pollution and blockages are visible and easily dealt with.
    - Disadvantages: Need to give careful consideration to crossings.
- **Swales**: Swales are shallow, broad and vegetated channels designed to store and/or convey runoff and remove pollutants. They can be designed to promote infiltration where soil and groundwater conditions allow. Check dams and berms also can be installed across the flow path of a swale in order to promote settling and infiltration.
    - Advantages: Easy to incorporate into landscaping, Good removal of urban pollutants, reduces runoff rates and volumes, Low capital cost, Maintenance can be incorporated into general landscape management, Pollution and blockages are visible and easily dealt with.
    - Disadvantages: Not suitable for steep areas or areas with roadside parking, limits opportunities to use trees for landscaping, risks of blockages in connecting pipe work

Ideally, the surface water drainage network will be by gravity, however, in the case that the network requires some pumping to reach the discharge points, the attenuating chamber and pumps required will need to be designed.

When designing the surface water drainage network, special attention should be given to minimum slopes and maximum flow velocities in order to enable self-cleaning and mitigate the potential for erosion:

- Allowable slopes: to enable self-cleaning minimum allowable slopes should be:
    - Grassed channels 0.5% (1:200)
    - Concrete lined 0.3% (1:400)

- Flow velocity: it is recommended that when designing conveyance structures flow velocities should not be higher than 2m/s for a 1 in 10 years return period event.

Planting / Vegetation

During development of the surface water management design the engineer should work with the masterplan and landscape architects to identify potential for improving planting and vegetation linked to the surface water management strategy.

In addition to promoting biodiversity, improving aesthetics and enhancing wellbeing, plants also perform vital functions in a site when used appropriately including:

- Providing shade and reduces temperature extremes
- Managing pests and vectors
- Creating windbreaks and/or reducing noise
- Slowing runoff
- Encouraging evapotranspiration and/or infiltration
- Improving air quality and/or water quality
- Supporting food production
- Stabilizing slopes and managing erosion

Attenuation

In the case of the total site surface water flow being higher than the allowed discharge flow, some attenuation structures will need to be designed.

The total attenuation volumes should be calculated to comply with the flood protections agreed at the worst-case storm event.

Discharge

An agreement will need to be registered in relation to the location of the surface water discharge points and the maximum flows allowed. Depending on where the system will be discharging these locations and flows will need to be agreed with different implementing authorities (sewerage authority or environmental authority most likely).

In the case of the site discharging again into the environment and discharge points and maximum flows agreements not being required, it is recommended that the discharge points and flows simulate as good as possible the current natural surface drainage (if greenfield) or even improves it in the case of a brownfield. To do this the SWM design should aim for:

- Discharge point(s) locations being as close as possible to the existing ones.
- Maximum discharge flows: In the case of a greenfield, discharge flows should not be higher than the currently estimated rainfall runoff. In the case of a brownfield, discharge flows should be reduced when possible, and approximate them as much as possible to the estimated original greenfield site rainfall runoff.

8.1.2 Water Supply

Based on the water supply strategy developed during the site masterplan, a water supply network design should be undertaken covering the following aspects: water source connection, water quality and treatment methods, water demand, water storage and water distribution network.

Water source connection

The type, location and size of the connection to the water supply source(s) will be confirmed at this stage. Depending on the type of sources different types of connections will be required. In the case of connecting to the municipal water network or obtaining water from the underground, the water source connections will need to comply with the agreements achieved with the different authorities. This also applies for abstracting from a river or a lake.

Water quality and treatment methods

Water should be safe for the purpose intended at all times. According to the *Bhutan Drinking Water Quality Standard of 2016*, both urban and rural networks from a service provider shall comply with these standards.

In the case of getting water from an offline source, the Bhutan Drinking Water Quality Standard establishes a series of parameters and concentrations for urban and rural drinking water supply. These have been included in Appendix J: Drinking water quality parameters.

In the case of a water source not complying with these parameters a water treatment strategy should be developed including an evaluation of the location, space and energy requirements.

In the case of the water sources not meeting minimum drinking water quality to comply with its intended use, water treatment methods will need to be designed at this stage.

Water demand and water storage

The final calculation of the water storage required will be done based on the demand of the latest uses specified in the architectural design and the total amount of day's demand to be stored. Water storage will also need to be designed for fire protection based on the fire strategy requirements.

- Demand: To calculate the amount of water per day that is necessary, the different uses and quantities required should be forecasted. A list of the most common water demand indicators in a school, as recommended by UNICEF, are provided in Table 15.

Table 15 Water Uses and Demand, UNICEF [32]

Use	Demand
Day schools	5 litres per person per day for all schoolchildren and staff
Boarding schools	20 litres per person per day for all residential schoolchildren and staff
Flushing toilets	10–20 litres per person per day for conventional flushing toilets/1.5–3 litres per person per day for pour-flush toilets
Anal washing/cleansing	1–2 litres per person per day
Other uses	Additional water demands as irrigation will need to be taken into account in addition to the quantities above
Firefighting	Coordination with the emergency services / fire safety authority will be required in order to plan water demand requirements for firefighting as well as fire hydrant locations. In many cases, a separate tank and distribution network exclusive for this use may be required and should be planned accordingly

- Storage: The amount of water storage required is determined with consideration of the estimated demand and the reliability of the water source (the more reliable the source, the less storage that may be required). As a minimum it is recommended to have storage for three days, however, this should be increased if there is a considerable risk of the water supply not being constant. If storage for extended periods is required, special attention should be given to water quality.

Based on this, a specific type of water storage tank and a safe location will be defined following the principles agreed in the masterplan. Consideration should be given to the possibility of designing dual or partitioned tanks to allow maintenance. Above ground tanks can help with leak detection.

In the case of water pumps being required, the pump performance and power requirements will need to be designed and its location planned in the vicinity of the water storage tanks.

Water distribution network

From the water storage tanks, a distribution network will need to be designed to feed each of the water supply locations required.

Sufficient water-collection points and water-use facilities should be available in all the critical points within the school, allowing convenient access water for drinking, personal hygiene, food preparation, cleaning and laundry. As a minimum, a reliable drinking water point should be accessible for staff and students at all times.

The most appropriate material for the distribution network will be agreed on. The design of the water network will be done considering the material specifications selected. The final design should include layouts, long sections, dimensions, valves required and their location, details and performance specifications.

When designing the water supply network, it is recommended that the flow velocity should be a maximum of 1.5m/s and a minimum of 0.6m/s.

Ideally water distribution mains should aim for constant gradients with a maximum steepness of 1%, however the gradients will be highly dependent on the site topography and should be defined by its minimum coverage (normally around 1m). It will be necessary in each case to assess the pipe routes, operating pressures and velocities at points of use and other key points - and then adjust the gradient and/or include measures such as pressure reducing valves, air chambers, air valves and washout valves as necessary to ensure the system operates within the recommended velocity and pressure limits. Also, if a water main is very steep (>20-25%), it will need to be anchored to the ground using anchor blocks or anchor joints.

Sub-metering of water use in the site (for example, by building or group of buildings) should be considered to enable monitoring and encourage water use reduction.

8.1.3 Sanitation

Based on the sanitation and hygiene strategy developed during the site masterplan, a final design should be undertaken covering the following aspects: toilets, sewerage drainage network, containment and treatment plant.

Toilets

The final number, type and location of the toilets will need to be agreed including any additional space required for menstrual hygiene management.

- Number of toilets: Boys' and girls' facilities should be in separate toilet blocks, or toilet areas separated by solid walls (not lightweight partitions) and should have separate entrances. It may be appropriate to provide separate toilets for staff and students, particularly where special toilets are provided for young children.

  The minimum number of toilets planned should be one per 20 girls and one for female staff; one toilet plus one urinal per 40 boys, and one for male staff. When possible, this provision shall be doubled for primary schools (i.e. 1 toilet per 10 girls and 1 toilet plus 1 urinal per 20 boys). At least one toilet cubicle should be accessible for staff and children with disabilities, preferably one for females and one for males.

In the case of wet toilets being designed, final discharge flows will need to be calculated. In the case of the sanitation outflows being connected into the municipal sewerage network, discharge flow will need to be agreed with the relevant implementation authority.

- Waste water flowrate (Q_{ww})**:** The total peak discharge from toilets by gravity into the sewerage should be calculated as follows:

$$Q\_ww = \sqrt{}(2 * No. of\ toilets) \qquad \text{[litres/sec]}$$

The location and type of connection of the sewerage outflows in the toilets will need to be coordinated with the architects.

Sewerage network

A sewerage drainage network will be designed from the different toilets to either the municipal sewerage network or to the agreed containment.

The most appropriate material for the distribution network will be agreed on. The design of the sewerage network will be done considering the material specifications selected. The final design should include layouts, long sections, dimensions, manholes required and their location, details and performance specifications.

Ideally, the sewerage network will be by gravity, however, in the case that the network requires some pumping to reach either the connection point or the septic tank, the attenuating chamber and pumps required will need to be designed.

When designing the sewerage network, it is recommended that the minimum flow velocity at 1/3 of the maximum design flow is 0.75m/s. If that cannot be achieved, the minimum recommended gradient for the pipes would be 1.25% (1:80) for 100mm diameter pipes and 0.7% (1:150) for 150mm diameter pipes or bigger.

Containment and treatment plant

In the case of not connecting into the municipal network, the final design of the sewerage containment and treatment methods required will need to be designed.

A secure space should be designed for the provision of the containment and plants, considering the needs that the treatment methods may have (i.e. construction, access, power supply, chemicals storage and maintenance.)

- Location: The tank should be located downhill from the source of sewage and at least 15m from the nearest water supply. This is a minimum and should be more if the ground is rocky and fissures could take the outflow further. It should be at least 3m from the nearest building. The tank location and surface water drainage design should avoid the risk of surface water flooding around the septic tank. Vehicle access should be provided to the tank, but avoid the risk of the traffic loading on the tank.
- Estimated space: When calculating the dimensions of the septic tank take into account both its total volume required as well as its length, width and depth ratio. General guidance suggests that the total length should be two or three times the width.
- Soak Field / Soak Pit: Space must be planned for soak fields and soak pits. A large area of land is normally required as septic tank effluent can infiltrate very slowly, depending on the soil properties. Soakaway fields can also block easily and typically need to be replaced every 5 years or so.
- Emptying: Sludge removal should be carried out from the surface to avoid the need to enter the tank which may contain poisonous gases. An access route for the vacuum truck should be identified when planning the tank location.

Typically, there should be a maximum of 50m between the septic tank and the truck parking location.

Hygiene

- Handwashing: A toilet is not complete without a handwashing point with soap, water and adequate drainage. The design should include convenient handwashing facilities so that handwashing after using the toilet can become a routine activity for schoolchildren, teachers and staff.

  In addition to near the toilets, other locations may be also identified as relevant for handwashing for use during lunchtime or at the playground. For example, locating a handwashing facility near the classroom of younger children allows for better monitoring. When locating handwashing units, it is important to plan for provision of both water and drainage.

- Menstrual hygiene management: When planning the number of female toilets, it is important to consider the inclusion of a Menstrual Hygiene Management (MHM) room. It is recommended that a minimum of 1 MHM room should be planned for every 5 female toilets. The MHM room should be provided with running water and proper drainage of wastewater. The location of an incinerator will also need to be planned for disposing of menstrual waste.
- Showers in boarding schools: It is recommended that a minimum of one shower is available for 20 users in boarding schools (users include students and residential staff). Separate showers should be designated for staff and students, and segregated for male/female. At least one shower should be accessible for females with disabilities and one for males with disabilities. Showers shall be provided with access to hot water.
- Laundry facilities: In boarding schools, facilities should be provided for laundry services with access to hot water.

8.1.4 Solid waste management

Based on the solid waste management strategy developed during the site masterplan, and a waste generation forecast a final design should be done for the waste collection aspects including number of bins, centralised storage size, location and access requirements.

In the case of any waste treatment infrastructure being required (composting), a secure place shall be designed considering the needs that method may require (i.e. power supply, water supply, maintenance, truck access).

Waste generation forecast

A waste generation forecast should be developed for the school to better understand the total weights and volumes of waste generated. Waste generation rates for each type of use in the school should be used to size the waste storage and agree the frequency of waste removal.

Table 16 reflects some estimation rates for the most typical uses in a school:

Table 16 Estimated waste generation rates

Use	Rate
Schools	0.10 kg/person/day
Laboratories	0.16 kg/m^2/day
Dining	1.27 kg/m^2/day
Landscaping	0.001 kg/m^2/day

Waste segregation

According to the Waste Prevention and Management Regulation of 2012 [33] provision shall be made for segregation of bio-degradable and non-biodegradable wastes as a minimum; and the area for placement of waste bins shall identified during the building approval process.

Waste collection

Based on the solid waste strategy adopted, specific spaces will need planning for disposal and collection of waste, including identifying a place with safe access to waste collection vehicles from the relevant Implementing Authority. Waste collection points will need to be designed and coordinated with the architecture design so they are safely accessible to the relevant authority.

8.1.5 Power Supply

Based on the power strategy developed during the site masterplan, a final design should be undertaken for the power connection and on-site power distribution network.

Power connection

Based on the updated average and peak power demand, the final connection points with the external power supply network will need to be agreed with the relevant implementation authority.

In the case of an MV/LV transformer substation being required, a secure place shall be designed considering the needs that it may require.

If alternative sources of energy are going to be implemented, connections points should also be coordinated with the electrical engineer responsible for that design.

Power distribution network

An LV network will be designed from the different power connections to the various locations required, including site illumination.

In the case of an MV/LV transformer substation being required, an MV network will be designed from the external power connection to the substation.

The most appropriate material for the cable ducting will be agreed. The design of the electricity distribution network will be done considering the material specifications selected. The final design should include layouts, the number of ducts required and its diameter, access chambers required and their location, details and performance specifications.

To improve spatial planning, and enable more efficient construction and maintenance, utility routes – including power networks – should be coordinated with each other.

Sub-metering of energy use in the site (for example, by building or group of buildings) should be considered to enable monitoring and encourage energy use reduction.

8.1.6 Information Communications and Technology (ICT)

Based on the ICT strategy developed during the site masterplan, a final design should be undertaken for the telecommunications connection and onsite distribution network.

Communications connection

Based on the updated communications network demand, the final connection points with the external provider's network will need to be agreed with the relevant implementing authorities.

In the case of an antenna being required, a secure place shall be designed considering the needs that it may require.

Communications distribution network

A combined communications networks will be designed from the different connections to the various locations required.

The most appropriate material for the cable ducting will be agreed. The design of the communications distribution network will be done considering the material specifications selected. The final design should include layouts, the number of ducts required and its diameter, access chambers required and their location, details and performance specifications.

8.1.7 Access and circulation

Based on the access and circulation strategy developed during the site masterplan, a final design should be undertaken for the road connection and internal circulation.

Road connection

A final road access design will need to be agreed and designed with the relevant local authority to accommodate the final travel demands across all modes of transport.

Internal circulation

A final internal circulation design including parking spaces for all modes of transport, pick up/set down facilities for buses and cars, and access for services facilities will be designed at this stage.

Parking: Provision must be made in the design for parking requirements. Depending on the location of the school and available site size, the parking requirements may vary. Table 17 suggests a recommendation for planning vehicular and cycle spaces in a school.

Table 17 Recommended allowances for vehicular and cycle spaces

Type	Urban Context	Rural Context
Car	1 car parking space per 15 children/students in urban areas	1 space per 20 children/students in urban areas
Motorcycles / Scooters	Minimum of 1 space or 1 space per 20 car spaces	Minimum of 1 space or 1 space per 20 car spaces
Cycles	1 cycle space per 10 pupils plus 1 space per 20 staff	1 cycle space per 10 pupils plus 1 space per 20 staff

On all new school sites where it is likely that pupils will travel to and from school in buses, sufficient space should be reserved to allow coaches to enter the site, drop off and pick up pupils. In addition to this, adequate drop off and pick up facilities for cars should also be provided.

However, where the site is constrained, it may be possible to provide drop-off / pick-up space outside of the school in the public highway subject to agreement with the highway authority and appropriate design.

Servicing: Consideration will be also given to the access requirements for servicing the site including:

- General deliveries to site (range of lorry types)
- Maintenance equipment and fuel for infrastructure works (e.g. septic tanks, generators, etc.)
- Collection of waste

The internal campus should be largely pedestrianised, in order to minimise pollution and create a safe learning environment. Segregation between cars and pedestrians should be encouraged, with a clear demarcation created at the entrance to prevent visitor and staff cars from entering the wider campus.

Road finishes and highway layouts will be designed in alignment with the site planning design. The design of all internal road should be done following the Bhutan Urban Roads Standards.

Traffic Circulation

Both the pedestrian and vehicular traffic routes should be well organized so that they may circulate safely.

In order to reduce accident risks and minimize noise, vehicular access within the campus should be kept to a minimum with sufficient parking space.

Footpaths should follow the safest and the direct routes between facilities.

9 Building Permit

The design stage of implementation concludes with the Building Permit application.

The Building Regulations 2018 includes the application form for a Building Permit and the process set out in this document should be followed. In addition to the completed form the following documents should be submitted to the local government for approval:

i.	2 sets (A3/A4) of architectural, structural, electrical, water supply and sanitation drawings duly signed by the designers.
ii.	Copy of the latest Lag Thram/ Land Ownership Certificate
iii.	Copy of latest site plan
iv.	Copy of planning permit
v.	Certificate of the designers

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Appendix A: Site Appraisal Questionnaire

Safety

- Is the site adjacent to or near roadways with a high volume of traffic?
- Has the site records of any contaminants/toxics in the soil or groundwater, such as from landfills, dumps, chemical plants, refineries, fuel tanks, nuclear plants, or agricultural use of pesticides or fertilizer?
- Is the site near any sources of air and toxic pollution which will be detrimental to the health and safety of the school users?
- Is the site on or near a fault zone or active fault?
- Is the site within a 100-year flood plain area?
- Is the site affected by any potential landslides or falling rocks?
- Have they been identified any social hazards in the neighbourhood, such as high incidence of crime and drug or alcohol abuse?
- Is the site close to high-voltage power lines?
- Is the site close to high-pressure lines, for example natural gas, gasoline sewer or water lines?
- Is the site close to high decibel noise sources such as airports, major traffic and factory machineries? (The recommended background noise level is 45 decibels or lower.)
- Is the site close to any open-pit mining?
- Is the site within a dam inundation area or 100- year flood plain?
- Has an Environmental Site Assessment been conducted for the selected site?
- Is the site within 500m of railroad tracks?
- Is the site within 5km of an airport runway?
- Is the site within 1km of a helipad?

Location

- Are there safe walking areas around the suggested site?
- Is the site centrally located so it avoids extensive transporting and minimise student travel distance?

- Is the site compatible with current and probable future zoning regulations?
- Is the site close to libraries, parks, museums, health centres and other community services?
- Does the site have a favourable orientation to wind and natural light?

Size and shape

- Is the site selected net surface consistent with the applicable standards and needs required?
- Does the length-to-width ratio does not exceed 2:1?
- Is there sufficient open play area and open space?
- Has the site potential for expansion for future needs?
- If needed, is there enough space for adequate and separate bus loading and parking?

Topography and soils

- Is the site very steep? If yes, is it feasible to mitigate them?
- Does the site have rock ledges or outcroppings?
- Does the site have good natural surface and subsurface drainage?
- Does the site have natural level area for playfields?
- Is the site in proximity to faults or fault traces?
- Does the site have stable subsurface and good bearing capacity?
- Is the site prone to slides or liquefaction?
- Is the site prone to flash flood?
- Does the site have good percolation for septic system and drainage?
- Does the site have adequate water table level where applicable?
- Is the site in an existing land fill? If yes, is it reasonably well compacted

Accessibility

- Is the site nearby obstacles such as crossings on major streets and intersections, narrow or winding streets, heavy traffic patterns?
- Does the site have good access by a variety of roads?

- Are there any natural obstacles such as grades or gullies near the site?
- Does the site have freeway access for bus transportation?
- Does the site have good routing patterns for foot traffic?
- Is the site located in a remote area, with no sidewalks, where students have to walk more than one hour to and from school?
- Is the site easily reachable by emergency response vehicles?

Utilities / Public services

- Has the site availability for connecting the main utilities? (i.e.: water, electricity, sewer, ICT, gas)
- If not, is it feasible of bringing utilities to site at reasonable cost?
- Has the site any restrictions related to right of way?
- Has the site coverage from fire and police protection?
- Is the site accessible by public transportation?
- Is the site covered for trash and garbage disposal?

Environment

- Will the school construction disturb the natural habitat and ecosystem of the locality?
- Is the site free from sources of noise that may impede the instructional process?
- Is the site free from air, water and soil pollution?
- Is the site free from smoke, dust, odours, and pesticide spray?
- Does the site provide aesthetic view from and of the site?
- Is the site compatible with the educational program?

Availability and legal issues

- Is the property or site vacant and available immediately?
- Is the site owned by the state?
- Is the site on the market for sale? If yes, Is the seller motivated to sell within your timeframe?
- Does the owner of the site have land ownership certificate?

- Is the site currently occupied by other buildings, residents or users? If yes, has it been agreed a condemnation of buildings and relocation of residents?
- Are there zoning restrictions? Will there be a need for zoning variances or lengthy hearings? Required setbacks? Legal easements or rights-of-way across the property? Prior title issues?
- Are you permitted to display signage on the site?
- Will building permits be available within the required timeframe?
- Are there any political issues that would block approval of the site?

Cost

- Is the total cost of the site purchase (i.e.: purchase of property, severance damages, relocation of residents and businesses, legal fees etc.) reasonable?
- Are the enabling works (i.e.: site preparation including, but not limited to, drainage, parking, driveways, removal of existing buildings, and grading) reasonable?
- Are there any costs related to toxic clean-up beyond the owner's obligation?
- Are there any environmental mitigation costs link to the site?
- Does the site have reasonable maintenance costs?
- Is sufficient financing available to complete the transaction within the required timeframe?

Public acceptance

- Is there a generally good public acceptance of the proposed site?
- Is there a generally good receptivity from the Dzongkhags/Thromdes?
- Is the proposed site coordinated with future community plans?
- Did the site receive a negative environmental impact report?
- Is the site currently zoned for prime agriculture or industrial use?

Appendix B: Site Selection Scoring Sheet

Site Identification: Evaluator:

Site location: **Total area:**

Estimated value:

Selection Criteria	**0**	**1**	**2**	**3**	**4**	**5**		**Factor* (1 - 4)**	**Total**	**Key Comments**
Safety (Dangerous – Safe)							X			
Location (Remoteness – Proximity)							X			
Size and shape (Insufficient – Sufficient)							X			
Topography and soils (Unsuitable – Suitable)							X			
Accessibility (Obstructed - Accessible)							X			
Utilities / Public services (Unavailable – Available)							X			
Environment (Friendly – Hostile)							X			

Availability and legal issues (Easy – Complicated)							X			
Cost (Expensive – Economical)							X			
Public acceptance (Conflict – Harmonious)							X			
TOTAL										
*This factor applies a weighting in order to promote/suppress the influence of more/less critical criteria on the overall score. It should be determined by the assessment team for each project as the criticality of each item will vary according to the project specific conditions.										

Appendix C: Hazard Risk Assessment Reports & Sources

Title of Assessment	Year Conducted	Leading Agency	Hazard Covered	Area Covered
Biological hazards on import of chicken, (Meat, DOC, eggs, used eggs tray, infected feeds from Infected farms,) Plants: uncertified plant and plant products, soil, bio-agent.	2012-2015	BAFRA (MoAF)	Biological hazards (Bacterial & Viral)	Exporting countries and importing agencies
Forest fire risk area and hazard mapping	2014-2015	DOFPS (MOAF)	Fire	All Dzongkhags
Geological and geo-thermal assessments for slope stability of Trashigang Dzong	2013	DCHS (MoHCA)	Landslide	Trashigang Dzong
Need assessment for earthquake depilation condition for the country	2005-2015	DCHS, DOC (MoHCA)	Earthquake	All Dzongkhags
Probabilistic seismic hazards assessment	2010-2017	DGM (MoEA)	Earthquake	All Dzongkhag
Landslide inventory mapping in Samtse and Chukha	2012-Ongoing	DGM (MoEA)	Landslide	Samtse and Chukha Dzongkhags
Updating GLOF hazard map along Punatsangchu valley	2015-2019	DGM (MoEA)	Flood	Punatsangchu valley
Monitoring and assessment of changes in glaciers, snow and glacio-hydrology in Bhutan	2014-2017	DHMS (MoEA)	GLOF, Flood	Four basins of Wangchu, Punatsangchu, Magdechu and Chamkharchu
Earthquake risk assessment and impacts on structural failures	2008-2015	DGPC	Earthquake	Hydropower infrastructure
Risk of fire emergencies inside powerhouse	2008-2015	DGPC	Fire	Hydropower infrastructure
Vulnerability assessment on earthquake	Dec 2013-Jan 2014	MoE	Earthquake	Seven dzongkhags
HVCA for all hazards covering all Dzongkhags (Education/SAVE)	2016	MoE	Multi-hazard	All Dzongkhags

Title of Assessment	Year Conducted	Leading Agency	Hazard Covered	Area Covered
Initial seismic vulnerability assessment of JDWNRH	2012	JDWNRH	Earthquake	JDWNRH
Initial seismic vulnerability of district hospitals in Trashiyangtse and Trashigang	2013	MoH & GHI	Earthquake	Trashiyangtse District Hospital and Tashigang District Hospital
Vulnerability and adaptation assessments (SNC)	2011	NEC	Vulnerability assessment for water, agriculture and forest	Wangchu river basin (Thimphu, Haa, Paro and Chhukha) Kanglung (maize), Bhur (rice), Phobjikha (Potato), Entire country (forests)
Geotechnical study and hazard mapping for Valley Development Planning	2013-Ongoing	MOWHS	Multi Hazard	Numerous Valleys and Urban areas
Bridge condition assessment	2013-2015	DoR (MoWHS)	Flood	All Dzongkhags
Slope disaster study Rapid Baseline Assessment of Local Preparedness and Responsiveness to Climate Induced Hazards	2014-2016 2015	DoR (MoWHS) NEC	Landslide Climate induced hazards	80 kms stretch along Tronsa-Wandgi-Reotala National level
Vulnerability and adaptation assessment on health outcomes associated with climate variability and change	2012 - 2014	MOH	Vector borne diseases, water borne diseases and climate induced disasters	National Level
Study on the conservation of rammed earth buildings in the Kingdom of Bhutan	2013-2017	DOC (MoHCA)	Earthquake	National level (Wang-duphodrang Dzong Case Study)
Study of typology of rammed earth buildings, workshop resolving structural issues related to	1999-2007	DOC (MoHCA)	Landslides	National level

Title of Assessment	Year Conducted	Leading Agency	Hazard Covered	Area Covered
Traditional Bhutanese Buildings particularly Dzongs (case: Wangduphodrang Dzong)				
Detailed soil surveys and maps	1999-2007	NSSC (MOAF)	Landslides	National level
Seismic Risk Assessment		Thimphu Thromde	Earthquake	National level Thimphu Thromde

Source: Bhutan Disaster Risk Management Status Report, Bhutan Department of Disaster Management

Appendix D: Site Investigation Procedures & Checklist

Walk-over survey[2]

The walk-over survey, which is sometimes described as a site reconnaissance or site inspection, is an integral part of the site investigation process and should not be omitted. The whole site should be covered carefully on foot, making full use of available maps and photographs. The survey should not be confined to the site itself but should include the surrounding area and its building stock.

Some simple tools that are likely to be needed include the following:

❒ 20 m or 30 m tape to measure the position of features of interest;

❒ compass to orientate the site map;

❒ pocket penetrometer or hand vane to assess the strength of clay soil;

❒ abney level or clinometer to measure the ground slope angle in the area;

❒ auger, spade and polyethylene bags for taking soil samples;

❒ camera for visual records.

Topic Questions to be addressed

Topography, vegetation and drainage

- Does the site slope? What is the maximum slope angle?
- Is there evidence of landslips on or adjacent to the site or on similar ground nearby?
- Are there springs, ponds or water-courses on or near the site?
- Are, or were there, trees, or hedges growing in the vicinity of proposed construction?

Ground conditions

- What geological strata lie below the site and what problems are associated with this geological setting?
- Is the site covered by alluvium or other soft deposits?
- Is there information on the strength and compressibility of the ground?
- Is shrinkable clay present?
- In these soil conditions, is it likely that groundwater will attack concrete?

[2] From Geotechnics for Building Professionals, J A Charles

Previous use

- Is there evidence of previous building development?
- Has there been mining or quarrying activity in this area?
- Are there coal seams or other mineral resources under the site?
- Have there been changes in ground level (e.g. by placement of fill)?

Proposed building

- What area will the buildings occupy?
- What foundation loading is expected?
- How sensitive will the structure be to differential foundation movement?
- What soils information is required for the design of likely types of foundation?
- Is specialist geotechnical advice required?

Standard Penetration Test (SPT)[3]

Aim

To perform standard penetration to obtain the penetration resistance (N-value) along the depth at a given site.

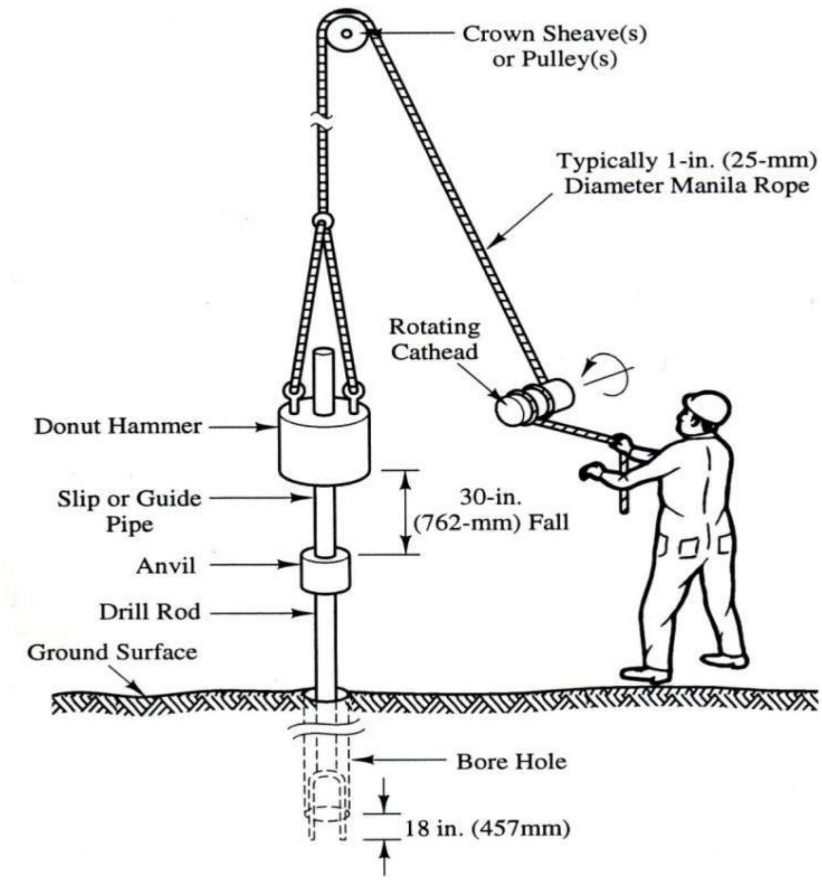
Equipment

- Tripod (to give a clear height of about 4 m; one of the legs of the tripod should have ladder to facilitate a person to reach tripod head.)
- Tripod head with hook
- Pulley
- Guide pipe assembly
- Standard split spoon sampler
- A drill rod for extending the test to deeper depths
- Heavy duty post hole auger (100 mm to 150 mm diameter)
- Heavy duty helical auger
- Heavy duty auger extension rods
- Sand bailer
- Rope (about 15 m long & strong enough to lift 63.5 kg load repeatedly)
- A light duty rope to operate sand bailer
- Chain pulley block
- Casing pipes
- Casing couplings
- Casing clamps

[3] From: https://civilblog.org/2015/11/27/how-to-do-standard-penetration-test-spt-of-soil-on-site/

- Measuring tapes
- A straight edge (50 cm)
- Tool box

Setup



Procedure

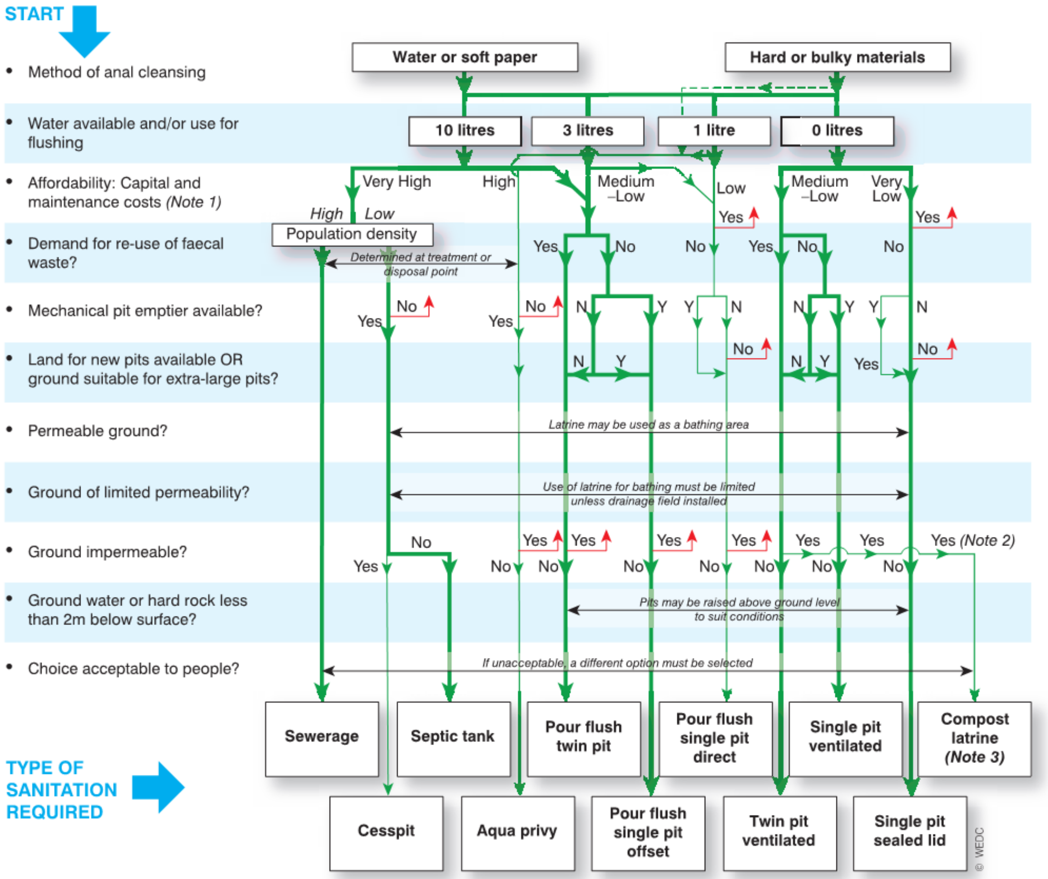
1. Identify the location of testing in the field
2. Erect the tripod such that the top of the tripod head is centrally located over the testing spot. This can be reasonably ensured by passing a rope over the pulley connected to the tripod head and making the free end of the rope to come down and adjusting the tripod legs such that the rope end is at the testing spot. While erecting and adjusting the tripod legs, care should be taken to see that the load is uniformly distributed over the three legs. This can be achieved by ensuring the lines joining the tips of the tripod legs on the ground forms an equilateral triangle. Further, it should be ensured that the three legs of the tripod are firmly supported on the ground (i.e. the soil below the legs should not be loose and they should not

be supported on a sloping rock surface or on a small boulder which may tilt during testing.)

3. Advance the bore hole, at the test location, using the auger. To start with advance the bore hole for a depth of 0.5 m and clear the loose soil from the bore hole.
4. Clean the split spoon sampler and apply a thin film of oil to the inside face of the sampler. Connect an A-drill extension rod to the split spoon sampler.
5. Slip the 63.6 kg weight on to the guide pipe assembly and connect the guide pipe assembly to the other end of the A-drill rod.
6. The chain connected to the driving weight is tied to the rope passing over the pulley at the tripod head. The other end of the rope is pulled down manually or with help of mechanical winch. By pulling the rope down, the drive weight, guide pipe assembly, A-drill rod and the split spoon sampler will get vertically erected.
7. A person should hold the guide pipe assembly split spoon sampler to be vertical with the falling weight lowered to the bottom of the guide assembly.
8. Now place a straight edge across the bore touching the A-drill rod. Mark the straight edge level all-round the A-drill rod with the help of a chalk or any other marker. From this mark, measure up along the A-drill rod and mark 15 cm, 30 cm and 45 cm above the straight edge level. Lift the driving weight to reach the top of the guide pipe assembly travel and allow it to fall freely. The fall of driving weight will transfer the impact load to the split spoon sampler, which drive the split spoon sampler into the ground. Again lift the drive weight to the top of travel and allow it to fall freely under its own weight from a height of 75 cm. as the number of blows are applied, the split spoon sampler will penetrate into the ground and the first mark (15 cm mark) on the drill rod approaches the straight edge.
9. Count the number of blows required for the first 15 cm, second 15 cm and the third 15 cm mark to cross down the straight edge.
10. The penetration of the first 15 cm is considered as the seating drive and the number of blows required for this penetration is noted but not accounted in computing penetration resistance value. The total number of blows required for the penetration of the split spoon sampler by 2nd and 3rd 15 cm is recorded as the penetration resistance or N-value.
11. After the completion of the split spoon sampler by 45 cm, pull out the whole assembly. Detach the split sampler from A-drill rod and open it out. Collect the soil sample from the split spoon sampler into a sampling bag. Store the sampling bag safely with an identification tag for laboratory investigation.
12. Advance the bore hole by another 1 m or till a change of soil strata whichever is early.
13. The test is repeated with advancement of bore hole till the required depth of exploration is reached or till a refusal condition is encountered. Refusal condition is said to exist if the number of blows required for the last 30 cm of penetration is more than 100.

14. The test will be repeated in number of bore holes covering the site depending on the building area, importance of the structure and the variation of the soil properties across the site.
15. The SPT values are presented either in the form of a table or in the form of bore log data.

Appendix E: Guide to sanitation selection (WEDC)



Note 1: Not all possibilities are illustrated as it is assumed that water availability is related to affordability
Note 2: Use extra large pits or consider composting
Note 3: Also dependent on willingness to collect urine separately, demand for compost, availability of ash or vegetable matter etc.
Note 4: ↑ = a different option must be chosen

Original source: FRANCEYS, R.W.A. 1991. 'A guide to sanitation selection', In: PICKFORD, J. (ed.) *The Worth of Water*. Rugby, UK: Practical Action Publishing.

Appendix F: Example Room Data Sheet and space requirements

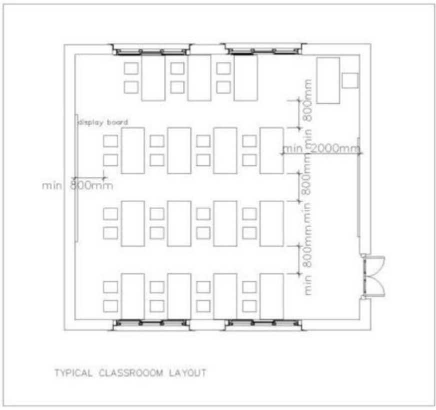
School Planning & Building Division, Directorate of Services, Ministry of Education
School Design Guidelines, 2020
TYPICAL ROOM DATA SHEETS

Room: **Classrooms**

Spatial Planning
Floor Area

Primary		m^2/pupil
Middle Secondary		m^2/pupil
Higher Secondary		m^2/pupil
Floor to Ceiling		m

Typical Layout



TYPICAL CLASSROOM LAYOUT

Environmental Criteria

Minimum Temp		oC
Maximum Temp		oC
Relative Humidity		%RH
Minimum ventilation		l/s/person
Process Extract		
Space Heating		

Services

Cold Water (Potable)	
Cold Water (Non potable)	
Hot Water	
Drainage	
Traps/Filters	
Gas	
Electricity	

Sanware

	Quantity	Notes
Sinks		

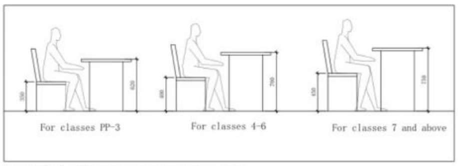
Electrical Outlets	Quantity	Spacing
Single Sockets		
Double Sockets		

Equipment

Laptops	

Lighting	Lux
General	
Task Lighting	

Furniture



CHAIR AND DESK HEIGHT FOR THE DIFFERENT CLASSES

Notes

Space Requirements: Classrooms

The dimension of the classroom will vary depending on the numbers of student in each class and the strength of the school.

It is recommended not to have more than 24 students in a class for primary school and 30 students in secondary school as per the National Education Policy

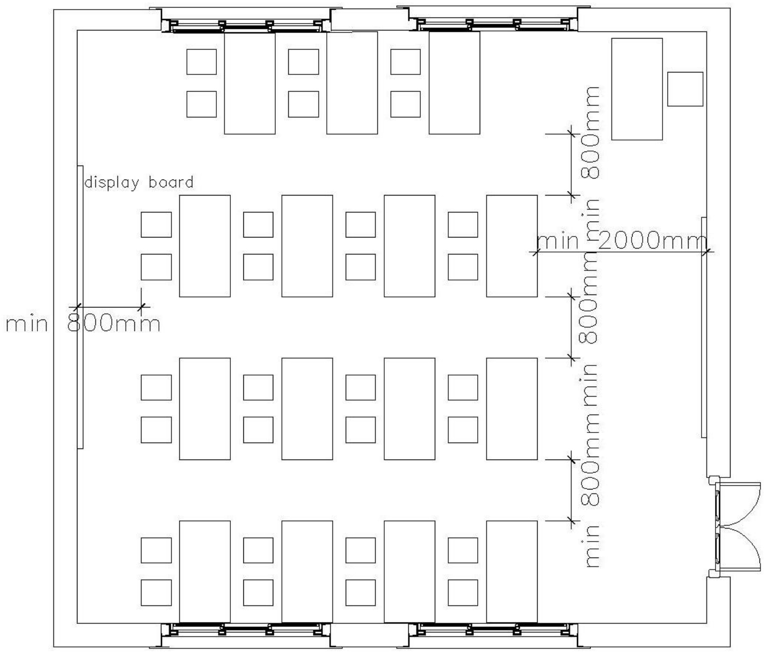
The minimum recommended area is 1.5 sqm per student.

The minimum clear height for classrooms should be 2.8 meters for temperate regions and 3.2 meters for tropical regions to accommodate ceiling fans and 2.7m for alpine regions

A class room should have a display board in addition to a black/green board on a wall.

The classroom window sill height should be appropriately designed so that the desks do not hit the glass panes.

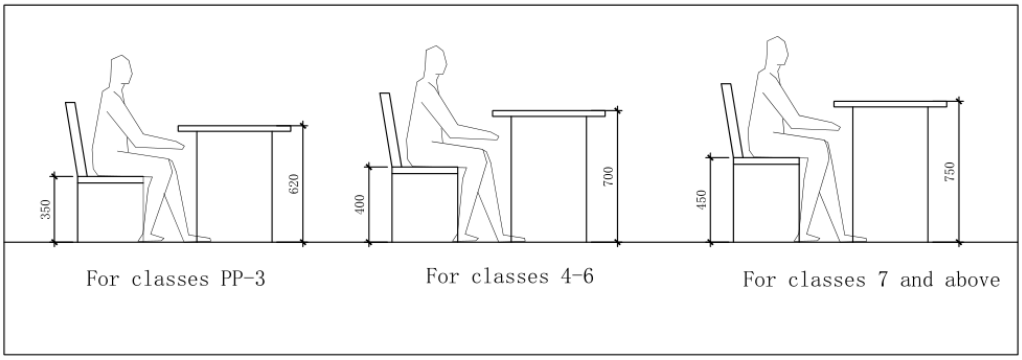
For conventional teaching method, basic classroom module is square or rectangular in shape.



TYPICAL CLASSROOOM LAYOUT

A cupboard or a shelf to store notebooks for the students in each classroom will enhance the functionality of the area.

The classroom furniture should be compatible to the user heights. At least one set of furniture should be accessible for disabled students.



CHAIR AND DESK HEIGHT FOR THE DIFFERENT CLASSES

Space Requirements: Staff rooms

A staff room is provided for the teaching staffs to prepare for their daily lessons.

It is also a space where they interact and share their knowledge and socialize.

Staff rooms should be centrally located in the school to provide easy access from all around the campus and also offer passive surveillance.

It will also serve as resource room and have cupboards and shelves for stocking reference books.

The size of the room will depend on the number of teachers in a particular school but the minimum recommended space is 2.0 square meter per teacher.

Each teacher should be provided with adequate storage shelves and cupboards which maybe lockable.

Space Requirements: Administration Unit

Principal's office: It should be able to accommodate around 4-5 people for discussion with space for file racks and cupboards. The minimum recommended office area is 20 sqm. An attached toilet should be provided for convenience.

Vice principal's office: The number of vice principals vary with school. Therefore the number of offices for Vice Principals should be provided accordingly. The minimum recommended area is about 15 sqm for each office.

General office: It can be open office with work stations for general staffs and finance officers. The office size will depend on the size of the school and hence the number of staff working therein.

Photocopy room: It is also advisable to have small photo copy room near the office and staff for their convenience.

Storage room: It is essential to have a storage room to store supplies and books. They should be lockable and located in ground floors for easy access.

Records room: A room to store records of the school should also be provided. It should be located near the principal's office. In addition to being secure it also needs to be designed with fire resistant considerations.

Conference hall: To facilitate staff meetings a conference hall to accommodate all the teachers is required. The minimum recommended area is 1.5sqm per teacher.

Examination center: This is a room where the examination papers can be sorted, arranged and securely stored. Therefore, it has to be highly secured. It can be about 15-20sqm with stacking and storing shelves including a space where few exam in-charge teachers can sit and discuss.

The examination center should also include a room to accommodate twin beds and attached toilet.

Staff toilet: Separate toilets for male and female staff with continuous supply of water should be provided in close proximity. A ratio of 1 toilet to 10 staff is recommended.

Space Requirements: Laboratories

Science laboratories

All the 3 science subject labs viz. chemistry, physics and biology are required in schools that have classes VII and above.

For a primary school it will suffice to have a single science lab where simple demonstrations can be performed to encourage and develop interest in different science subjects.

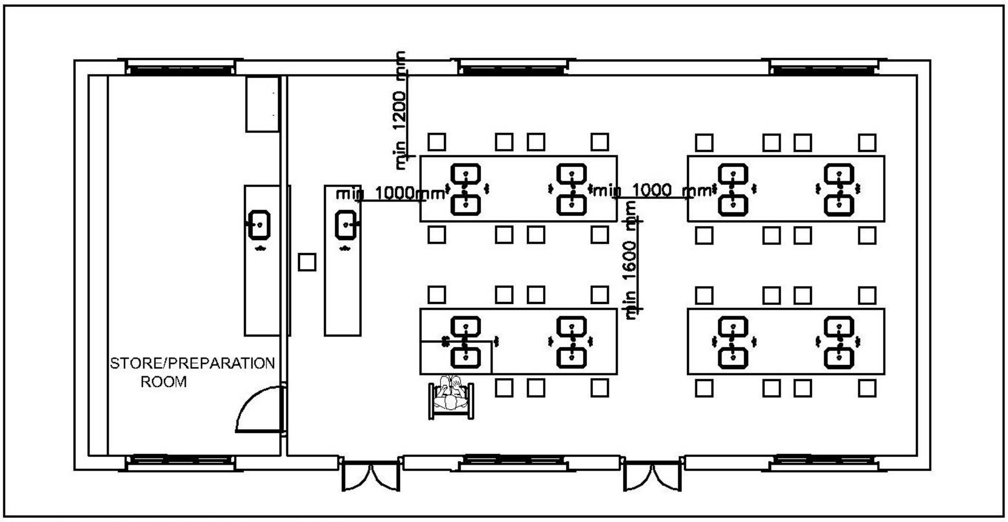
The minimum recommended area is 2.0 sqm per student for comfortable functioning.

Both chemistry and biology labs should include adequate sinks with water supply.

Extra amenities and precautions are required for chemistry labs, such as gas line, acid resistant sinks, work tops and pipes.

In chemistry labs for higher classes where there is intensive use which produces toxic and flammable gases during experiments, exhaust hoods or mechanical ventilations should be installed. Chemical wastes should be disposed separately and carefully.

It is also recommended to keep fire extinguishers in labs where fire risks are high. Each lab should have a store cum preparation room attached. All the labs need to have a separate work table in front for teachers to allow for demonstration. A work table should be specially designed at lower level for students with disabilities/special needs.



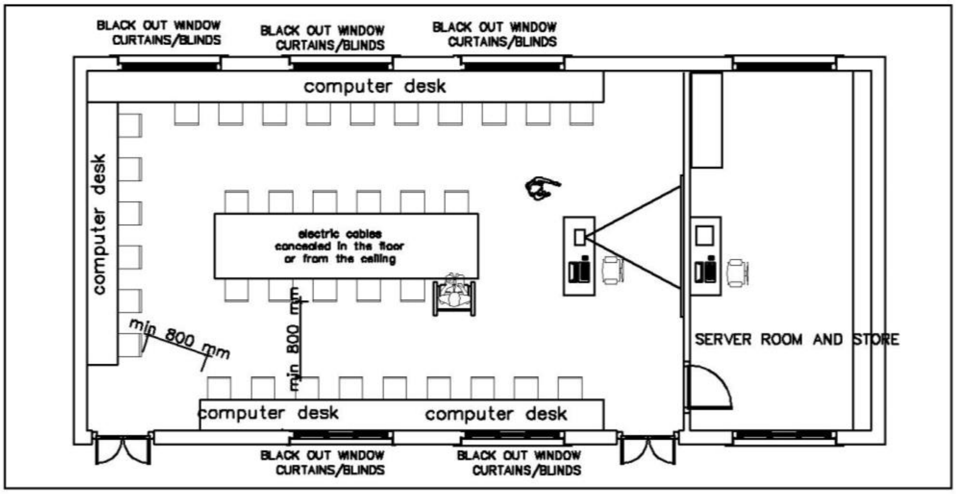
TYPICAL CHEMISTRY LAB LAYOUT

Space Requirements: Computer labs

A computer lab should at least fit in 30 computers to accommodate an entire class at a time. It should also have a separate sever room located adjacently**.** The minimum recommended area is 2.0 sqm per student for comfortable functioning. The computers should be aligned along the wall for simpler electrification.

The location of the computers placed in the center of the room should be well planned in earlier stage so that the cables can be embedded in the floor to avoid tripping hazards. The lab should be well ventilated to prevent overheating due to heat generated by the equipment**.**

To avoid glares, computer labs should be provided with dark curtains which can render the room dark when required. Allowance should be kept for projector screen on the front wall.



TYPICAL COMPUTER LAB LAYOUT

Space Requirements: Geography Lab

This lab will be essentially required in schools which provide Arts subject for classes XI and XII. It should have big tables to spread out maps and also appropriate storage for them. It should also be equipped with a computer and projector for instructional purposes. The minimum recommended area is 2.0 sqm per student .

Space Requirements: Library/Media center

Separate areas for book shelving and reading areas would be required.

Reading areas and number of books will depend on the school enrollment. The reading areas should at least be able to accommodate single class strength i.e. 24-30 students at a time. A minimum of 1.5 sqm per student should be allotted for reading areas.

The shelving arrangement should have clear line of sight from the circulation desk for the purpose of surveillance. Recommended aisle width between two shelves is 900mm. Allowance should also be made for electronic books by providing computers with internet access.

A librarian's office should be located within the library with the view window into the reading area. The minimum recommended area for librarian's office is 10sqm.

Space Requirements: Music, Visual Art, Drama and Dance

These are subjects relating to co-curricular activities of the school. Students should be taught, encouraged and nurtured to explore their various interests and talents.

Music room should consider acoustic requirement to improve sound in the room as well as limit sound outside the room. These room should also have wider doors to bring in big musical instruments.

For dance and music room, higher ceiling height should be incorporated to facilitate flexibility in vertical movements.

Art classes would require an area of 3.0 sqm per student with good view to the outside to provide inspiration. Art room should have display boards and shelves to showcase the works of the students. They should also have a wash basin with water supply. All the finish materials of the art room should be smooth, washable and non-absorbent.

All these rooms should have appropriate safe storage rooms for supplies and equipment.

Space Requirements: Health room

A school should have a room dedicated to health care in case of emergency. This room should have washable floor finish and fit in at least 2 beds. It should have attached toilet. It should also have a medical cabinet stored with the basic medicinal needs such as the first aid kit.

Space Requirements: Counseling room

This is a room where a counselor provides counseling to students, staff and parents on various matters. This room should be located carefully. If they are located too close to the main circulation area, users may not avail the facility for fear of being mocked hence they should be appropriately located yet not totally isolated to ensure privacy of the users.

This room should have good view and soothing colors equipped with appealing furniture to provide calm, relaxing and inviting atmosphere.

Space Requirements: **Multipurpose Hall**

This hall should be flexible in its use; it may be used for assembly, dining, physical education, indoor sports and games, drama, music, debates,presentations and so on.

In most schools they are also used by the community for social gatherings, parents' meeting etc. and therefore it should be located close to the entrance gate, easily accessible to the public with sufficient parking space.

Depending upon their intended usage, ancillary facilities such as stores, kitchens, serving area, toilets and green rooms have to be provided appropriately.

Space Requirements: **Dining Area**

A dining hall in a day school which is used only for lunch should be located closer to the academic area, where as a dining hall used for boarding school needs to be strategically located in between hostels and academic zone for both day and evening use.

The size of the dining area will be determined by the total school enrollment and the number of students availing dining services.

The minimum recommended area is 0 .85 sqm per student for primary schools and 1.5 sqm per student for secondary schools. An additional 15% of the dining floor area should be provided for serviving area.

The floor area of the dining hall usually tends to be large and hence the height should also be designed proportionately. It is also preferred to have easily washable floor finishes for dining areas.

The dining area should have wash basins close to the entrance so that students can wash their hands before and after eating. Drinking water facilities should also be provided within the dining hall at appropriate location. Appropriate methods should be in place to to dispose waste food.

If required dining halls can also be multifunctional and serve as auditorium, physical education room, etc.

Space Requirements: Kitchen

Kitchen should be clean and hygienic with washable floors and walls. The kitchen should include energy efficient cooking stove, proper exhaust chimney, enough dry and wet stores, adequate preparing and cooking place, big pots and pan storing and washing area, dish washing area and appropriate waste disposal system.

The minimum recommended kitchen area should be 60 sqm excluding the ancillary facilities such as the toilets, store and offices.

It should also be accessible by vehicular road for easy delivery of supplies.

The kitchen should be closely located with the dining area and well connected with covered walkway to ensure safe delivery of food in times of rain.

Space Requirements: Vocational Training Workshop

Depending on what kind of vocational training a school is planning to provide, appropriate training room/space must be allocated in design stage.

Space Requirements: Hostels

Hostels should be designed to accommodate preferably 8 students but not exceeding 16 students in a room.

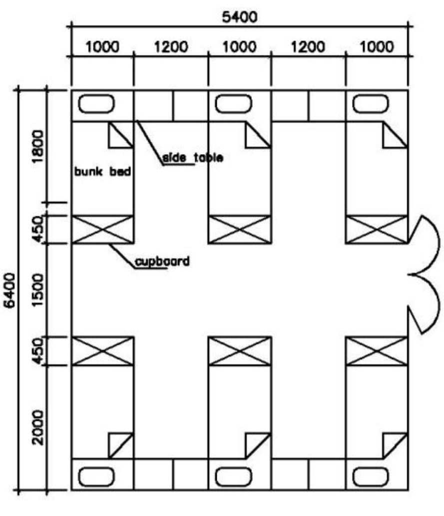
The minimum recommended space for hostel room is 4 sqm per student if using single bed and 3 sqm per student if using bunk bed without the provision of study table within the rooms.

Although single beds are preferred in hostel rooms, bunk beds can be provided where there is acute shortage of space and budget.

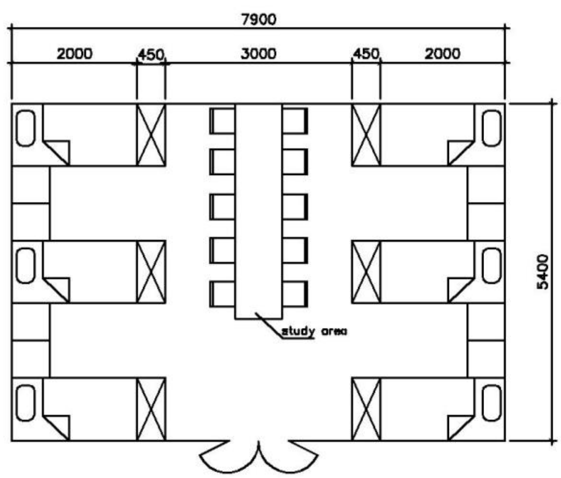
If bunk beds are to be provided the clear room height should not be less than 3.2 m for temperate regions. For tropical regions the room height must not be less than 3.4 m to accommodate ceiling fans. Further care must be taken to ensure than fans are not located directly above the beds.

Separate hostels must be provided for girls and boys with reasonable distance between them to allow for security and privacy.

Few examples of compact hostel room design are shown below:



TYPICAL ROOM PLAN WITHOUT STUDY AREA



TYPICAL ROOM PLAN WITH STUDY AREA

A separate warden/ matron quarter/caregiver can be located nearby, or they can be integrated in the hostel structure itself.

The hostel building should include a study hall if they are located a bit far from the academic buildings, otherwise they can use the nearby classrooms for their evening studies.

An opportunity to relax in the hostel is an integral element in a healthy boarding school system, hence it is important to provide a recreation room.

A recreational room can be of two kinds, one where the students can gather, discuss, socialize or watch TV, the other for physical activity where they can play in door games such a table tennis, carom, chess, etc.

A sick room should be provided close to the warden/matron's quarter to isolate and monitor when a student is not feeling well.

Enough toilets and shower cubicles must be provided. A ratio of 1 toilet for 15 girls and 1 toilet for 15 boys plus 1 urinal for 40 boys. A minimum of 1 MHM room should be provided for every floor in the girls' hostel. A ratio of 1 shower cubicle for 20 students should be provided in both girls and boys hpstel. A toilet and a shower should be be made to accommodate students with disabilities.

Hot water provision must be made available for shower, laundry and wash basin. Areas for washing clothes and covered drying areas must be included in a hostel design.

Space Requirements: Toilets

Privacy, cleanliness and safety are the design parameters for achieving good toilet designs. Toilets must be clean and have continuous water supply. Separate toilets to be provided for both girls and boys.

A ratio of 1 toilet for 20 girls and 1 toilet plus 1 urinal for 40 boys is recommended as per the UNICEF WASH (Water, Sanitation and Hygiene in Schools) manual.

Special provision must be provided for girls' toilet with sanitary disposal feature

(MHM).

At least one unit of toilet must be made universally accessbile in a school.

Toilet fixtures should be mounted at appropriate heights for the age of the users. Walls and floors should be washable. Moreover floors should be slip resistant and effort must be made to keep the floors dry at all times to curb slip hazards.

Accessible cut-off valves must be provided to each major wing of the building or each individual building when designing water supply systems. This will facilitate repairs without having to cut off water to the entire facility.

Space Requirements: Staff quarters

Staff quarters in the campus should be provided depending upon the need and the availability of renting private houses in the vicinity. The room sizes of the quarters should be of comfortable size and at par with the available housing in the region.

Space Requirements: Physical Education/ Sports Area

Physical education programs not only teach physical skills but mentors other aspects of life such as goal setting, team participation, self-esteem development, decision making and leadership, therefore it is an important component in a campus design.

In our context, most physical education happens out door in the play field. Outdoor play area should have easy access to shade and water supply for both drinking and washing.

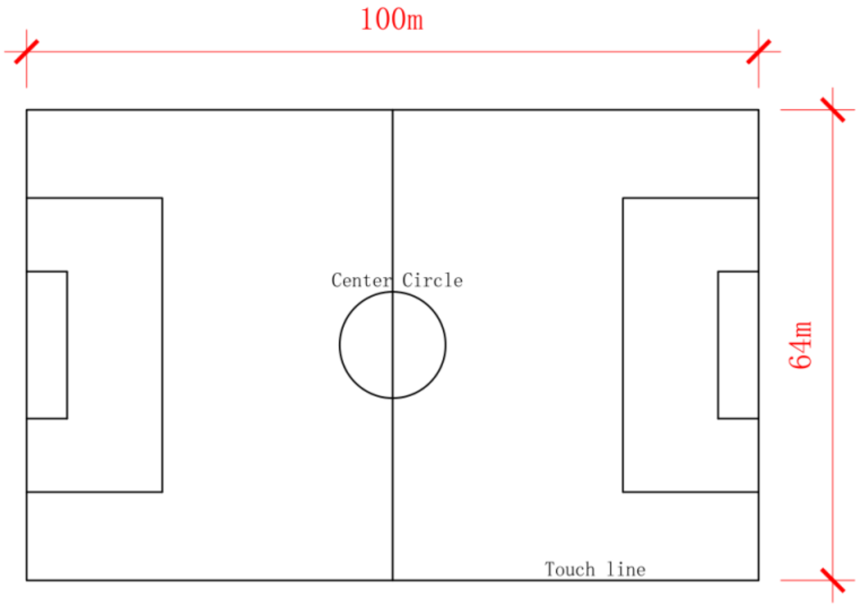
Play areas should be clearly demarcated and also separated from the parking areas to avoid vehicular accidents especially in urban areas.

All the equipment in the play areas should be installed at age appropriate heights of the users.

These play fields tend to produce very high level of noise which can disturb the classes. Hence it is recommended that they are located at reasonable distance from the classroom area.

Ideally, all playfields should be provided at international standard sizes.

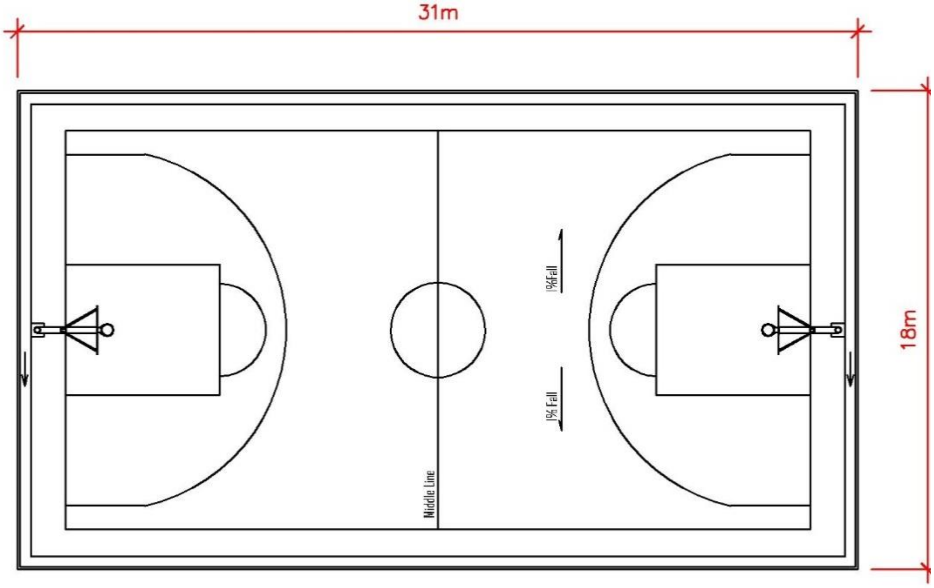
A standard football field is of size 100x64m or 70x46m as per the available space.



Football Dimension

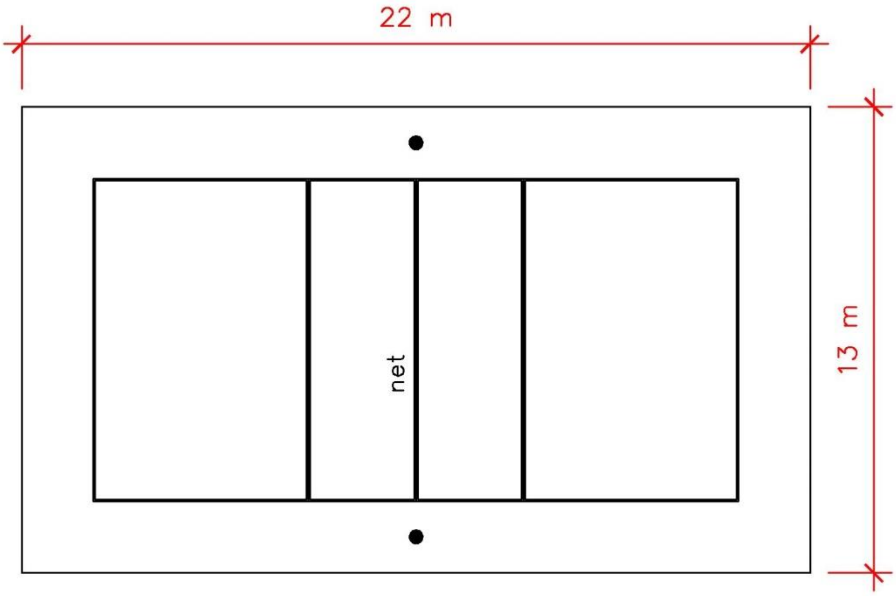
It is recommended to have two basketball courts in a school one each for boys and girls. However when that is not possible due to any reason at least one basketball court must be provided.

A basketball court size is 31mx18m.



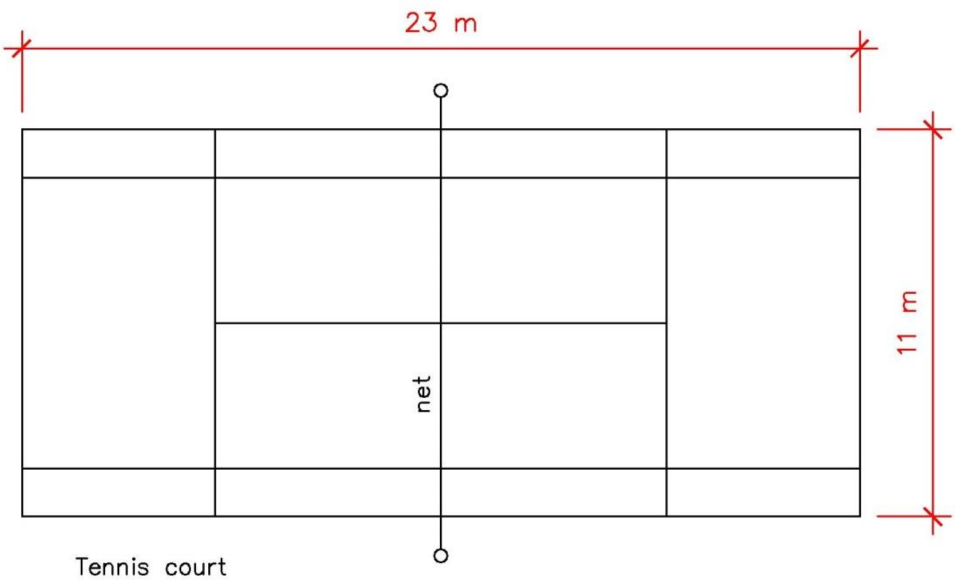
Basketball Court

A standard Volley ball court size is about 22mX13m



Volleyball Court

A tennis court is of 23mx11m



Tennis court

Space Requirements: Courtyard/Assembly Ground

As morning assembly/prayer is an important part of the daily school activities, courtyards/Assembly grounds form a mandatory part of the school campus design. Generally, the courtyard is of rectangular or square in plan. The recommended space is 0.6 sqm per student.

The courtyard may be paved or covered with grass. However maintaining the grass cover can be challenging.

It has become an accepted norm to put a Jampelyang statue and a national flag in front of the courtyard, hence it is crucial to consider them in the planning and designing stage.

A raised platform in the front for the teachers to stand and supervise including a podium with microphone should also be part of courtyard design.

Space Requirements: Circulation and Emergency exits:

Campus circulation

It is not absolutely necessary for all the buildings to have vehicular access. Buildings which are frequented by publics and those that require continuous delivery such as the kitchen would need easy vehicular access.

Vehicular access can be designed around the peripheral so that the internal circulation is mainly pedestrian to mitigate traffic accidental risks and also to reduce noise pollution.

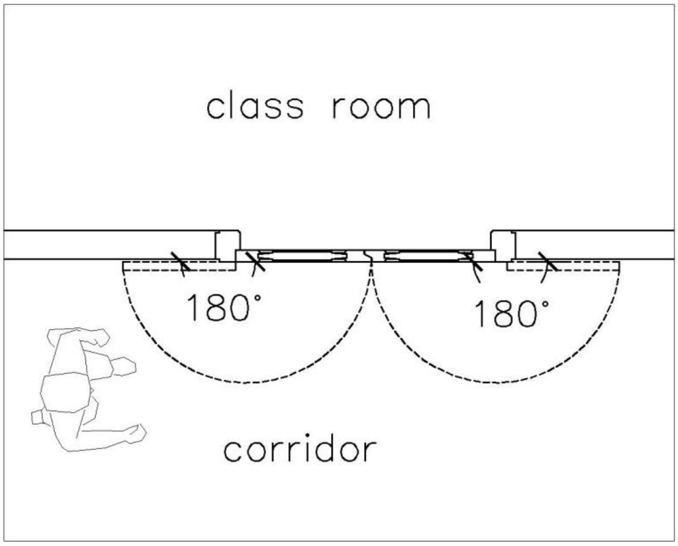
However the various school buildings and facilities need to be well connected with footpaths, covered walkways and appropriate ramps wherever needed.

All buildings will require enough space around them for vehicles to ply only in case of emergency. They can be part of the landscape and need not be paved as vehicular road.

Building Circulation

If the numbers of users in a building exceeds 200, more than 2 exits should be provided. For general rule of thumb, for every 150 users 1 exit door must be provided.

Classroom doors should have minimum of 1.0 m clear open, preferable opened towards the direction of egress. In order to obstruct the free flow of the corridors the doors should be open able close to 180 degrees.



Door can be made open able to 180 ° to prevent obstructing free movement in the corridor

Recommended width of major corridors in mm are shown in the table below:

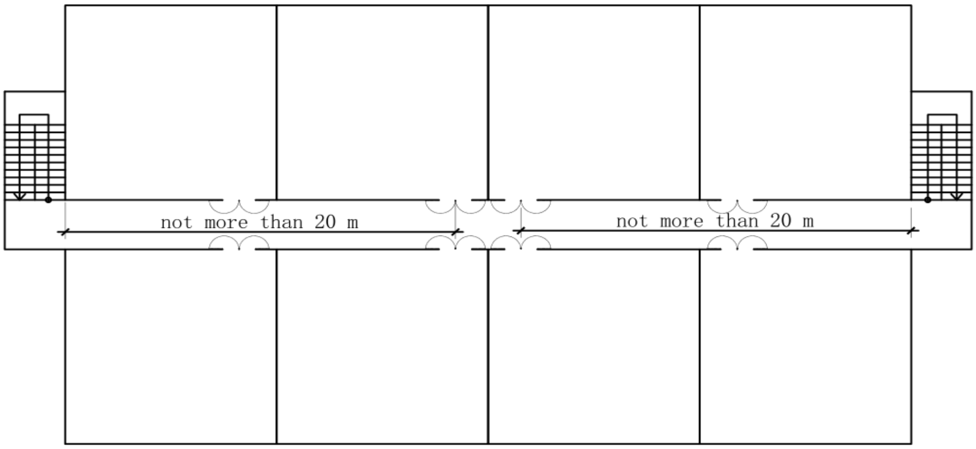
Type of School	Type of corridor	Minimum width (mm)	Recommended width (mm)
Primary School	Singly loaded	1200	1500
	Doubly loaded	1500	2000
Secondary School	Singly loaded	1500	2000
	Doubly loaded	2000	2500

For comfortable staircase, the minimum tread should not be less than 270-300 mm and riser between 150-180 mm.

The minimum staircase width for 150 users should be 1.2 m and 1.5 m for 250 users.

As a general thumb rule an extra flight of staircase would be required for every 250 extra users.

The maximum distance from a classroom door to the emergency exit should not be more than 20 meters.



MAXIMUM DISTANCE FROM A DOOR TO EMERGENCY EXIT

An additional 600mm to be considered if lockers are placed in the corridors on one side or additional 900mm if lockers are placed on either side of the corridor.

Careful thought should be given for railing design; the balustrades should not be very wide apart or too low to avoid falling accidents to students and objects.

The minimum height of the staircase and balcony railing is 1000 mm and the gap between balustrades should not be more than 125mm.

Appendix G: Example Accommodation Schedules

Primary Schools – from BB99 [34]

pupil places number of classes Forms of Entry (FE) and type			90 pupils 3 classes **1 FE infants**		180 pupils 6 classes **2 FE infants**		120 pupils 4 classes **1 FE junior**		240 pupils 8 classes **2 FE junior**		360 pupils 12 classes **3 FE junior**	
	max. group size	average area (m^2)	no. of rooms	total area (m^2)	no. of rooms	total area (m^2)	no. of rooms	total area (m^2)	no. of rooms	total area (m^2)	no. of rooms	total area (m^2)
basic teaching												
reception class	30	66	1	66	2	132						
infant classbase	30	60	2	120	4	240						
junior classbase	30	60					4	240	8	480	12	720
specialist practical												
food/science/D&T	8	24	1	24	1	24	1	24				
food/science/D&T	8	38							1	38	1	38
ICT/ group room: (no. of computers)												
ICT suite: (no. of computers)			(8)	38	(15)	38	(8)	38	(16)	38	(24)	56
halls												
main hall (used for dining)	30		1	125	1	150	1	140	1	180	1	180
small hall	30	80										
studio	30	50									1	50
learning resource areas												
Library resource centre	15 to 30		1	18	1	24	1	21	1	29	1	37
small group room (SENco)	5 to 8	12	1	12	1	12	1	12	1	12	1	12
small group rooms	5 to 8	9			1	9	1	9	1	9	2	18
TOTAL TEACHING AREA				**403**		**629**		**484**		**786**		**1111**
staff and admin.												
head's office/meeting room			1	10	1	12	1	10	1	12	1	14
senior management offices		8							1	8	1	8
staff room			1	18	1	28	1	20	1	35	1	50
general office			1	8	1	10	1	8	1	10	1	12
sick bay (adjacent)		3	1	3	1	3	1	3	1	3	1	3
entrance/reception			1	2	1	3	1	3	1	4	1	5
copier/reprographics				2		5		2		5		7
SENco/MI/group room		12	1	12	1	12	1	12	1	12	1	12
interview/social services		8			1	8			1	8	1	8
storage												
class storage (reception)		3	1	3	2	6						
class storage (infant and junior)		1.5	2	3	4	6	4	6	8	12	12	18
specialist stores		6 or 8	2	12	2	16	2	16	3	18	3	24
PE store (adjacent to hall)		12	1	12	1	12	1	12	1	12	1	12
PE store (external)		4	1	4	1	4	1	4	1	4	1	4
non-teaching storage												
central stock		8	1	6	1	8	1	8	1	8	1	8
cloakrooms/lunch box storage		3		9		18		12		24		36
dining chair/table store (no. of sittings)			(2)	7	(2)	12	(2)	8	(2)	12	(3)	12
staging/appliance store			1	4	1	4	1	4	1	8	1	8
community store		4	1	4	1	4	1	4	1	4	1	4
caretakers /maintenance store			1	4	1	5	1	4	1	5	1	6
cleaner's store		1.5	2	3	2	3	2	3	2	3	3	4.5
TOTAL NET AREA				**529**		**808**		**623**		**993**		**1367**
recommended net area				**529**		**808**		**622**		**994**		**1366**
non-net area												
kitchen (full-service)			1	28	1	41	1	32	1	50	1	68
servery				6		6		6		8		8
toilets (and personal care)												
reception toilets			2	8	3	12						
other pupil toilets				10		20		20		40		60
accessible toilets/hygiene facilities				7		7		7		7		7
staff toilets				3.5		7		7		10.5		14
circulation		**net x 23%**		**122**		**186**		**143**		**228**		**314**
plant (incl. server)		**net x 3%**		**17**		**25**		**20**		**31**		**42**
partitions		**net x 5%**		**26**		**40**		**31**		**50**		**68**
TOTAL GROSS AREA				**757**		**1152**		**889**		**1418**		**1948**
recommended gross area (net at 70% of gross)				**756**		**1154**		**889**		**1420**		**1951**

Secondary Schools – from BB98 [35]

basic teaching
halls
learning resources
staff and administration
storage
dining and social
non-net

curriculum emphasis				900 11 to 16 Places								215 16 to 18 Places			
				option A: science, design and technology		option B: music, sport		option C: performing arts, business and enterprise		option D: languages, art, humanities, mathematics and ICT		option X: science, design and technology, music, performing arts		option Y: languages, art, humanities, maths & ICT, business, sport	
net capacity range				834 to 927		850 to 945		865 to 962		882 to 981		137 to 361		153 to 378	
	max. group size	average area (m^2)	net capacity places	number of rooms	total area	number of rooms	total area	number of rooms	total area	number of rooms	total area	number of rooms	total area	number of rooms	total area
English, Modern Foreign Languages, Humanities and Mathematics		60		20	1200	21	1260	22	1320	23	1380	4	220	7	385
seminar rooms (sixth form)	16	43	26	–	–	–	–	–	–	–	–	–	–	4	172
large classrooms	30	66	30	8	528	4	264	–	–	–	–	–	–	–	–
min. classrooms	30	56	30	12	672	12	672	22	1232	–	–	–	–	–	–
classrooms	30	60	30	–	–	5	300	–	–	23	1380	4	240	3	180
ICT clusters	10	varies	–	–	–	1	24	4	88	–	–	–	–	1	32
small group rooms (including FLA) or sixth form study	12	varies	–	3	30	3	30	3	30	3	30	1	30	1	10
Head of Year offices	–	8	–	4	32	4	32	4	32	4	32	–	–	–	–
staff workrooms	–	20	–	2	40	2	40	2	40	2	40	add	14	add	21
general teaching store rooms	–	3	–	7	21	7	21	7	21	8	24	2	6	3	9
Information Technology/ Business Studies				2		2		3		4		4		7	
IT/BS rooms (sixth form or KS4)	20	60	20	–	–	–	–	1	60	1	60	3	180	5	300
IT room or language lab.	30	77	27	2	154	2	154	2	154	3	231	1	77	2	154
ICT technician	–	8	–	1	8	1	8	1	8	2	16	–	–	–	–
Head of Year office	–	8	–	1	8	1	8	1	8	1	8	–	–	–	–
staff workroom (shared with science)	–	20	–	1	20	1	20	1	20	1	20	add	7	add	14
ICT store room	–	3	–	1	3	1	3	1	3	1	3	1	3	2	6
server	–	8	–	1	8	1	8	1	8	1	8	–	–	–	–
Science				8		7		7		6		3		2	
science laboratories	30	90	30	8	720	7	630	7	630	6	540	3	270	2	180
small group room or sixth form study (shared with IT/BS)	–	30	–	–	–	–	–	–	–	–	–	1	30	–	–
science preparation room(s) and chemicals store	–	varies	–		104		91		91		78	add	49	add	36
Design and Technology				6 plus resource		6		5		4		1		0	
food room	20	101	24	1	101	1	101	1	101	1	101	–	–	–	–
food preparation room	–	12	–	1	12	1	12	1	12	1	12	–	–	–	–
resistant materials	20	varies	27	2	224	2	224	2	224	1	116	–	–	–	–
resistant materials prep room	–	50	–	1	50	1	50	1	50	1	50	–	–	–	–
electronics and control systems	20	90	30	1	90	1	90	1	90	1	90	–	–	–	–
textiles	20	77	27	1	77	1	77	1	77	1	77	–	–	–	–
graphic products	20	90	30	1	90	1	90	–	–	–	–	1	90	–	–
design resource area	12	50	16	1	50	–	–	–	–	–	–	–	–	–	–
staff work room (shared with art)	–	20	–	1	20	1	20	1	20	1	20	add	7	–	–
practical store rooms	–	6	–	7	42	7	42	5	30	5	30	1	6	–	–
Art				2		2		2		3		0		1	
large art room (textiles or 3D)	30	105	30	2	210	2	210	2	210	2	210	–	–	–	–
kiln room	–	4	–	1	4	1	4	1	4	1	4	–	–	–	–
general art room	30	90	30	–	–	–	–	–	–	1	90	–	–	1	90
darkroom	5	12	–	1	12	–	–	1	12	1	12	–	–	–	–
art/design resource area	20	varies	–	–	–	–	–	–	–	1	43	1	30	–	–
practical store rooms	–	6	–	4	24	4	24	4	24	6	36	0	0	2	12
Music and Drama				1		2		3		3		1		0	
music recital	30	90	28	1	90	1	90	1	90	1	90	–	–	–	–
music classroom	30	67	23	–	–	1	67	–	–	1	67	1	67	–	–
music group/practice rooms	6	7	–	4	28	7	49	4	28	7	49	3	21	–	–
music ensemble room	10	20	–	1	20	1	20	1	20	1	20	1	30	–	–
recording/ control room	4	12	–	1	12	1	12	1	12	1	12	–	–	–	–
staff work room (shared with PE)	–	20	–	1	20	1	20	1	20	1	20	add	7	–	–
Drama studio	30	90	28		0	0	0	1	90	1	90	–	–	–	–
Audio-visual studio (media studies)	30	90	28		0		0	1	90	–	–	–	–	–	–
instrument store	–	10	–	1	10	1	10	1	10	1	10	–	–	–	–
music and drama stores	–	6	–	1	6	2	12	3	18	1	6	1	6	–	–

basic teaching
halls
learning resources
staff and administration
storage
dining and social
non-net

curriculum emphasis				900 11 to 16 Places								215 16 to 18 Places			
				option A: science, design and technology		option B: music, sport		option C: performing arts, business and enterprise		option D: languages, art, humanities, mathematics and ICT		option X: science, design and technology, music, performing arts		option Y: languages, art, humanities, maths & ICT, business, sport	
	max. group size	average area (m^2)	net capacity places	number of rooms	total area	number of rooms	total area	number of rooms	total area	number of rooms	total area	number of rooms	total area	number of rooms	total area
Physical Education															
4-court sports hall	60	594	60	1	594	1	594	1	594	1	594	–	–	–	–
activity studio	30	150	30	1	150	1	180	–	–	–	–	–	–	–	–
multi-gym	12	40	–	–	–	1	40	–	–	–	–	–	–	–	–
PE and external stores	–	varies	–	2	97	3	115	1	80	1	80	–	–	–	–
pupil changing rooms and showers	N/10	59		2	118	2	118	2	118	2	118	add	40	add	40
staff and visitor changing rooms and showers		8		2	16	3	24	2	16	2	16	–	–	–	–
Central Resources															
main hall	–	varies	30	1	280	1	280	1	310	1	280	add	65	add	65
library resource centre and careers	N/10	varies	30	1	155	1	140	1	155	1	155	add	20	add	45
sixth form study areas	50	80	30	–	–	–	–	–	–	–	–	–	–	can vary	80
librarian and Head of sixth form offices	–	8	–	1	8	1	8	1	8	1	8	1	8	1	8
central stock and library stores	–	6	–		12		12		12		12	add	5	add	5
chair store(s)	–	varies	–		18		18		18		18	add	6	add	6
secure/exam/community stores	–	8	–	2	16	2	16	2	16	2	16	1	8	1	8
dining area (hot meals)	N/4	varies	–	can vary	215	can vary	205	can vary	200	can vary	240	can vary	90	can vary	90
social and sandwich area(s)	varies	varies	–	can vary	35	–	–	can vary	70	–	–	can vary	95	can vary	105
kitchen (incl staff and stores)	–	101	–	1	101	1	101	1	101	1	101	add	25	add	25
Inclusion Support															
SEN resource base (case conference/tutorial)	18	20	–	1	20	1	20	1	20	1	20	–	–	–	–
small group room (SEN etc)	6	16	–	1	16	1	16	1	16	1	16	–	–	–	–
SEN therapy/MI room	4	18	–	1	18	1	18	1	18	1	18	–	–	–	–
SENco office	–	8	–	1	8	1	8	1	8	1	8	–	–	–	–
SENco/wheelchair/ appliances storage	–	12	–	1	12	1	12	1	12	1	12	add	4	add	4
hygeine facilities (incl. shower)	–	30	–	can vary	30	can vary	30	can vary	30	can vary	30	–	–	–	–
Administration															
head's office	–	12	–	1	12	1	12	1	12	1	12	–	–	–	–
meeting room	–	16	–	1	16	1	16	1	16	1	16	–	–	–	–
senior management offices	–	8	–	4	32	4	32	4	32	4	32	–	–	–	–
general office	–	48	–	1	48	1	48	1	48	1	48	add	6	add	6
entrance/reception and adjacent sick bay	–	16	–	1	16	1	16	1	16	1	16	–	–	–	–
staff room (social)	–	varies	–	1	60	1	60	1	60	1	60	add	20	add	25
reprographics	–	varies	–	1	26	1	26	1	26	1	26	–	–	–	–
community and other offices	–	8	–	6	48	4	32	6	48	5	40	1	8	1	8
Other															
maintenance store(s)	–	8	–	1	8	1	8	1	8	1	8	add	4	add	4
cleaners' stores	–	1.5	–	6	9	6	9	6	9	6	9	2	3	2	3
lockers for personal storage	–	–	–	–	63	–	63	–	63	–	63	–	15	–	20
community lockers (out of school hours)	–	–	–	4	–	4	–	4	–	4	–	–	–	–	
pupil toilets (incl. accessible cubicles)	–	2.7	–	varies	129	varies	129	varies	129	varies	129	varies	30	varies	30
staff toilets	–	3.5	–	varies	32	varies	32	varies	32	varies	32	varies	21	varies	21
total timetabled spaces				**42**		**43**		**44**		**45**		**13**		**17**	
total basic teaching					2956		2969		3048		3142		924		904
total halls					1024		1054		904		874		65		65
total learning resources					347		355		385		361		161		167
Total Teaching Area					**4327**		**4378**		**4337**		**4377**		**1150**		**1126**
total staff and administration					440		424		440		440		77		82
total storage					511		522		481		471		115		113
total dining and social					250		205		270		240		185		195
circulation assuming net as 70% of gross					**1520**		**1520**		**1520**		**1520**		**420**		**420**
plant not including server					**152**		**152**		**152**		**152**		**45**		**45**
partitions					**247**		**247**		**247**		**247**		**71**		**71**
Total Gross Area					**7881**		**7890**		**7881**		**7881**		**2179**		**2178**

(net 70.1% of gross)

Appendix H: Performance Objectives in Seismic Design

The qualitative performance objectives are further developed to quantitative performance objectives in terms of member strength capacity, member local deformation (plastic hinge rotation, brace axial shortening and elongation, panel member shear distortion angle, etc.) and global structural deformation acceptance limits, some examples of these from ASCE 41-06 are given in Table 18 and Table 19.

The performance of structures is verified explicitly and directly for each level of earthquake excitation, without the use of either the response modification factor (R) or the importance factor (I). In addition, other subjective factors, such as the system overstrength factor (Ω0), the redundancy factor ρ and displacement amplification factor (Cd), are also not used. Since the most likely response of the structure is analysed, the seismic force and deformation demands can be compared directly with the acceptance limits. As a result, the performance based seismic design methodology brings with it clarity of performance both qualitatively and quantitatively.

Table 18 and Table 19 show some qualitative and quantitative global performance objectives suggested by ASCE 41-06 for an earthquake hazard level corresponding to a 475 year return period.

Table 18 Damage control and building performance levels. From ASCE 41-06 Table C1-2

	Target Building Performance Levels			
	Collapse Prevention Level	**Life Safety Level**	**Immediate Occupancy Level**	**Operational Level**
Overall Damage	**Severe**	**Moderate**	**Light**	**Very Light**
General	Little residual stiffness and strength, but load-bearing columns and walls function. Large permanent drifts. Some exits blocked. Infills and unbraced parapets failed or at incipient failure. Building is near collapse.	Some residual strength and stiffness left in all stories. Gravity load-bearing elements function. No out-of-plane failure of walls or tipping of parapets. Some permanent drift. Damage to partitions. Building may be	No permanent drift. Structure substantially retains original strength and stiffness. Minor cracking of facades, partitions, and ceilings as well as structural elements. Elevators can be restarted. Fire protection operable.	No permanent drift. Structure substantially retains original strength and stiffness. Minor cracking of facades, partitions, and ceilings as well as structural elements. All systems important to normal

Table 18 Damage control and building performance levels. From ASCE 41-06 Table C1-2				
	Target Building Performance Levels			
	Collapse Prevention Level	Life Safety Level	Immediate Occupancy Level	Operational Level
		beyond economical repair.		operation are functional.
Non-structural components	Extensive damage.	Falling hazards mitigated but many architectural, mechanical, and electrical systems are damaged.	Equipment and contents are generally secure but may not operate due to mechanical failure or lack of utilities.	Negligible damage occurs. Power and other utilities are available, possibly from standby sources.

Table 19 Structural performance levels and damage for main structural systems. From ASCE 41-06 Table C1-3				
Elements	Type	Structural Performance Levels		
		Collapse Prevention	Life Safety	Immediate Occupancy
Steel Moment Frames	Primary	Extensive distortion of beams and columns panels. Many fractures at moment connections, but shear connections remain intact.	Hinges from local buckling of some beam elements. Severe joint distortion; isolated moment connection fractures, but shear connections remain intact. A few elements may experience partial fracture.	Minor local yielding at a few places. No fractures. Minor buckling or observable permanent distortion of members.

Table 19 Structural performance levels and damage for main structural systems. From ASCE 41-06 Table C1-3

Elements	Type	Structural Performance Levels		
		Collapse Prevention	Life Safety	Immediate Occupancy
	Secondary	Same as primary.	Extensive distortion of beams and column panels. Many fractures at moment connections, but shear connections remain intact.	Same as primary.
	Drift	5% transient or permanent.	2.5% transient; 1% permanent.	0.7% transient; negligible permanent.

Appendix I: The Modified Rational Method[4 5 6]

The Modified Rational Method was presented by HR Wallingford in 1981 as a simplistic technique for those designing or analyzing small sewer systems or for planning urban drainage schemes. Once the layout and preliminary sizing of a system has been determined by the Modified Rational Method, the design can be refined by dynamic routing of the flow hydrographs through the system.

The idea behind the Modified Rational Method is that for a spatially and temporally uniform rainfall intensity "i" which continues indefinitely, the runoff at the outlet of a catchment will increase until the time of concentration t_c, when the whole catchment is contributing flows to the outlet. The peak runoff is given by the following expression:

$$\boldsymbol{Q_p = 2.78\, C\, i\, A}$$

where: Q_p = design event peak rate of runoff (l/s)

C = runoff coefficient (dimensionless)

i = rainfall intensity for the design return period (in mm/hr)

A = total catchment area being drained (in hectares (ha))

Note: 2.78 is a conversion factor to address the rainfall unit being in mm/hr.

Due to the assumptions of homogeneity of rainfall and equilibrium conditions at the time of peak flow, the Rational Method should not be used on areas larger than 1.5 km^2

without subdividing the overall catchment into smaller catchments and including the effect of

Runoff coefficient

C is the least precisely known variable in the Modified Rational Method. Proper selection of the runoff coefficient requires judgement and experience on the part of the designer. The value of C depends on the impermeability, slope and retention

4 The Modified Rational Method (HR Wallingford, 1981),
5 Stormwater Drainage Manual (Drainage Services Department of Hong Kong, 2018)
6 The SuDS Manual (Ciria, 2015)

characteristics of the ground surface. It also depends on the characteristics and conditions of the soil, vegetation cover, the duration and intensity of rainfall, and the antecedent moisture conditions, etc.

The coefficient C may be regarded as a combination of two separate coefficients:

$C = C_V C_R$, where:

C_V = volumetric runoff coefficient

C_R = dimensionless routing coefficient

Value of C_V

The volumetric runoff coefficient **C_V** may be defined as the proportion of the rainfall on the catchment which appears as surface runoff in the storm drainage system.

For impervious areas (paved and roof) and for developed urban areas a value of **C_V = 1.0** is commonly used.

In less developed areas, the following **C_V** values may be used but it should be checked that the pertinent catchment area will not be changed to a developed area in the foreseeable future. Particular care should be taken when choosing a C_V value for unpaved surface as the uncertainties and variability of surface characteristics associated with this type of ground are known to be large. It is important for designer to investigate and ascertain the ground conditions before adopting an appropriate runoff coefficient. Designers may consider it appropriate to adopt a more conservative approach in estimation of C_V values for smaller catchments where any consequent increase in cost may not be significant. However, for larger catchments, the designers should exercise due care in the selection of appropriate C_V values in order to ensure that the design would be fully cost-effective.

Surface Characteristics	Runoff coefficient, CV*
Asphalt	0.7 -0.95
Concrete	0.8 – 0.95
Brick	0.7 – 0.85
Grassland (heavy soil **) Flat Steep	 0.13 – 0.25 0.25 – 0.35
Grassland (sandy soil **) Flat	 0.05 – 0.15

Steep	0.15.0.20

* For steep natural slopes or areas where a shallow soil surface is underlain by an impervious rock layer, a higher C value of 0.4 - 0.9 may be applicable.

** Heavy soil refers to fine grain soil composed largely of silt and clay

Value of C_R

Examination of typical time-area diagrams, rainfall profiles and rainfall-runoff data led to the recommendation of a constant value of $\mathbf{C_R = 1.3}$ for both design and simulation. However, the routing coefficient (which addresses the fact that some parts of the site will generate flows to a downstream point faster than others) tends to be ignored.

Rainfall intensity (i)

i is the average rainfall intensity selected on the basis of the design rainfall duration and return period. The design rainfall duration is taken as the time of concentration, t_c. The time of concentration gives the maximum flow rate at a point in the network in order to size the conveyance component. The rational method assumes that the whole catchment contributes runoff to a point in the system that has the longest time of concentration of any drainage branch. The rainfall intensity for this duration is used to calculate the flow.

Time of concentration t_c

The time of concentration is the time for a drop of water to flow from the remotest point in the catchment to its outlet. The time of concentration is defined by:

$$\mathbf{t_c = t_e + t_f}$$

where $\mathbf{t_e}$ is the time of entry and $\mathbf{t_f}$ is the time of flow through the pipe system to the point under consideration.

Time of entry (t_e)

The time of entry is the time taken for flow from the remotest point to reach the most upstream point of the drainage system. Below are the recommended values for the time of entry:

Return period	Time of entry (minutes)
5 years	3 - 6
2 years	4 - 7
1 year	4 - 8
1 month	5 - 10

Time of flow (t_f)

Time of flow is the time taken to flow through the pipe system to the point under consideration. The time of flow may be determined from the pipe full velocity.

Appendix J: Drinking water quality parameters

Urban drinking water

Table 20 Parameters (Urban)

Sl.No	Parameter	Unit	Maximum permissible Limit
1	Colour (TCU)	Hazens Unit	15
2	Odour	-	non-objectionable
3	pH	-	Acceptable range 6.5 – 8.5
4	Taste	-	non-objectionable
5	Turbidity	NTU	5

Table 21 General Chemical Parameters causing undesirable effect (Urban)

Sl.No	Parameter	Unit	Limit
1	Calcium	mg/L	No permissible limit but recommended < 75
2	Free Residual Chlorine*	mg/L	Target range 0.2 – 0.5
3	Iron	mg/L	No permissible limit but recommended < 0.3
4	Manganese	mg/L	0.4* Maximum permissible limit
5	Sulphate	mg/L	No permissible limit but recommended < 250

* *Chlorine residual must be maintained throughout the distribution system*

Table 22 Chemical Parameters of health concern (Urban)

Sl.No	Parameter	Unit	Maximum permissible Limit
1	Fluoride (to be tested for ground and spring water only)	mg/L	1.5
2	Nitrates	mg/L	50
3	Arsenic	mg/L	0.01
4	Lead	mg/L	0.01
5	Mercury	mg/L	0.006

Table 23 Microbiological Parameters (Urban)

Sl.No	Parameter	Unit	Maximum permissible Limit
1	*E.Coli*	CFU/100ml sample	0

Rural drinking water

Table 24 Physical Parameters (Rural)

Sl.No	Parameter	Unit	Target limits
1	Conductivity	µS/cm	1000
2	Odour	-	Un-objectionable
3	Appearance		Un-objectionable
4	pH	-	6.5 – 8.5
5	Taste	-	Un-objectionable
6	Turbidity	NTU	5

Table 25 - Microbiological Parameters (Rural)

Sl.No	Parameter	Unit	Risk Assessment	
1	*E.Coli*	CFU/ml	0	Safe Water
			1 - 10	Low Health Risk
			11 - 50	Intermediate to High Health Risk
			>50	Grossly Polluted