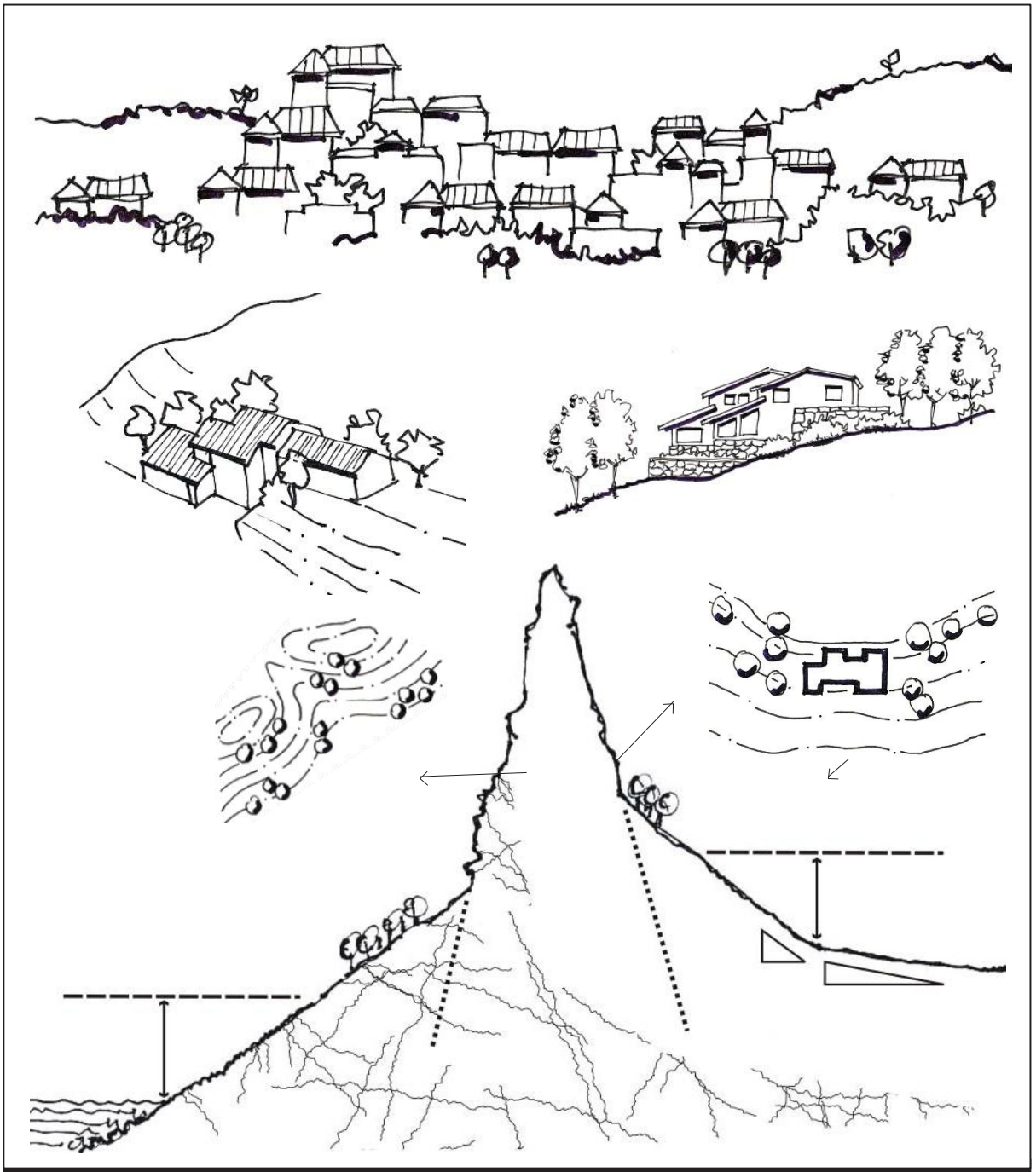
Mauritius

Planning Policy Guidance 9



Development on Sloping Sites and Landslide Hazard Areas

28 March 2016

Ministry of Housing and Lands

Planning Policy Guidance

Development on Sloping Sites and Landslide Hazard Areas

The Design Sheet on Design for Sloping Sites in PPG 1 has been re-worked as **PPG 9: Development on Sloping Sites and Landslide Hazard Areas** with materials and mapping input from the Japanese International Cooperation Agency (JICA) Expert Team and the Disaster Risk Reduction Strategic Framework and Action Plan (August 2012).

This document is issued as:

PPG 9: Development on Sloping Sites and Landslide Hazard Areas

Application of the Guidance:

This Planning Policy Guidance (PPG) is prepared to control and guide development over sloping sites with a view to protecting life and property. It should be used as a precautionary approach in determining development applications for such sites.

It further intends to guide and assist developers, relevant stakeholders and the general public in designing and scoping their projects. Applicant should ensure that they have followed the design process and standards spelt out in other PPGs and they should strive to comply as far as possible with the design principles enunciated in this document.

A Planning Policy Guidance is prepared and issued to Local Authorities under Section 13 of the Planning and Development Act (PDA) 2004 which stipulates that "*Every local authority to which planning policy guidance is issued shall comply with such guidance*" and "*A planning policy guidance shall prevail, to the extent of any inconsistency, over a development plan whether the development plan was made before or after the planning policy guidance.*"

Effective Date: Monday 28th March 2016

For additional information, queries may be addressed to:-

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1.0 INTRODUCTION

Steep slope areas on mountain flanks have an aesthetic and scenic quality which provides opportunities for residential development, but they also present special challenges in designing development that is safe, economical, and maintains the natural character of mountain slopes. Steep slopes pose problems as they are vulnerable to natural disasters and human induced triggers, are expensive to develop and require regular monitoring.

Pressure to develop mountain slopes in Mauritius has recently intensified. The pressure is particularly intense on those slopes that offer a view out to sea as well as for special projects developed under specific schemes. Mountain slopes are also subject to illegal occupation by vulnerable landless groups seeking an adequate shelter.

Consequently, this design guidance aims at assisting planners, developers and local councils in submitting and processing of development applications on sloped terrain. Subdivision and site design on sloping sites is expected to respond to the unique characteristics of each site, avoiding significant disruption of the natural terrain as much as possible. The main elements to be considered in the assessment of any sloping site are:

(a) topographical analysis of slopes over 10%.

(b) Slope stability (geologic constraints including landslides and active fault lines).

(c) Drainage courses, riparian corridors and erosion.

(d) Site layout, orientation, prevailing wind patterns and grading.

(e) Infrastructure, sewage disposal systems and access.

(f) Vegetation such as individual trees, grouping of trees and shrubs, habitat types and fire hazards.

(g) Development capacity/density and other design guidelines.

(h) Aesthetics (viewpoints, ridgelines, visibility from off-site).

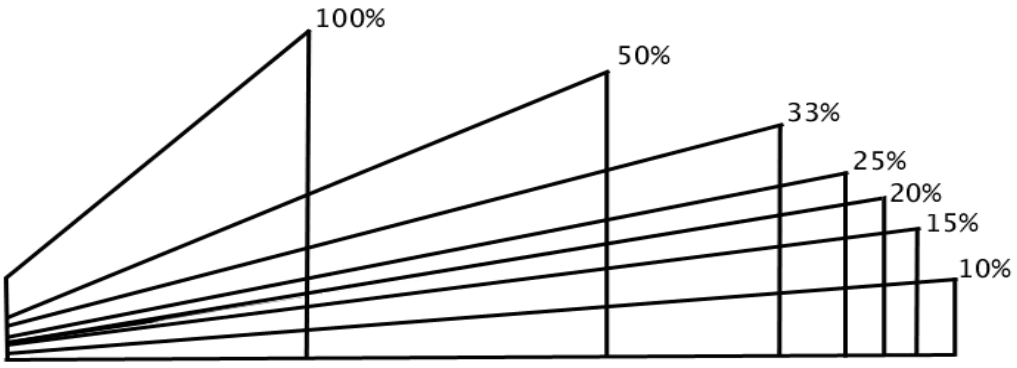
2.0 DEFINITION OF STEEP SLOPES

Thirty-eight (38%) percent of the land area in Mauritius is considered as environmentally sensitive with nearly four-fifths of this area being attributable to moderate and steep slopes. The Environmentally Sensitive Areas mapping has categorised all sloping land as:

Steep slopes: **Gradient above 20 % in Category 1 of ESA classification** requiring protection through strict control on land use.

Moderate slopes: **Gradient 10 – 20% in Category 2 of ESA classification** where some degree of alteration permitted with sites maintained in a healthy state.

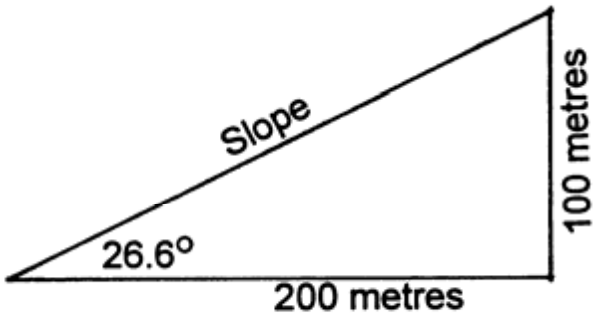
Steep slopes are defined as lands in their **natural state that have a slope angle of 20% or greater for a minimum horizontal distance of 10 metres.**



3.0 CALCULATION OF STEEP SLOPES

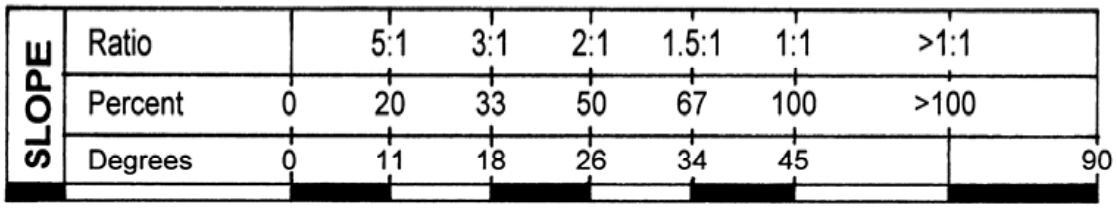
The steepness of slopes can be described in **degrees**, a **ratio**, or as a **percentage**. The accompanying figures describe the measurement of a slope and provide a means of quickly estimating equivalencies between the three scales.

A 100 metre in elevation change over a horizontal distance of 200 metres can be expressed as:

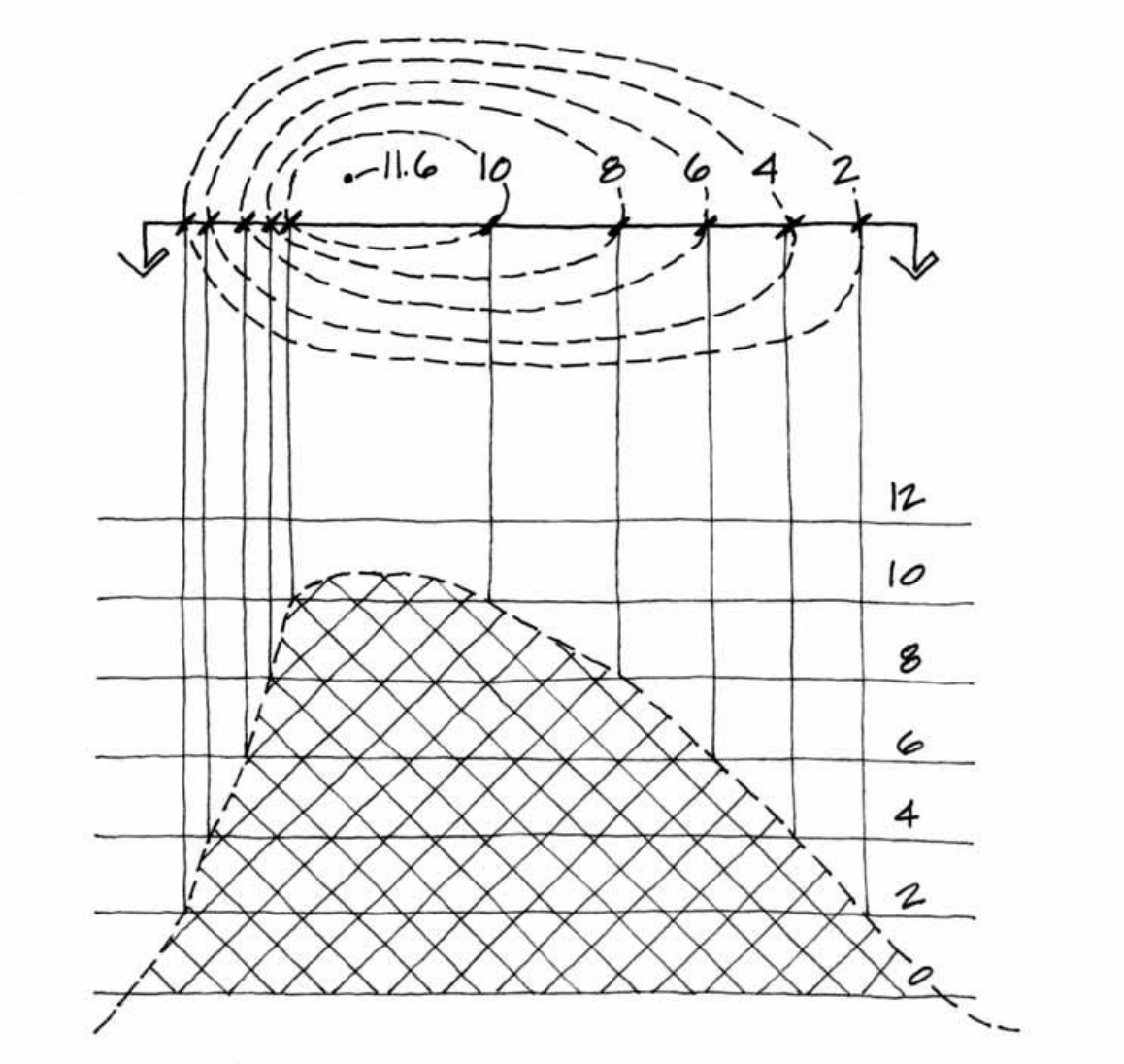


100m in elevation change over a horizontal distance of 200m can be expressed as:

RATIO horiz.:vert. = 200:100 = 2:1
PERCENT vert./horz. = 100/200 = 50%
DEGREES 26.6° (n.b., tan 26.6° = 0.5)



4.0 REPRESENTATION OF SLOPES ON MAPS



Contour lines represent each step in elevation of the ground at a specific contour interval (e.g. each one, two or five metres increase in elevation might be marked). Steep slopes result in close contour lines while widely spaced contour lines result from the plotting of gentle grade changes.

5.0 Stability of Slopes

The steepness of slopes does not necessarily correlate with the stability of slopes. Stability also depends on factors such as geologic materials, soils, moisture content and vegetation cover.

Mountain slopes are stable most of the time, but some inherent conditions of a slope such as steepness, rock type and structure, can make a slope susceptible to failure. Slopes can be gradually weakened by a range of processes such as deforestation, weathering, erosion, undercutting and uncontrolled water discharges.

The most common landslide trigger is prolonged or intense rainfall. Slope modification can also be a common trigger of landslides. The removal of vegetation, often the first step in land development, can reduce the stability of sloping ground. Land originally stable under heavy vegetation cover commonly goes through a phase of land sliding when that cover is removed.

On slopes with adequate soil cover, shrubs and trees are usually advantageous, as they add root strength, reduce concentrated overland water flow, and can alter the rate of water infiltration into the ground.

Modification of the landscape by cut and fill earthworks (grading) can have a profound effect on slope stability. Detrimental human activity includes the formation of unsupported cuts, slope loading (surcharge) by filling. Excavating for house basements, building platforms and access roads creates potentially unstable slopes which may need to be supported to prevent landslides.

Slides tend to occur mostly on slopes between 30-60%.

This Design Guidance should be applied to proposals for development on the slopes of the Mountain Ranges as listed in the First Schedule of the Forest and Reserves Act 1983 or as subsequently amended and as defined in the Environmentally sensitive maps and any other locations where steep (>10%) slopes exist.

- As a general guide development should not be any higher than 45 metres above the mountain base, or in the case of slopes facing the sea, 45 metres above Mean Sea Level.
-
  Development is not allowed on slopes greater than 20%

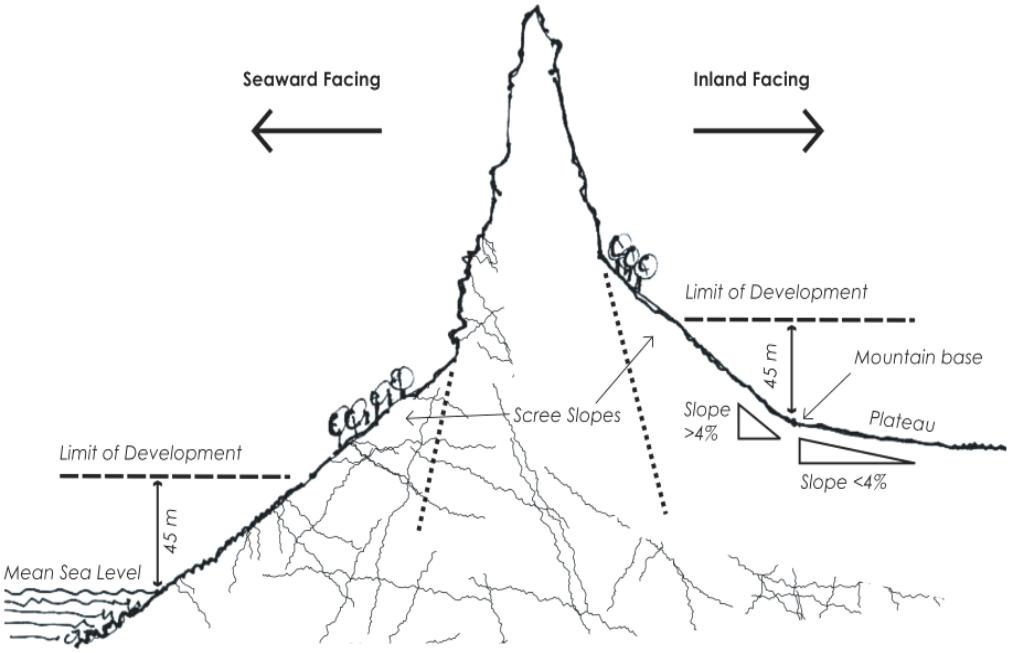
- Development is not allowed in landslide hazard zones (yellow zone) – (Section 8).

- Development is not allowed in special hazard zones (red zone) – (Section 8).

TABLE 1: General guide on Degree of slope / Development Potential

0% to 3%	**Generally suitable for all development and uses.**
3% to 8%	**Suitable for medium density residential development, agriculture, industrial and institutional uses.**
8% to 20%	**Suitable for moderate to low-density residential development, but great care should be exercised in the location of any commercial, industrial or institutional uses.**
Over 20%	**Only used for open space, limited agricultural and certain recreational uses.**

Source: Adapted from Soil Surveys of Lehigh/Northampton Counties, Pennsylvania,



Height limitation of development on mountain slopes

Development on slopes may be allowed on

- Slopes below 20% where the integrity of existing slopes is retained on submission of information as per check list at ***Annex 1***;

- Development on slopes of average gradient of more than 20% with pockets below 20% exceptionally where the steep sections are limited to horizontal run of less than 10 metres and provided that there is a slope stability analysis by a qualified geotechnical engineer, creative design solution, risks to public safety mitigated and supported by the submission of information as per check list at ***Annex 1***.

6.0 SUBDIVISION ON SLOPING SITES

Subdivision and site design on slopes is expected to respond to the unique characteristics of each site, avoiding significant disruption of the natural terrain as much as possible. For planning new subdivisions on sloping sites, the following principles should be considered in addition to the other underlying principles guiding development on slopes:

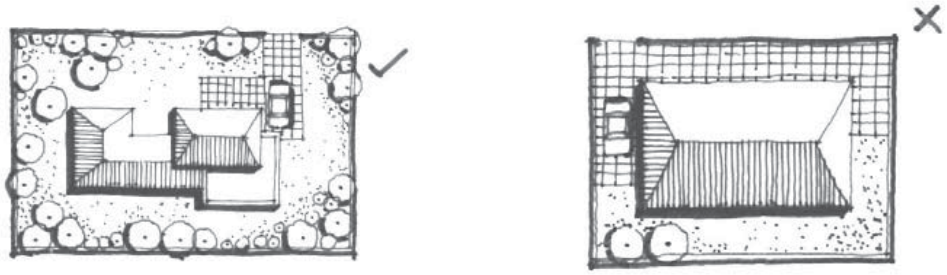
- When calculating lot area for subdivisions, steeper portions of site with slope of 20% or greater should be excluded.

- Each single parcel created by subdivision must have a plot size of not less than 1000m^2 excluding steeper portions exceeding 20% and must show the proposed building footprint.

- Each subdivided plot of land must neither be densified by extending the building footprint nor subdivided to create sub-plots.

- Building setbacks should be used in a flexible manner to protect slopes and natural features from development encroachments. Proposed setbacks, driveways and building pads should be shown on grading and subdivision development plans.

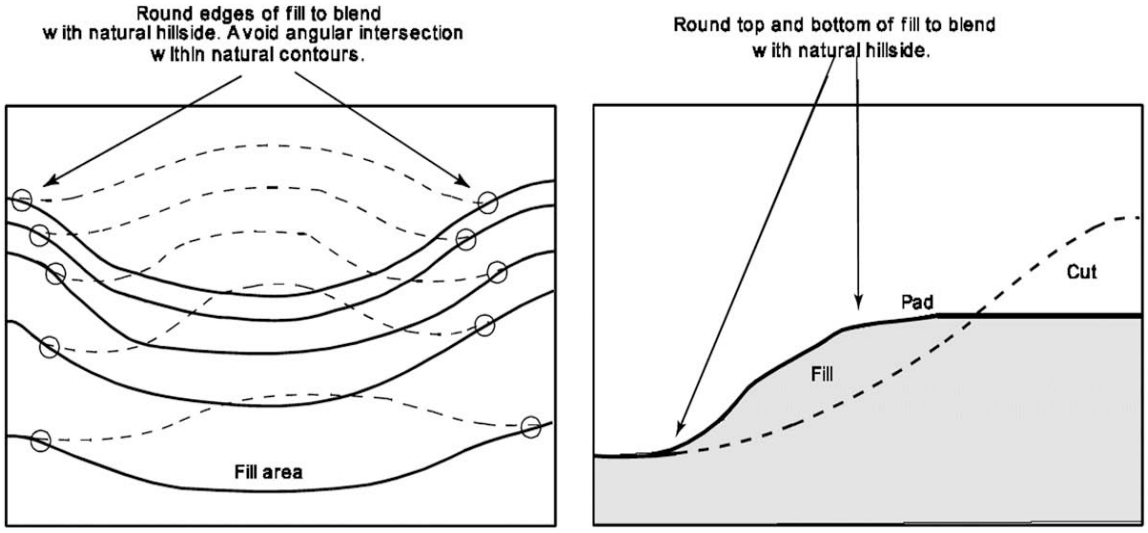
- The maximum plot coverage for a subdivided lot (building footprint) should not exceed 12% with a maximum single volume restricted to 150cu.m.



7.0 DESIGN STANDARDS FOR SLOPING SITES

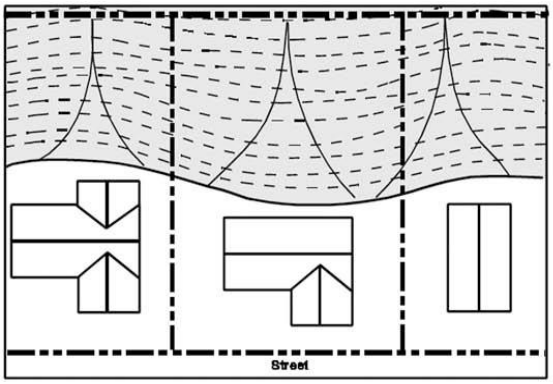
7.1 Standard 1: Development on steep mountain slopes shall respect existing natural landforms.

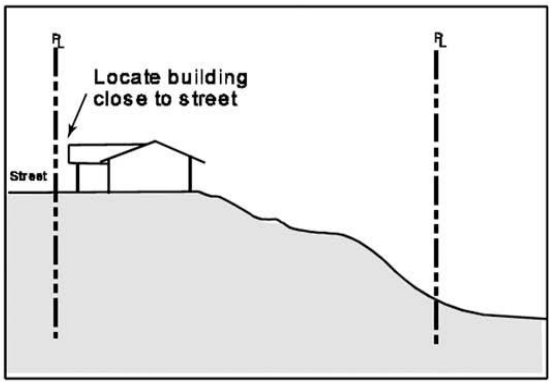
Newly created engineered slopes should be landform graded with undulating slopes, irregular/varying gradients, and with the top (crest) and bottom (toe) of new engineered slopes rounded to resemble natural landforms.

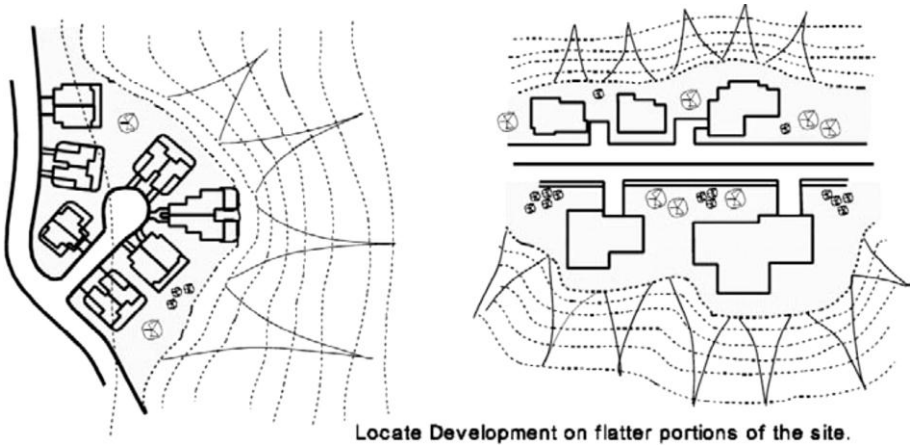


7.2 Standard 2: Site development shall be designed and sited to minimize impacts to the steep mountain areas.

- Development should be concentrated in the least steep areas of the site in order to preserve as much of the natural terrain as possible.
- Development could be located close to the street if required by topographical characteristics in order to preserve as much of the natural terrain as possible.
- When designing a structure on a lot, the siting, orientation and steep hillside disturbance should blend with the surrounding developed properties.





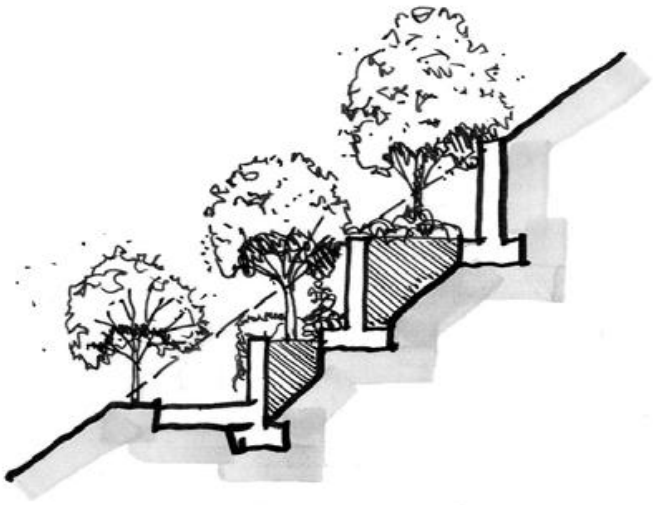


Locate Development on flatter portions of the site.

7.3 Standard 3: Construction of retaining wall

Retaining walls could be used to reduce the total extent of **grading** in the steep hillside areas, subject to the following:

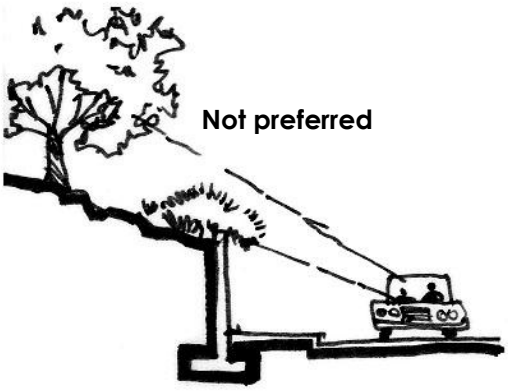
- The maximum height for a single retaining wall, measured from grade to grade, shall be 3 metres.
- When the overall retained height would exceed 3 metres, the retaining wall shall be broken into multiple stepped walls, with no individual wall height exceeding 1.8 metres.

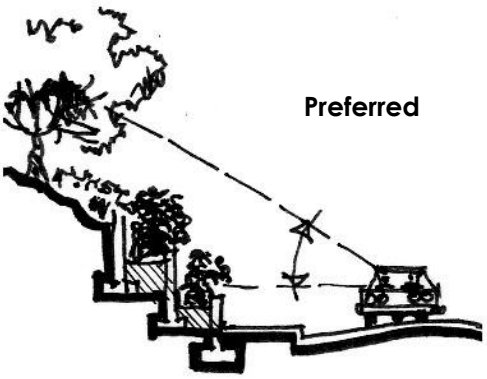


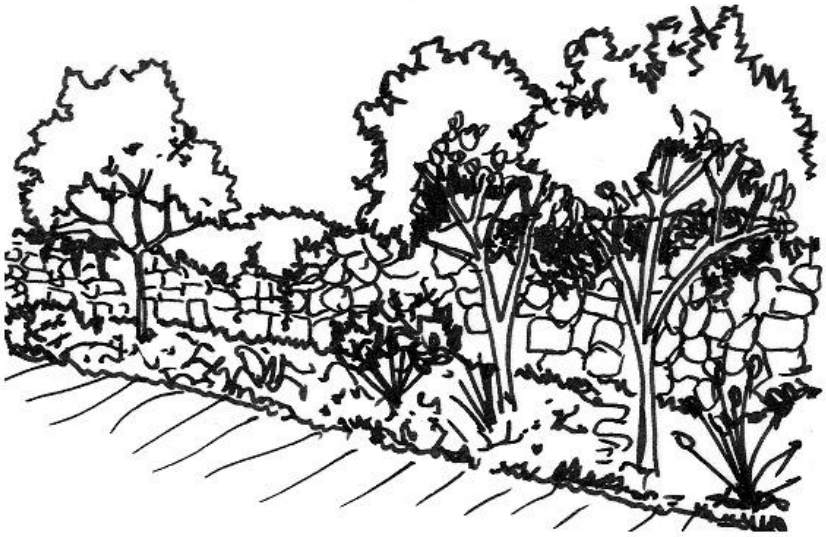
- A minimum horizontal distance as determined by the Client's Engineer shall be maintained between each individual wall in the stepped wall system, and shall be landscaped.

- Retaining walls should be parallel to the existing slope to reduce the visual impact of retention systems

- Landscaping should be provided adjacent to retaining walls, particularly along public roads. The setback for retaining walls along roads should reflect the wall height as taller plants will require a larger growing area below the wall.





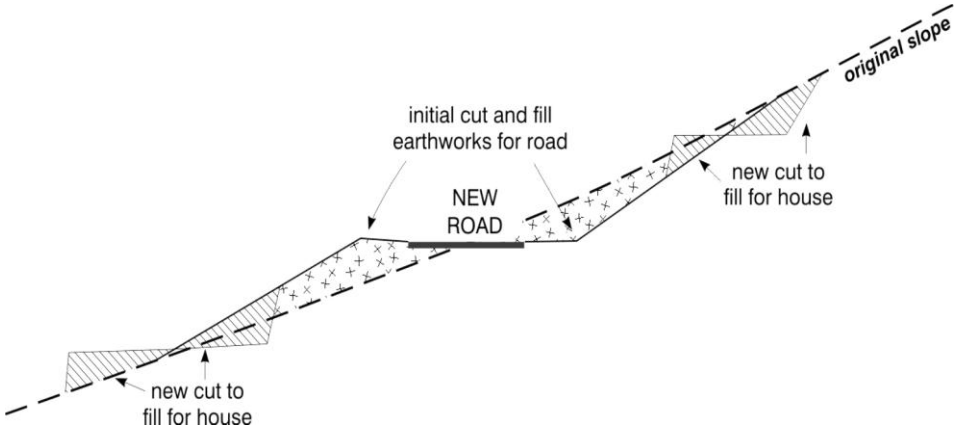


Landscaping in front of retaining wall

7.4 Standard 4: Grading and Earth works

- Adding material to the toe of a slope (buttressing), and/or removing material from the head of a slope, will usually increase slope stability by reducing shear stresses and thereby diminishing the likelihood of landslides.

- The addition of material near the head of a slope may lead to instability of the slope as a whole, as well as of the fill itself. This action, or surcharging, has an effect similar to removing material from the toe of the slope.



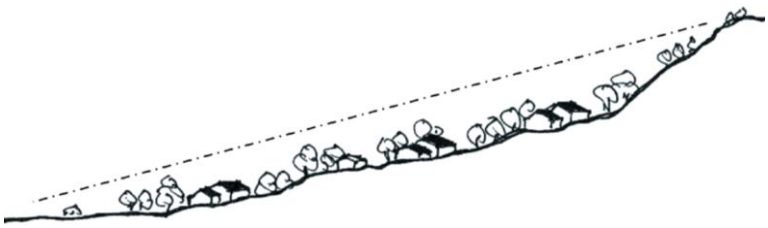
- Excavating house basements, building platforms and access roads creates potentially unstable slopes which may need to be supported to prevent landslides.

- Stability is often compromised by cut and/or fills for roads and access-ways which straddle across the slope. Good engineering practice and design, such as draining fills and building retaining structures for cuts, reduces landslide potential. Retaining walls require appropriate engineering design based upon realistic evaluation of the amount and weight of the soil to be retained, the capacity of the ground to support the foundations of the wall.

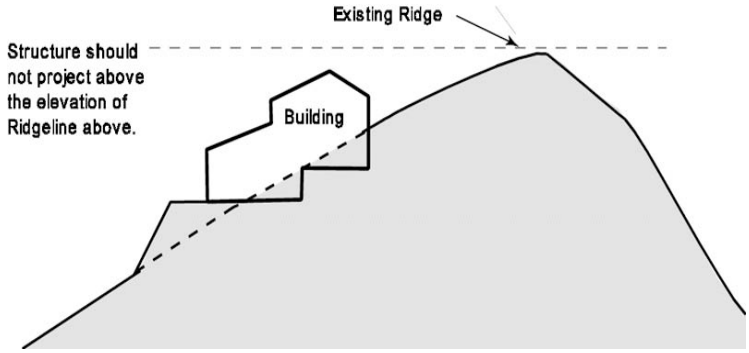
7.5 Standard 5: Site Location and Visual Impact

- Building profiles should not visually break the ridge line of the slope, especially when seen from important vantage points and buildings should not be built on the crest of slopes. The mountain side should act as a backdrop to the buildings.

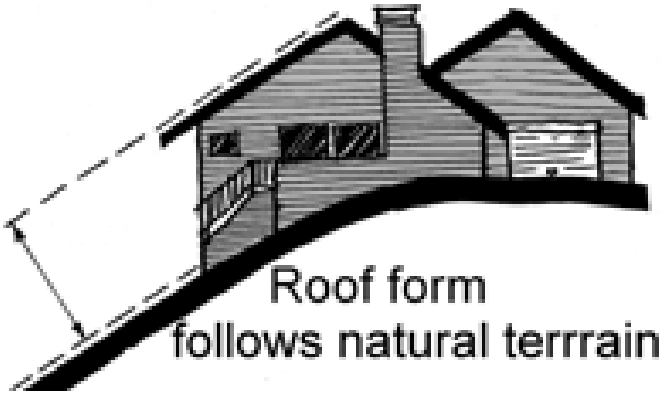
Development should not project above significant ridgelines



- Buildings and structures should be set back far enough from ridges and cliff edges so that the structure does not appear to be perched on the edge.

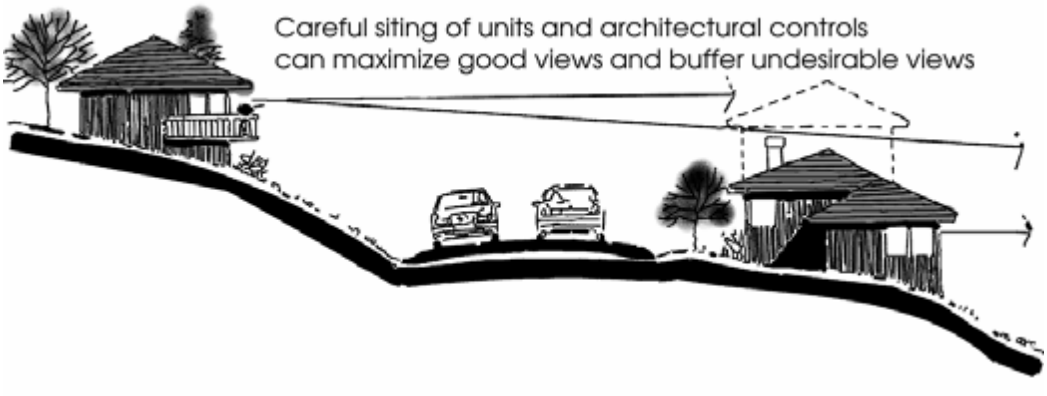


- The mountain or slope should act as the backdrop to the building. This is far more preferable to having the building project into a blue sky background. If the building or structure does break the plane of the natural backdrop, it should be designed to mimic the natural lines of the mountains and hillsides.



- Roof pitches can be designed to reflect the slope of the natural terrain and aligned so that the angle of the roof is approximately the same or less than the natural slope.

- Care should be taken to protect the view of dwellings both above and below any new development, and unit spacing should be such that views of the natural landscape are retained.

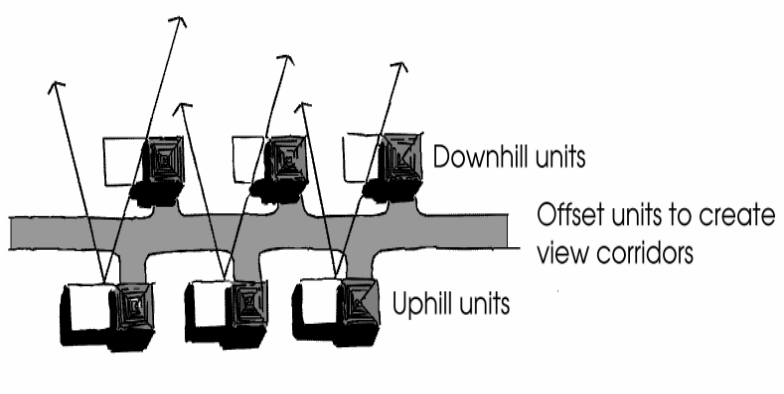


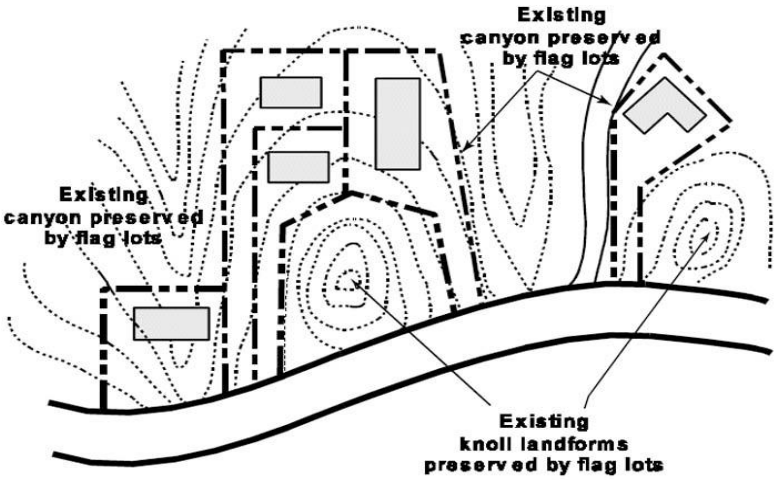
- Buildings should be placed far enough apart to reveal views of the mountain and the natural landscaped backdrop from other buildings and down slope. Buildings should be located to minimize interference with the views of nearby residences. Staggering buildings where appropriate will provide views between units that may otherwise limit the field of view.

- Buildings should be planned to enhance a site's natural features. The form, mass, profile and architectural features should be designed to blend with the natural terrain and preserve the undulating profile of the slopes. Multi storeyed buildings on or close to ridge lines should be avoided and on all sites lower profile buildings should be encouraged.

- In areas of varying topography, buildings higher than their surroundings are particularly prominent and due consideration must be given to distant views and important skylines. The same dwelling sited at different heights and locations can have very different impacts on the hillside and skyline.

- Permit applications for development on slopes must include sufficient information for judgements to be made regarding the acceptability of the development; for instance photo montages, elevations over a wide area showing the setting of the building as well as sections and contours.





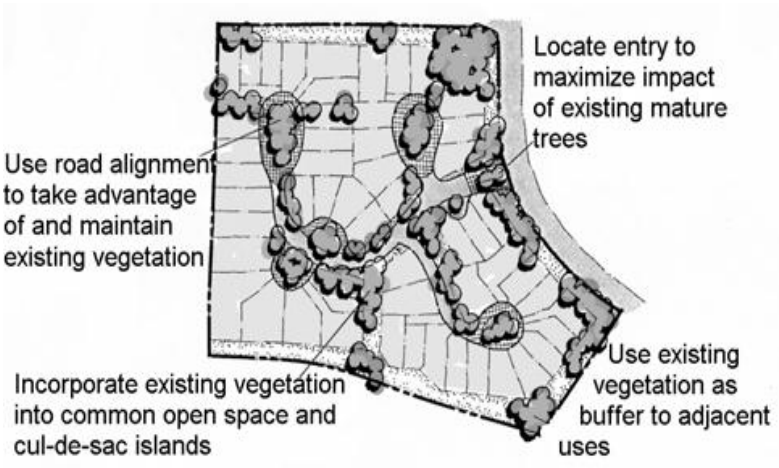
- Careful consideration should be given to the potential cumulative impacts of development within the hillside setting and upon existing ridgelines. Sufficient space should be retained between buildings to reveal appropriate views of ridges and the natural landscaped backdrop.

7.6 Standard 6: Retention of vegetation

Existing vegetation on hillsides is important to the ecological and aesthetic value of a site. In addition, vegetation serves an essential function in maintaining slope stability, drainage and erosion control.

The following guidelines provide guidance on landscape design including the selective removal and retention of vegetation within steep slope environments.

- Maintaining existing tree stands on sloped areas to be encouraged.
- Coordinating the selective removal of trees from individual building sites with site planning and architectural designs to retain the maximum amount of vegetation.
- Street planting in the front yard setback may be used to soften the view of buildings except where trees may inhibit significant views from the site, or where trees may preclude the construction of a sidewalk, pathway or impact public safety.
- Existing vegetation lines that reinforce the existing slope of the land should be maintained.
- Disturbed areas should be restored to their natural condition as soon as possible to minimize environmental impacts, with all effort undertaken to ensure that those areas to remain in their natural condition are conserved during construction.



- Existing and new vegetation should be placed to soften the mass of building as viewed from off site.

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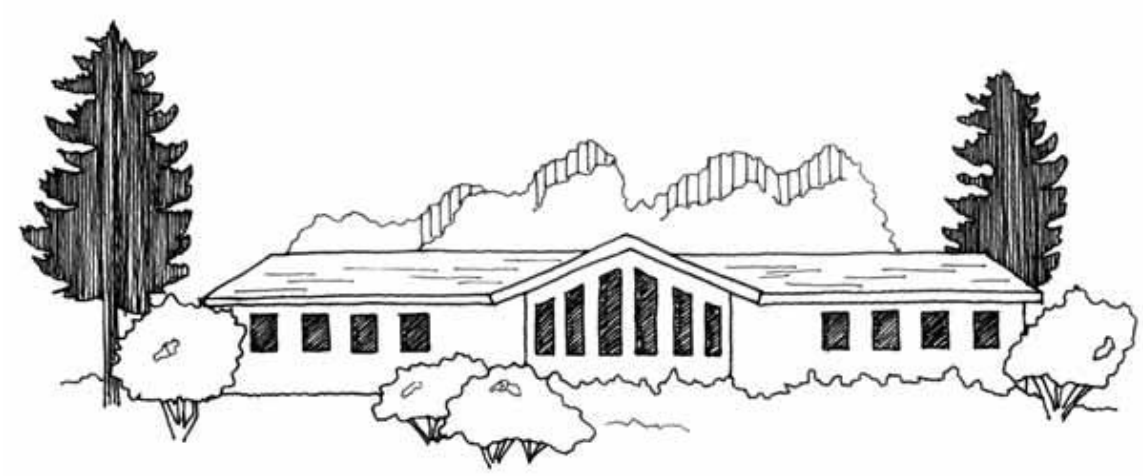


- Buildings sited to maximize views at the expense of natural vegetation should be resisted and buildings should not appear overly prominent or obtrusive.

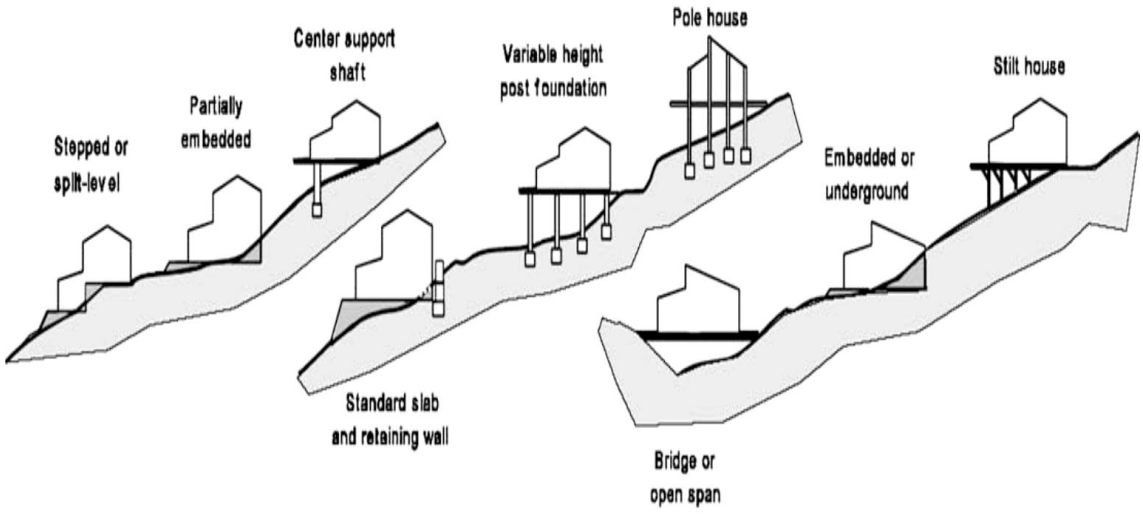
7.7 Standard 7: Architectural Form

- The form, massing and architectural features of buildings should be designed to blend with the natural terrain and preserve the undulations of the slopes. Roofs should be orientated in the direction of the slope and large gable ends should be avoided.

- Contrasting and varied horizontal and vertical building planes should be used to create various shades, and shadow patterns to reduce perceived bulk. Large expanses of wall in a single plane on downhill elevations should be avoided.

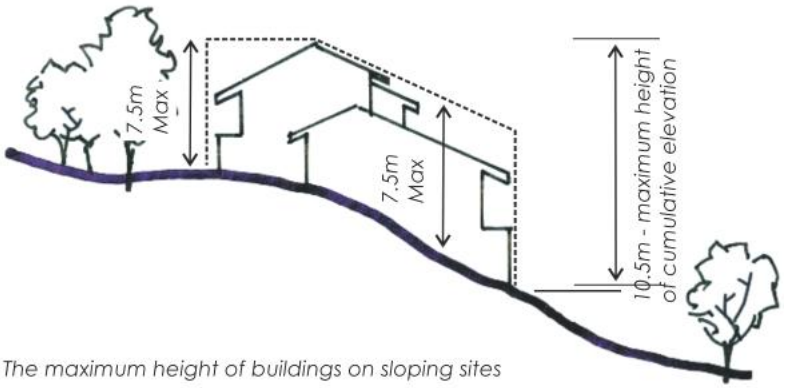
- The natural slope of the hillside should be maintained by using a stepped foundation and setting the building into the hillside to help integrate it with the natural landform. On downhill elevations, the use of single plane walls that exceed one storey should be avoided and upper storeys stepped up back from the level below.

- Structures and foundation types should be utilized that are compatible with the existing steep hillside conditions and require less grading. Split level and embedded structures should be encouraged.

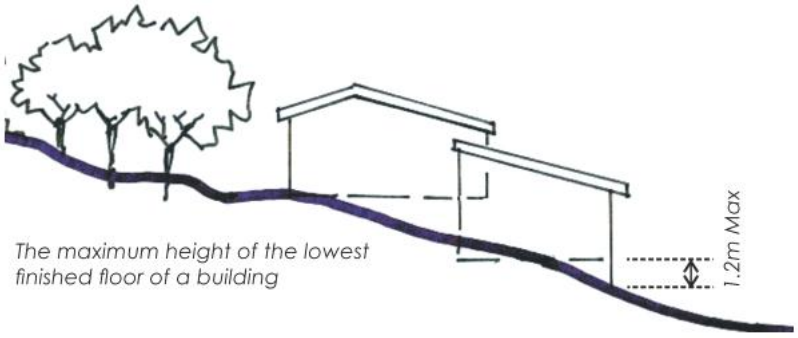


- Retaining walls may be used in basement wall applications in order to include the retaining wall as part of the structure. Stepped building design and terraced retaining walls should be constructed to facilitate slope adaptation to the site.

- The maximum height of buildings should not normally exceed 7.5m. The maximum height of a building's combined elevation should not normally exceed 10.5m measured from the lowest part of the building to the highest point.

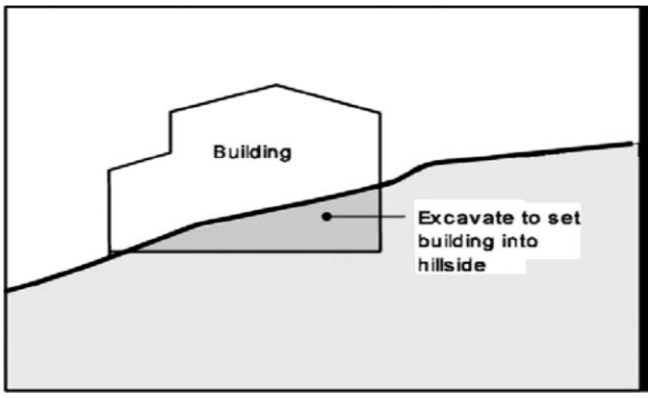


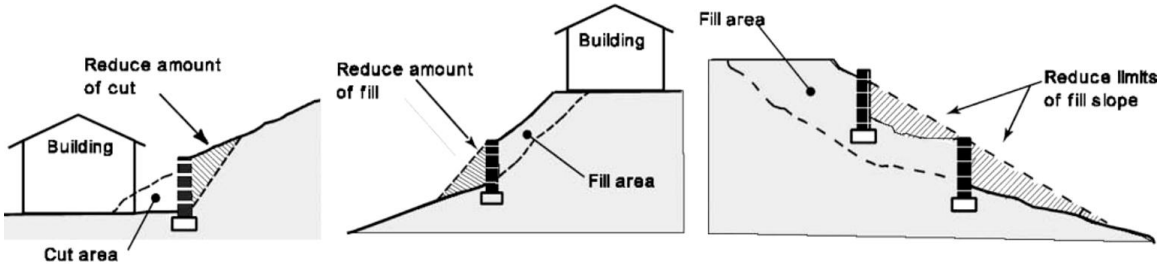
The maximum height of buildings on sloping sites



The maximum height of the lowest finished floor of a building

- The height of the lowest finished floor(s) of a structure, excluding basements, should not be more than 1.2m above existing grade to ensure buildings follow slopes.





- Retaining walls and structures should be planned in a curvilinear manner that reflects the natural contours of the landscape, and materials and finishes should harmonize both with the terrain and the buildings on the site.

- Long unbroken rooflines should be avoided. Instead, roofs should be broken into smaller components to reflect the irregular natural hillside patterns. The roof should be orientated in the same direction of the slope contour and large gable ends on downhill elevations should be avoided.

- Dark or earth tone colours should be used to make the building less conspicuous as seen from off site. White or light colours should be avoided. The colours used for buildings should harmonize with the natural colours of the hillside.

- Materials, colours and textures that reflect the natural setting and landscape of the hillside setting allow a house to blend with its surroundings. Smooth, shiny, reflective surfaces or bright colours for building walls that clash with the slope should be avoided.

Preferred

Continuous glass on less visible portion of structure

Not preferred

Continuous glass on most visible portion of structure

7.8 Standard 8: Infrastructure

Highways and utility infrastructure services should be of a high standard for developments on steeply sloping sites:

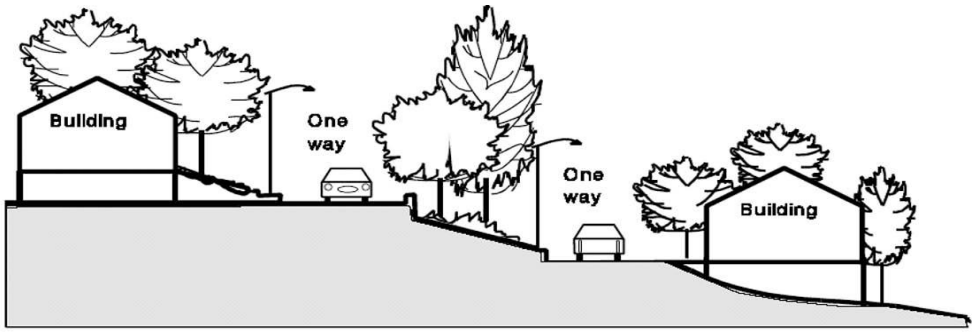
7.9 ROADS AND ACCESSES.

- Roads should be laid out to avoid steep grades and should normally not exceed 1:8 (12.5%). Conventional road layouts and standards may have to be adapted and utilization of one-way and/or split level roads to avoid excessive cuts and fills should be considered without compromising environmental, visual and public safety objectives.

- For local roads on steep slopes, grades up to 15% may be permitted for short sections (not exceeding 100 metres in length) if overall impacts are reduced and the natural character of the slope is retained. The "stopping sight distance" at intersections must not be negatively affected.

- Common driveways and vehicle access routes shared by two or more lots should be encouraged when significant site grading can be reduced. The grade of a common driveway should not exceed 14%. In general, in-and-out common driveways must be limited to servicing six lots.

- Up to 15 lots may be serviced with a one-way through-access driveway exiting onto a public road, depending on site-specific conditions.

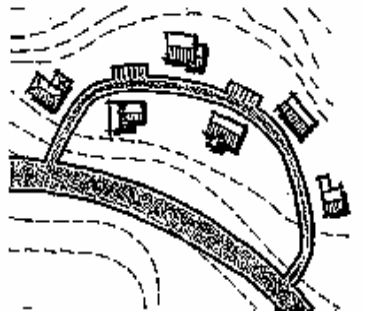


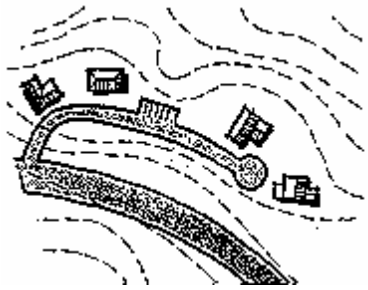
Split level roads can reduce site disturbance

- To minimize grading, roadways should be designed to complement the natural topography and conform to existing grades wherever possible.

- The development of major collector roads and the use of grid like street patterns should be minimized on steep slopes as they are not as easily adaptable to sloped terrain.

- The use of permeable materials on driveways is to be encouraged to enhance storm water drainage.





- Road design should pay necessary consideration to secure adequate and acceptable stability against external effects such as traffic load and rain and should be designed for easy /simple maintenance;

- In cut and fill slope, ground water drainage and gradient should be considered to avoid landslides, rock fall and slope disaster;

- The material strength, height, shape of an embankment to support the traffic load should be carefully considered to avoid deformation/ subsidence, by traffic load or the embankment;

- Road planning should be avoided in high risk areas such as landslides/slopes.

7.10 WATER DRAINAGE SYSTEM

- Storm water should be disposed of within the plot boundary or to a centralized storm water soakaways system and should not be allowed to flow to adjacent plots or into road reserves.

- Ground water drainage (open ditch, underground drain, or other facility) is required to drain off the surface water which can be the cause of landslides from the landslides/slopes failure risk area to another area.

- Special care is needed to control surface water drainage and engineering studies should be provided to show the effect that drainage might have on other properties. Inadequate drainage may trigger land slips.

- A subsoil drain system should be laid where necessary below slope or behind retaining wall to discharge ground water through filter layers behind the slope leading to outlets/cut off drains, weep holes and sub soil drain pipes.

7.11 WASTEWATER DISPOSAL

- On-site sewage and waste water disposal systems must take account of soil characteristics.

- The use of septic tanks may not be possible, or special designs might be required, because of the risk of effluent appearing at the surface in land/properties below the site being developed;

- Underground utility services and poles should not be placed in made-up ground and service lines should be located to minimize disturbance of vegetation and natural features.

- Water pressure from Central Water Authority facilities should be adequate to reach the upper limits of development on a high slope. A minimum residual pressure of 10 metres at property boundary is recommended. The provision of water to properties above the level of existing water storage reservoirs, or remote from the existing supply network may be difficult and/or costly to achieve. Early discussion should be held with the Central Water Authority. Services and utilities should be located to accommodate as far as possible gravity-fed infrastructure.

8.0 LANDSLIDE: ZONES AND HAZARDS

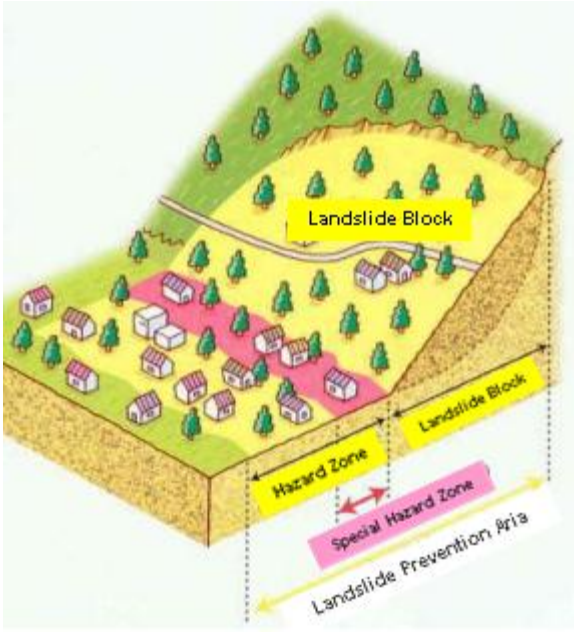
Normally no new development would be allowed in landslide zones due to likely risks of heavy damage to life and property. Identification of landslide zones requires a thorough knowledge of geomorphology, geological structure of rock type of area and their reaction to external and internal forces. A slope experiences two sets of stresses, one set holding the slope together (**shear strength**) and the other acting to move material downslope (**shear stress**). When shear stress exceeds shear strength, the slope fails and a landslide occurs. Land with steep slopes should therefore be assessed with rigor, especially for any trigger of potential damage.

Identification and designation of landslides zones by the Japan International Cooperation Agency (JICA)

Three areas identified at Chitrakoot, Quatre Soeurs and Vallée Pitot by JICA as actively experiencing landslides are shown on plans at **Annex 4, 5 and 6.** The two types of landslide zones indicated in the plans are explained hereunder.

Landslide Hazard Zone
(Yellow Zone - see diagram) is an area where inhabitants and buildings may be damaged when a landslide occurs. It is an area where landslide has been active in the past and though inactive presently, may be prone to future landslide activity in future.

Special Hazard Zone
(Red Zone – see diagram) is an area where inhabitants and buildings are expected to sustain heavy damage when a landslide occurs. It forms part of an active landslide block and an area below the bottom end (toe) of the landslide block that may be impacted by a landslide activity.



8.1 DESIGNATION OF THE TWO HAZARD ZONES:

Landslide Hazard Zone *(Yellow Zone) is designated as:*	***Landslide Special Hazard Zone*** *(Red Zone) is designated as:*
• Land potentially prone to instability/landslides. • land with recorded history of landslide activity. • an area within a distance equivalent to the length of the landslide mass from the bottom end of the landslide block (250m if the length of the landslide mass is longer than 250m)	• land potentially prone to instability/landslides. • land having geomorphologic setting similar to those having recorded history of landslide activity. • an area within 60m from the bottom end (toe) of the landslide block

*Note: **No new development** is permitted in the Landslide Hazard Zone and Landslide Special Hazard Zone.*

8.2 Identification of Landslide Hazards as per the Disaster Risk Reduction Strategic Framework and Action Plan

In addition to the work undertaken by JICA, the Ministry of Environment, SD, Disaster and Beach Management has prepared a report on the *Disaster Risk Reduction Strategic Framework and Action Plan*. The landslide hazard areas identified in the Action Plan and defined in terms of low to very high risk (4 classes) in regard to susceptibility to rock falls, landslides and rapid earth flows have been mapped showing a concentration in three main zones comprising the three main hilly and mountainous areas of the northern, eastern and south western part of the island and those areas surrounding the main hydrographic network along the river banks and vertical scarps. It is observed that there is a greater risk to landslides in the lower part of these hilly and mountainous areas whilst the risks to rapid earth flows is greater from the upper to the lower part of the main slopes of hilly and mountainous areas.

The hazard maps and landslide distribution zones are at **Annex 7**, **8, 9 and 10**. Maps at annexes 7 to 10 have been reproduced from corresponding maps at Figure 3.3.20, Figure 3.3.21, Figure 3.3.24, Figure 3.3.25 in the ***Disaster Risk Reduction Strategic Framework and Action Plan.*** These maps indicate the level of the landslide hazard as well as the main instability problems (landslide, rock falls and earth flows). ***Photo geology analysis and infield survey*** carried out in the three main landslide zones at a number of sites shown at **Annex 11** and Table at **Annex 12** indicate the type of instability present in those areas.

Development in the areas and environs of sites identified at **Annex 11** and **Annex 12** will require:

(i) further investigations of ground conditions by client's engineer in consultation with relevant authorities (Landslide Management Unit of the Ministry responsible for Public Infrastructure, the Ministry responsible for Environment, the Local Authority, the Disaster Risk Reduction and Management Centre) as to acceptability of development;

and

(ii) compliance with this planning policy guidance on the aspect of design on sloping sites provided the geotechnical report is found satisfactory by the competent authorities for undertaking the project and site is found buildable.

Planners, project promoters and land owners and relevant professionals should also consult the **Disaster Risk Reduction Strategic Framework and Action Plan Report** of the Ministry of Environment, Sustainable Development, Disaster and Beach Management for additional technical and scientific information. This Planning Policy Guidance serves as an additional statutory level of control besides the control provided as regards zoning in the relevant Outline Planning Schemes and guidelines issued under the Disaster Risk Reduction Strategic Framework and Action Plan.

8.3 Landslide Inventory and Classification by JET

Thirty two (32) sites were considered as landslide prone areas in the Ex-CONDS of 2010-2011. JET carried out a site reconnaissance on these landslide-prone sites and were re-classified (37 sites) district wise.

The results of the survey, site reconnaissance, characteristics, and evaluation of the landslides have been compiled into a landslide inventory and a landslide location map at Annex 13.

The type of disaster has been further sub-classified in to landslide, stream erosion, slope failure, damage to wall / embankment, cavern and rock fall.

ANNEXES

Annex 1

Information required for submission on development on slopes between 10-20%.

Site Constraint Analysis

- *Topographical Map (contour intervals, property lines, ridgelines, rock outcrops, cliffs and slope transition and breaklines).*
- *Geotechnical Evaluation if needed (see Annex 2).*
- *Slope analysis.*
- *Constraints analysis (geology, hydrogeology, utility services, soils, vegetation, wildlife etc.).*
- *Existing drainage course.*
- *Building locations and foundation design.*
- *Effect of surcharge due to proposed structures, retaining walls and future site grading for building platforms and accesses.*

Annex 2

Information required for Geotechnical Report on Slope Stability

A Geotechnical Report for slope stability prepared by a qualified geotechnical engineer / registered Civil Engineer is required for all sites where existing or final design grades reach a 20% gradient or where slope stability is an existing concern.

At the minimum, the required stability report should contain the following information:

- Property lines, easements and right of ways
- Stability limit, established with respect to most probable adverse ground water and loading conditions.
- Top of embankment or escarpment.
- Toe of slope.
- Soil types.
- Existing drainage course, Effect of ground water table and assessment of existing surface and subsurface conditions.
- Vegetation cover extent and types disturbed or native.
- Where the development at the toe of the slope is proposed, the report shall address the effect and extent of slope failure on the subject land and the adjacent properties and remedies to mitigate any failure.
- Erosion control and other mitigation measures e.g. drainage works, grading etc.
- Building foundations and foundation types.
- Effect of surcharges due to proposed structures, retaining walls and future site grading.

Annex 3

Information required for a Drainage Management Plan

Plans for all development on sloping sites must indicate how storm water run-off will be impacted by the development and how those impacts will be mitigated.

- Depending on the size of the development and complexity of the site conditions on steeper slopes, special attention must be paid to:
  - Hydrological conditions prior to and after development;
  - Protection of natural flow paths, volumes and storage resources;
  - Impacts on trees, vegetation and other environmental features due to changes in drainage patterns;
  - Water quality prior to, during and after development;
  - Sediment and erosion control; and
  - On and off-site drainage impacts (e.g, drainage from an upper lot to a lower lot); and
  - Measures taken to prevent other properties being adversely affected by the proposed development.

Chitrakoot

Annex 4

There was no movement on the borehole inclinometer BH–C5, however, due to the slopes are slightly steep around this area and building damages occurred in the past, it was designated as Yellow zone.

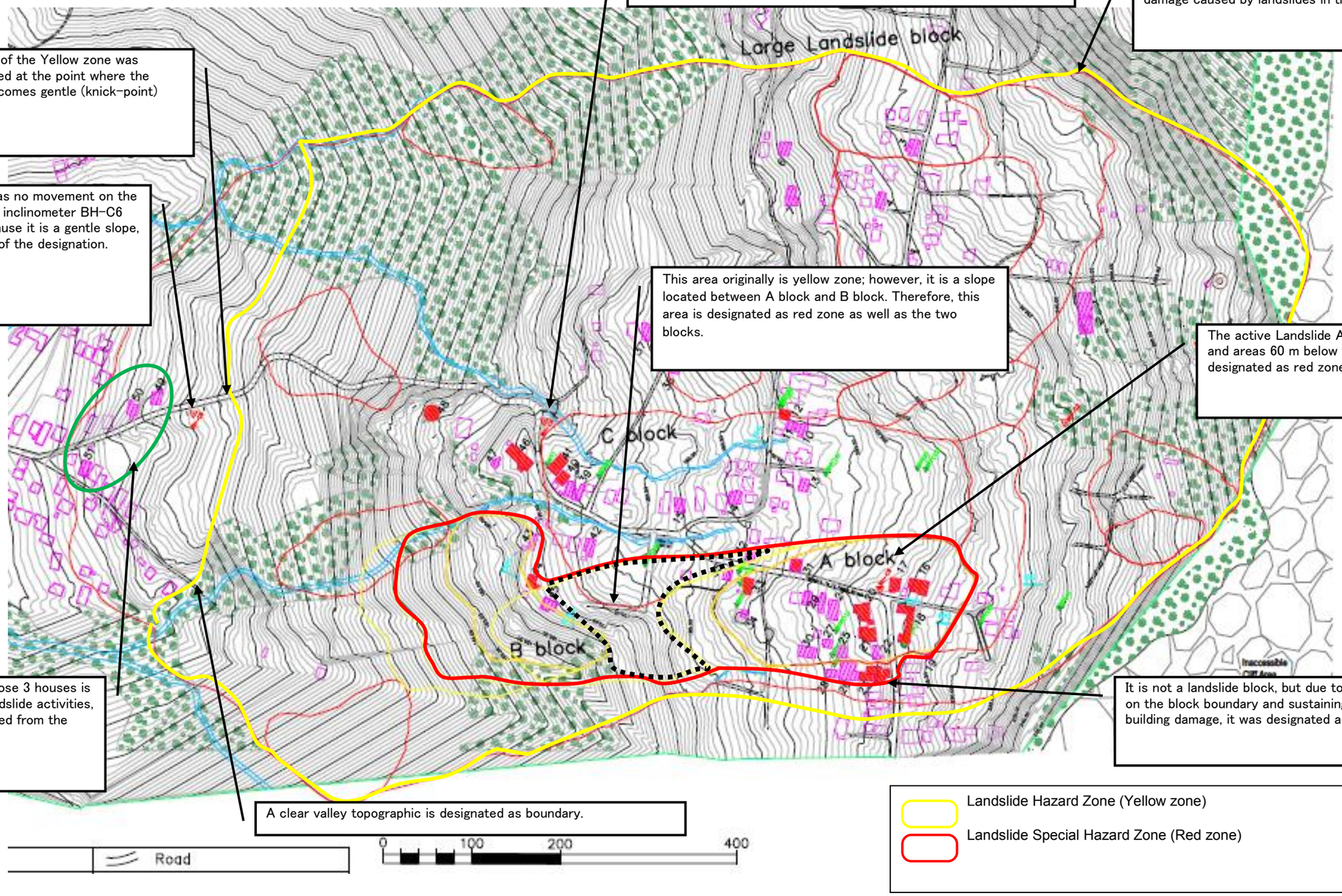
This area is designated as a large landslide block boundary as it is an area that has suffered building damage caused by landslides in the past.

The end of the Yellow zone was designated at the point where the slope becomes gentle (knick–point)

There was no movement on the borehole inclinometer BH–C6 and because it is a gentle slope, it is out of the designation.

This area originally is yellow zone; however, it is a slope located between A block and B block. Therefore, this area is designated as red zone as well as the two blocks.

The active Landslide A and B blocks and areas 60 m below them are designated as red zones.



The damage of those 3 houses is not caused by landslide activities, They were excluded from the yellow zone.

It is not a landslide block, but due to it being located on the block boundary and sustaining extensive building damage, it was designated as a red zone.

A clear valley topographic is designated as boundary.

Landslide Hazard Zone (Yellow zone)

Landslide Special Hazard Zone (Red zone)

Caution Note: The above map is for indicative purposes only. Detailed information may be obtained from the Ministry of Public Infrastructure and Land Transport (Landslide Management Unit)

Annex 5

N

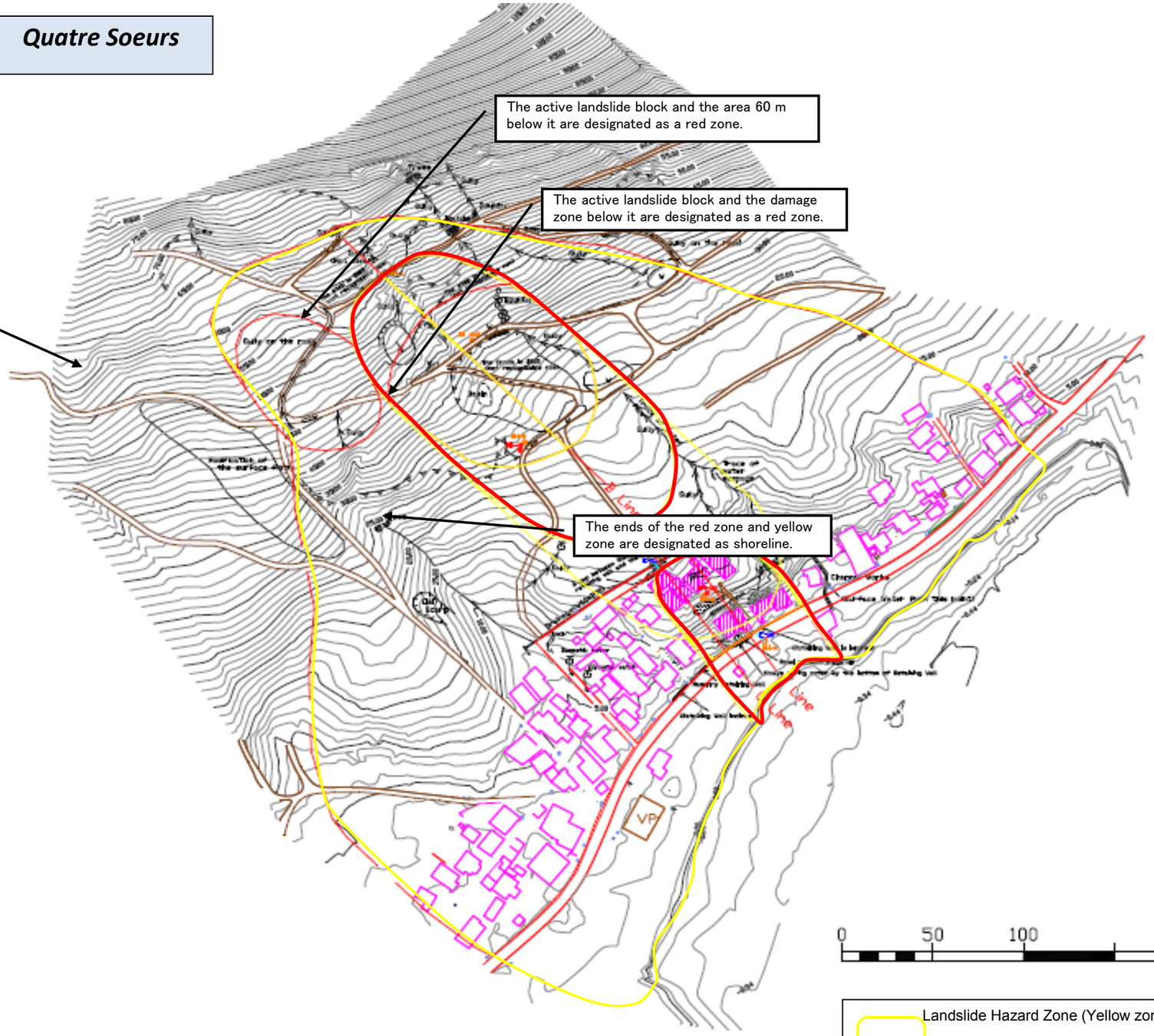
Quatre Soeurs

The active landslide block and the area 60 m below it are designated as a red zone.

The active landslide block and the damage zone below it are designated as a red zone.

A large, old landslide block that was determined by aerial photograph, geographic interpretation and survey, is designated as a yellow zone.

The ends of the red zone and yellow zone are designated as shoreline.



0 50 100 200

Landslide Hazard Zone (Yellow zone)

Landslide Special Hazard Zone (Red zone)

Caution Note: The above map is for indicative purposes only. Detailed information may be obtained from the Ministry of Public Infrastructure and Land Transport (Landslide Management Unit)

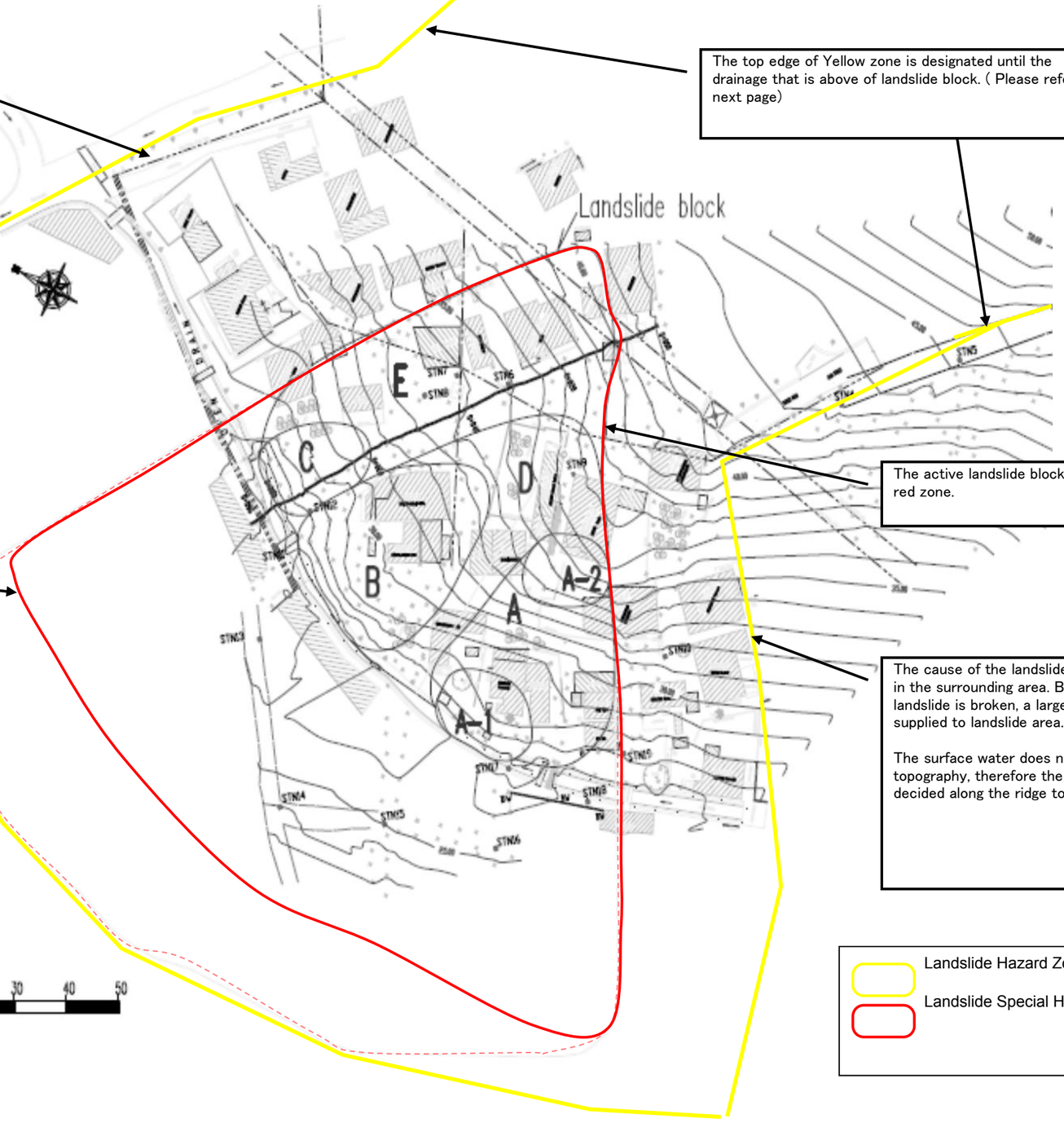
Annex 6

Vallée Pitot

The cause of the landslide is imperfection of the drainage in the surrounding area. Because the drainage above the landslide is broken, a large flow of surface water is supplied to landslide area.

The surface water does not flow beyond the canal at the side of the landslide block, therefore it is designated as the boundary.

The top edge of Yellow zone is designated until the drainage that is above of landslide block. (Please refer to next page)



The active landslide block is designated as a red zone.

The red zone is designated 60 m below the toe of the landslide block.

The cause of the landslide is imperfection of the drainage in the surrounding area. Because the drainage above the landslide is broken, a large flow of surface water is supplied to landslide area.

The surface water does not flow beyond the ridge topography, therefore the boundary of this area was decided along the ridge topography generally.

The yellow zone is designated from the lower part of the block (the length of the landslide block).

0 10 20 30 40 50

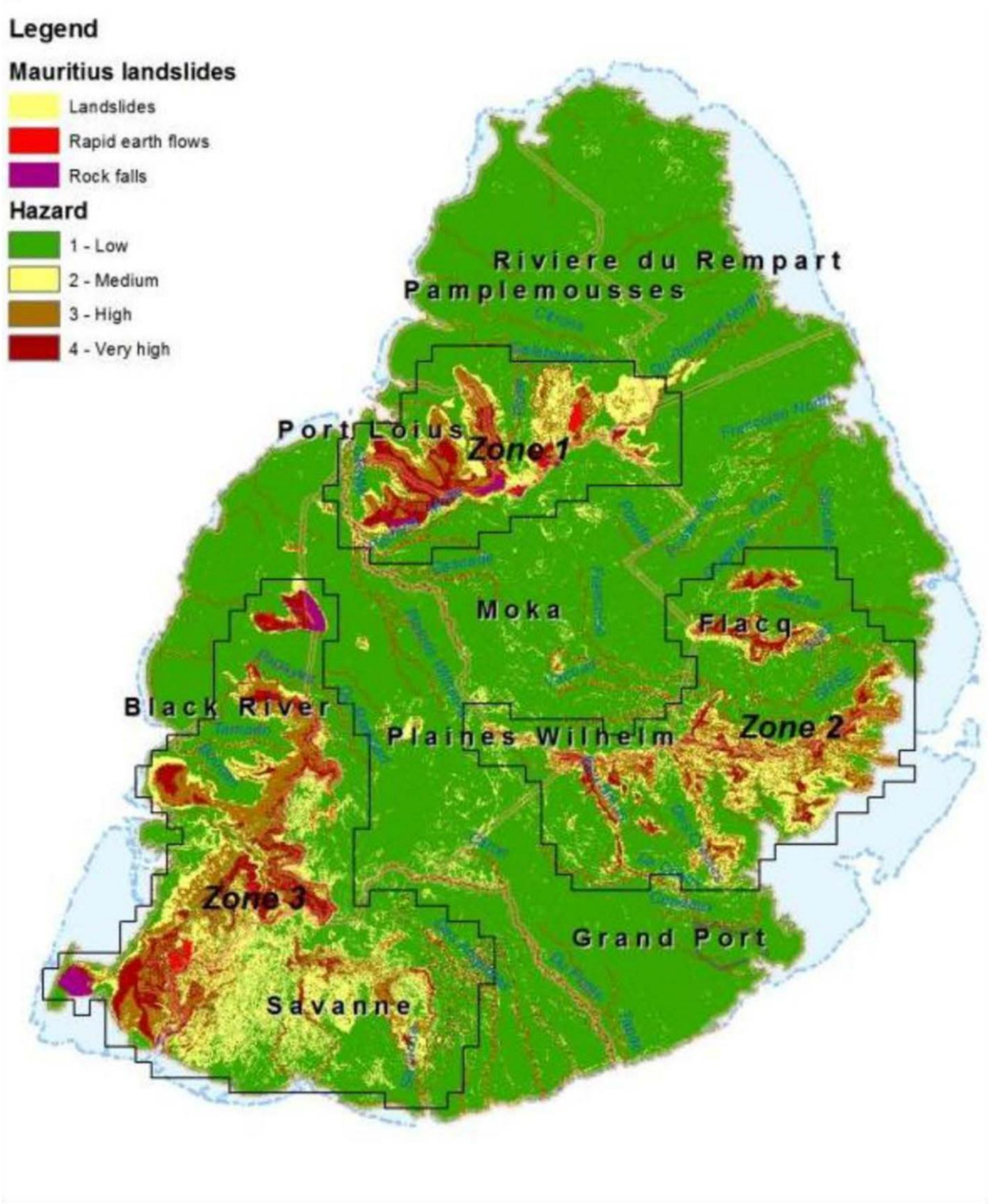
Landslide Hazard Zone (Yellow zone)

Landslide Special Hazard Zone (Red zone)

Caution Note: The above map is for indicative purposes only. Detailed information may be obtained from the Ministry of Public Infrastructure and Land Transport (Landslide Management Unit)

Annex 7

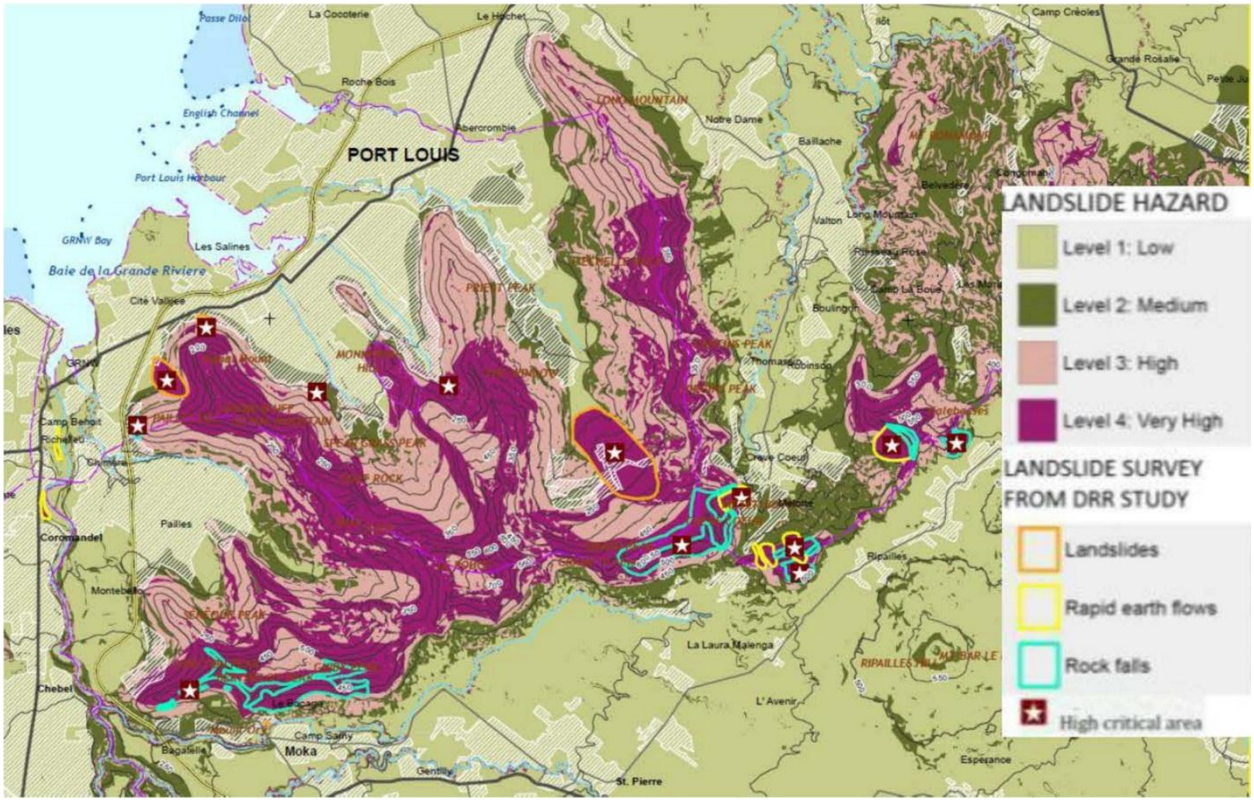
Map of Mauritius Landslide Zones



Caution Note: The above map is for indicative purposes only. Detailed information may be obtained from the Ministry of Environment, Sustainable Development, Disaster and Beach Management.

Annex 8

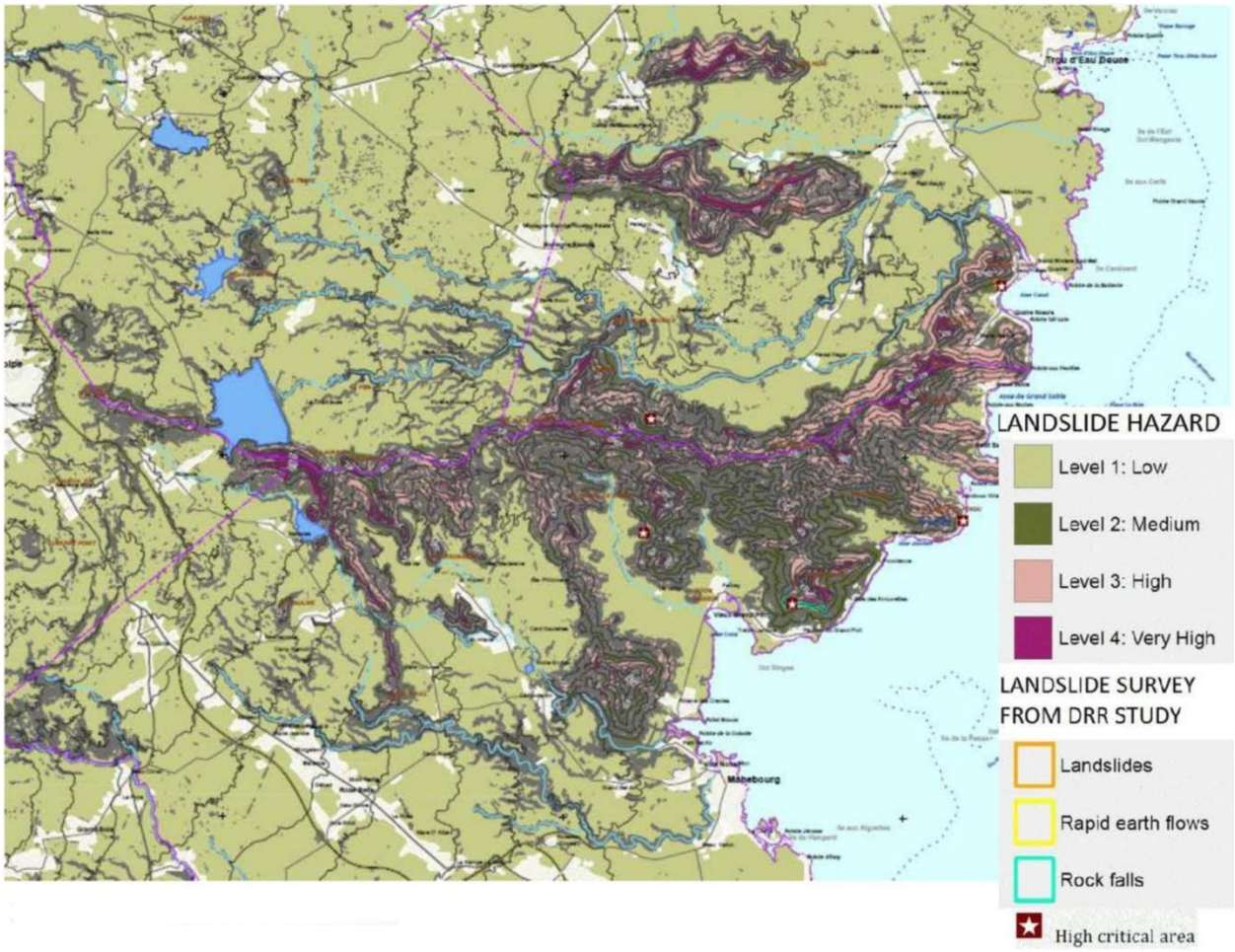
Map of Port Louis Landslide Hazard



Caution Note: The above map is for indicative purposes only. Detailed information may be obtained from the Ministry of Environment, Sustainable Development, Disaster and Beach Management.

Annex 9

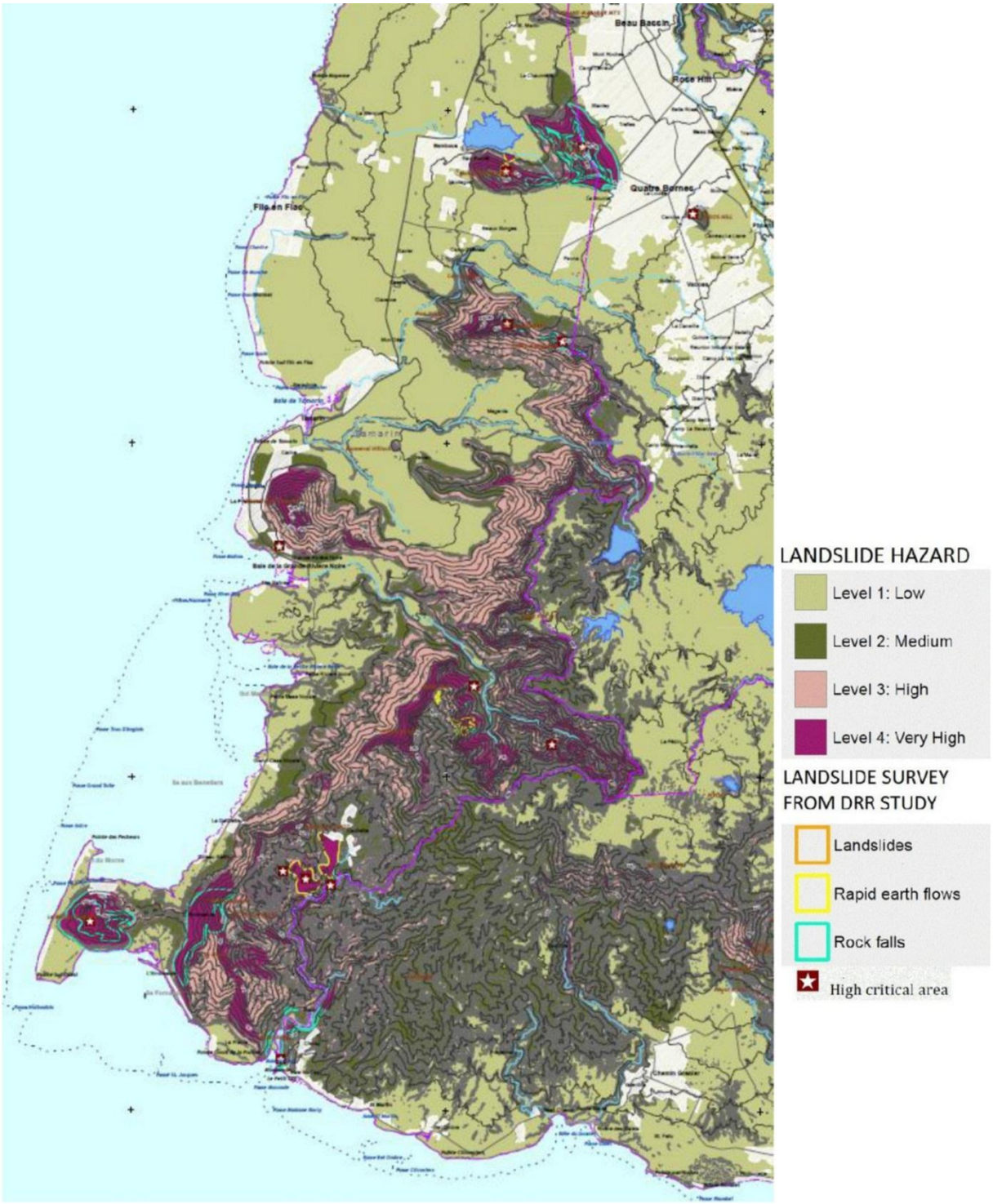
Map of Grand Port Landslide Hazard



Caution Note: The above map is for indicative purposes only. Detailed information may be obtained from the Ministry of Environment, Sustainable Development, Disaster and Beach Management.

Annex 10

Map of Black River Landslide Hazard

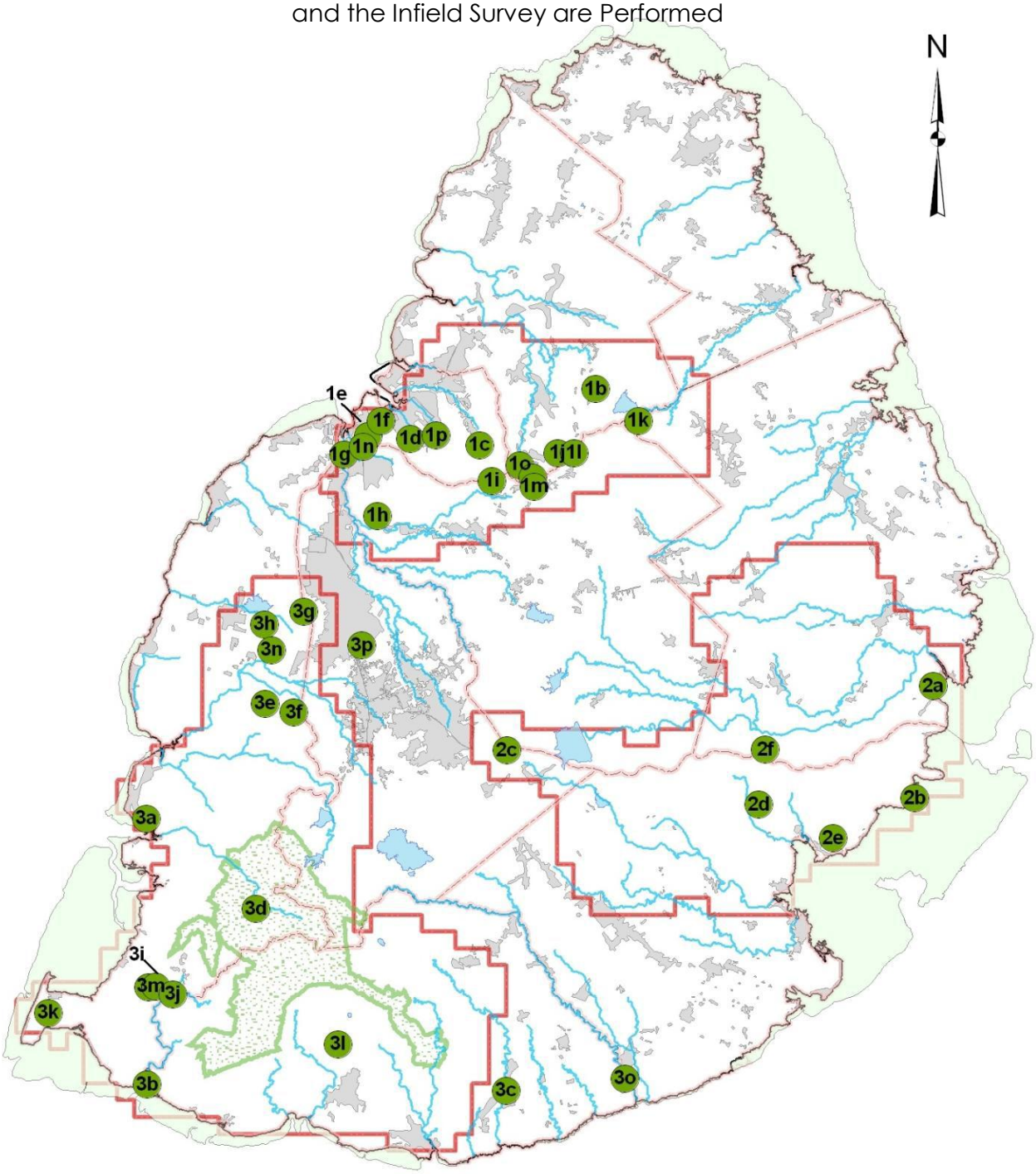


Caution Note: The above map is for indicative purposes only. Detailed information may be obtained from the Ministry of Environment, Sustainable Development, Disaster and Beach Management.

Annex 11

Map of Mauritius:

Location of Mountainous / Hilly Areas where the Photo-geological Analysis and the Infield Survey are Performed



Caution Note: The above map is for indicative purposes only. Detailed information may be obtained from the Ministry of Environment, Sustainable Development, Disaster and Beach Management.

Annex 12

ZONE 1

Code	Location	District	Type of landslide	Investigations
1a	Temple Road Creve Coeur	Pamplemousses	Rapid earth flows	Photogeology - in field survey
1b	Congomah Village Council	Pamplemousses	Rapid earth flows	Photogeology - in field survey
1c	Vallée des Petres - Chitrakoot	Port Louis	Landslides	Photogeology - in field survey
1d	Justice Street	Port Louis	Landslides	In field survey
1e	Camp Chapelon	Port Louis	Landslides	In field survey
1f	Mgr. Leen Street La Butte	Port Louis	Landslides	In field survey
1g	Morcellement Hermitage Coromandel	Plaines Wilhelm	Rapid earth flows	In field survey
1h	Junction Peak	Moka	Rock falls	Photogeology - in field survey
1i	Grand Peak	Port Louis	Rock falls	Photogeology - in field survey
1j	Calebasses	Pampleousses	Rapid earth flows	In field survey
1k	near Nouvelle Duvouverte	Flacq	Rock falls	In field survey
1l	Calebasses	Moka	Rock falls	In field survey
1m	Pieter Both - Ripailles	Moka	Rock falls	In field survey
1n	Camp Chapelon	Port Louis	Rock falls	Photogeology - in field survey
1o	Temple Road Creve Coeur	Pamplemousses	Rock falls - Rapid earth flows	In field survey
1p	Valleè Piton near Eidgah	Port Louis	Landslides - Rapid earth flows	Photogeology

ZONE 2

Code	Location	District	Type of landslide	Investigations
2a	Quatre Soeurs	Flacq	Landslides	Photogeology – in field survey
2b	Bambous Virieux	Grand Port	Rapid earth flows	Photogeology - in field survey
2c	Louis de Rochecouste	Plaines Wilhems	Landslides	Photogeology
2d	Piton	Grand Port	Landslides	Photogeology
2e	Lion Mountan	Grand Port	Rock falls	Photogeology - in field survey
2f	Pic Grand Fond	Flacq	Rapid earth flows	Photogeology

Caution Note: The above table is for indicative purposes only. Detailed information may be obtained from the Ministry of Environment, Sustainable Development, Disaster and Beach Management.

Annex 12 ctd/-

ZONE 3

Code	Location	District	Type of landslide	Investigations
3a	Grande Rivière Noire	Black River	Landslides	In field survey
3b	Baie du Cap	Savanne	Rock falls	In field survey
3c	Riviere des Anguilles	Savanne	Rock falls	In field survey
3d	Grande Gorges	Black River	Rapid earth flows	Photogeology
3e	Mt du Rempart	Black River	Rock falls	In field survey
3f	Trois Mamelles	Black River	Rock falls	In field survey
3g	Corps De Garde	Black River	Rock falls	Photogeology - in field survey
3h	M. Sainte Pierre- Cascavelle	Black River	Rapid earth flows	In field survey
3i	Piton du Canot	Black River	Rapid earth flows	In field survey
3j	Chamarel – Bay du Cap	Black River	Rapid earth flows Rock falls	Photogeology - in field survey
3k	Le Morne Brabant	Black River	Rock falls	In field survey
3l	Chamouny	Savanne	Landslides	Photogeology
3m	Chamarel Coloured Earth	Black River	Rapid earth flows	In field survey
3n	Cascavelle	Black River	Absent	Photogeology
3o	L'Escalier	Savanne	Rock falls	Photogeology - in field survey
3p	Candos Hill	Plaines Wilhems	Rapid earth flows	Photogeology

Sites of photo-geologic analysis form and of in field survey.

Caution Note: The above table is for indicative purposes only. Detailed information may be obtained from the Ministry of Environment, Sustainable Development, Disaster and Beach Management.

Annex 13

Landslide Inventory & Classification by JICA Expert Team

Revised 37 landslide hazard areas from Ex-CONDS (Source: JICA Expert Team)

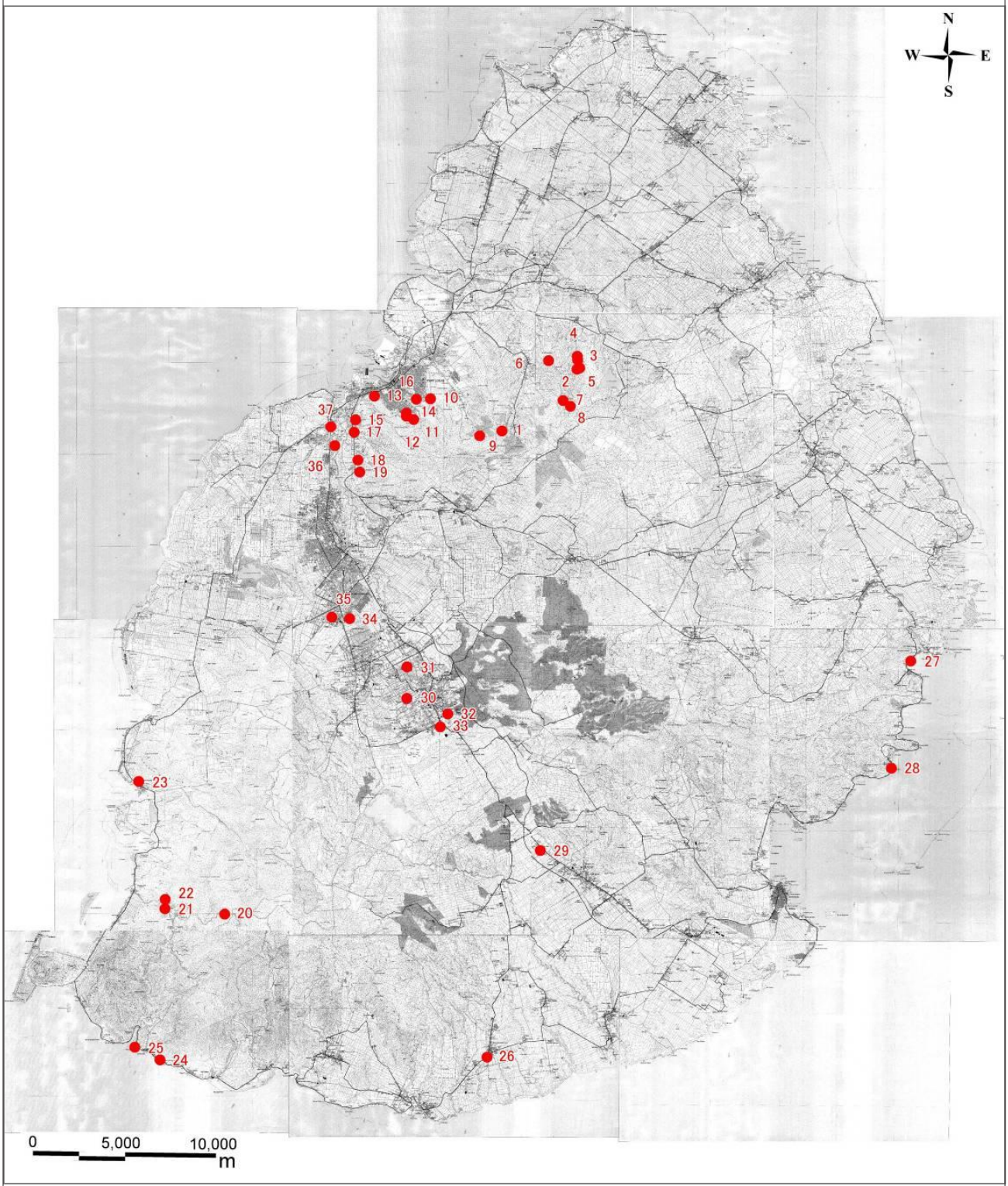
No.	Area name
Pamplemousses/Riviere du Rempart District Council	
1	Temple Road, Creve Coeur
2	Congomah Village Council (Ramlakhan)
3	Congomah Village Council (Leekraj)
4	Congomah Village Council (Frederick)
5	Congomah Village Council (Blackburn Lanes)
6	Les Mariannes Community Centre (Road area)
7	Les Mariannes Community Centre (Resident area)
8	L'Eau Bouillie
Municipality of Port Louis	
9	Chitrakoot, Vallee des Pretres
10	Vallee Pitot (near Eidgah)
11	Le Pouce Street
12	Justice Street (near Kalimata Mandir)
13	Mgr. Leen Street and nearby vicinity, La Butte
14	Pouce Stream
15	Old Moka Road, Camp Chapelon
16	Boulevard Victoria, Montague Coupe
Black River District Council	
17	Pailles : (i) access road to Les Guibies and along motorway, near flyover bridge
18	Pailles : (ii) access road Morcellement des Aloes from Avenue M.Leal (on hillside)
19	Pailles : (iii) soreze region
20	Plaine Champagne Road, opposite "Musee Touche Dubois"

Annex 13 cont'd

21	Chamarel : (i) near Restaurant Le Chamarel
22	Chamarel : (ii) Roadside
23	Gremde Riviere Noire Village Hall
24	Baie du Cap : (i) Near St Francois d'Assise Church
25	Baie du Cap :(ii) Maconde Region
GRAND PORT/SAVANNE DISTRICT COUNDIL	
26	Riviere des Anguilles, near the bridge
27	Quatre Soeurs, Marie Jeanne, Jhummah Streert, Old Grand Port
28	Bambous Virieux, Rajiv Gandhi Street (near Bhavauy House), Impasse Bholoa
29	Cave in at Union Park, Rose Belle
MUNICIPALITY OF CUREPIPE	
30	Trou-aux-Cerfs
31	River Bank at Cite L'Oiseau
32	Louis de Rochecouste (Riviere Seche)
33	Piper Morcellement Piat
MUNICIPALITY OF QUATRE BORNES	
34	Candos Hill at LallBahadoor Shastri and Mahatma Gandhi Avenues
35	Cavernous Area at Mgr Leen Avenue and Bassin
MUNICIPALITY OF BEAU BASSIN/ROSE HILL	
36	Morcellement Hermitage, Coromandel
37	Montée S, GRNW

Annex 13 cont'd

Inventory and Location Map (Source JET)



Landslide Location map (source: JET)

Annex 13 cont'd

Landslide Classification & Summary of Investigation (source: JET)

no.	Area name	Summary of the field investigation and interview	Kind of the disaster	
			General classification	Sub classification
1	Temple Road, Creve Coeur	Deformation on the concrete block wall and house caused by embankment deformation at the front yard (parking area) was confirmed. Another problem was inadequate surface drainage causing surface water from mountains to flow directly at houses during heavy rain.	Other	Damage of wall
2	Congomah Village Council (Ramlakhan)	A small stream flows under the road through a concrete pipe culvert, however, because it is too small it causes flooding and bank erosion during heavy rain.	Other	Stream erosion
3	Congomah Village Council (Leekraj)	A 1m high retaining wall that was constructed to build the road was reported to be leaning but it was found to be stable and no slope failure was observed.	Other	Damage of wall
4	Congomah Village Council (Frederick)	The 1m high retaining wall along the road was found to have collapsed due to erosion by surface water flow during rainy season.	Other	Damage of wall
5	Congomah Village Council (Blackburn Lanes)	A slope failure was confirmed on the side of the road.	Other	Damage of Embankment
6	Les Mariannes Community Centre (Road area)	There are a few slope failures and a lanslide in this site. The slope at the roadside collapsed during heavy rain in 2010 and a section of road was washed away. Since then, a retaining wall has been constructed and the site is currently stable.	Slope	Slope failure
7	Les Mariannes Community Centre (Resident area)	There appeared to be bank erosion on the left bank above the bridge.	Other	Stream erosion
8	L'Eau Bouillie	The cracks have been spotted on the road surface due to the deterioration of bearing capacity of the roadbed. However, the cracks have been repaired.	Other	Damage of Embankment
9	Chitrakoot, Vallee des Pretres	A clear landslide was confirmed. A landslide was reported to have damaged houses and a school after heavy rain in 2005. Drilling investigation and monitoring have been carried out, but not sufficiently. No countermeasures have been implemented. Therefore, a detailed investigation and monitoring are necessary while the countermeasures are expected in future.	Slope	Landslide
10	Vallée Pitot (near Eidgah)	Lately, housing developments are growing rapidly in this area. A landslide boundary of 35m x 20m was clearly detected. Several houses have been damaged and some cracks were observed. The situation of the damage was also reported in the newspaper.	Slope	Landslide
11	Le Pouce Street	Insufficient surface drainage means rain water concentrates in low area and erodes roads and houses in its path. Damage is negligible at present, although the maintenance of the surface drainage will be necessary.	Other	Stream erosion
12	Justice Street (near Kalimata Mandir)	An embankment has been constructed to build up the road, which caused an adjacent retaining wall to be pushed out and deformed. Insufficient surface drainage causing accumulation of groundwater could also be a factor causing this deformation.	Other	Damage of wall

Annex 13 cont'd

13	Mgr. Leen Street and nearby vicinity, La Butte	The landslide of La Butte occurred in 1986, and many houses and a school were damaged. As for this landslide, countermeasures were carried out in 1998, therefore further investigation of the landslide is unnecessary. However, Port Louis City wants to continue the monitoring on this landslide in the future.	Slope	Landslide
14	Pouce Stream	Every side of the channel is covered by concrete. The water level rises until the upper edge of the channel and erode beyond this point in the rainy season. The gabion has been set up at the lower part of slope at the channel and no damage has been reported yet. However, the deteriotion of the concrete wall is remarkable and the extention of the wall height will be necessary. Therefore, further investigation and countermeasures are advisable.	Other	Stream erosion
15	Old Moka Road, Camp Chapelon	The landslide topography is not clear, but five houses and two retaining walls were damaged while the spring water was spotted in two places. There are two possible causes of this, creep transformation of weak surface soil or a shallow landslide. Therefore, landslide investigation and monitoring are necessary while the countermeasures are expected in future.	Slope	Landslide
16	Boulevard Victria, Montague Coupe	The gabion was installed on the cut-slope when the road was constructed. There is no record of damage for this site but the angle of the wall is steep.Therefore, the observation of this wall is advisable.	Other	Damage of wall
17	Pailles : (i) access road to Les Guibies and along motorway, near flyover bridge	The slope failure has been spotted along the cut-slope (5m height) at the roadside of highway. The surface of the cut-slope has been weathered, and it is eroded by rain.	Slope	Slope failure
18	Pailles : (ii) access road Morcellement des Aloes from Avenue M.Leal (on hillside)	Insufficient drainage is causing erosion at the base of the water tank. Immediate remedial work is needed.	Other	Stream erosion
19	Pailles : (iii) soreze regin	Falling rocks at the upper slope and shallow slope failure at the middle and lower slope occurred in an area of housing. There is only slight damage for now, although shallow slope failure and cracks have been confirmed.	Slope	Slope failure
20	Plaine Champagne Road, opposite "Musee Touche Dubois"	Retaining walls have been constructed as countermeasures where the slope failure has been confirmed. It is currently stable, although there were a few cracks spotted in the retaining walls which are believed to be due to substandard construction.	Slope	Slope failure
21	Chamarel : (i) near Reataurant Le Chamarel	Cracks in the road shoulder have occurred due to a lack of bearing capacity . It is caused by insufficient soil compaction.	Other	Damage of Embankment
22	Chamarel : (ii) Roadside	Deformation of the road has been confirmed at the shoulder of the road due to a lack of bearing capacity. The embankment of stone masonry wall and retaining wall were constructed but it is insufficient.	Other	Damage of Embankment
23	Gremde Riviere Noire Village Hall	The crack at the base of village hall area and edge of concrete basketball court has been confirmed. However, the surrounding structures are not affected, therefore it is considered unlikely this damaged was caused by landslides. Rather it is likely to be caused by lack of bearing capacity of the ground or a problem with the structure itself.	Other	Damage of house
24	Baie du Cap : (i) Near St Francois d'Assise Church	A debris flow has occurred in the past and a block wall has since been constructed. Also, small surface failures have been observed frequently in this area.	Slope	Debris flow

Annex 13 cont'd

25	Baie du Cap :(ii) Maconde Region	A new road was built to reduce the damage from rock falls. However, rock falls and small rock failures are also a frequent occurance along the new road. The rocks are weathered, and there is a high possibility of rock fall in future.	Slope	Rock fall
26	Riviere des Anguilles, near the bridge	There are many houses built on the cliff here. The cliff is weathered severly and stream erosion occurs frequently. Therefore, the house will need to be relocated.	Other	Stream erosion
27	Quatre Soeurs, Marie Jeanne, Jhummah Streert, Old Grand Port	Landslide activity has been confirmed at the Quatre Soeurs area where many houses have been damaged. The groundwater level at the lower part of the landslide is high and is causing instability in the landslide. Drilling investigation and monitoring have been carried out, but not sufficiently. Further investigation and monitoring are necessary while the countermeasures are expected in future.	Slope	Landslide
28	Bambous Virieux, Rajiv Gandhi Street (near Bhavauy House), Impasse Bholoa	Slope failure was confirmed at the backyard of the house. No damge on the house was reported although the soil of the slope approached near the house. A retaining wall has been constructed independently.	Slope	Slope failure
29	Cave in at Union Park, Rose Belle	A cavity (4m x 4m x 3m depth) due to land subsidence was observed in the residential area. No damage was caused to the houses and the cavity was filled in with soil. Similar situation was confirmed nearby.	Other	cavern
30	Trou-AUX-Cerfs	The slope failure in the crater of the volcano occurred during heavy rainfall in 2005. The possibility of slope failure on the rear side is low. However, the slope failure on both sides can be expected.	Slope	Slope failure
31	River Bank at Cite L'Oiseau	Bank erosion and flooding is common in the rainy season when the river water level rises. There are more damage on the left side of the riverbank due to the strong collision of water. However, past damage has been restored by constructing a retaining wall.	Other	Stream erosion
32	Louis de Rochecouste (Riviere Seche)	The bank erosion and flood are common in the rainy season. The base of the houses have been eroded and the retaining wall of the houses are inclined.	Other	Stream erosion
33	Piper Morcellement Piat	The bank erosion and flood are remarkable in the rainy season. However, the past damage has been restored by constructing the retaining wall.	Other	Stream erosion
34	Candos Hill at LallBahadoor Shastri and Mahatma Gandhi Avenues	A clear landslide site was confirmed at the backyard of the house. The landslide topography and slope are clear while the spring water has been observed. The scale of this lanslide is small (40m x 35m) and no house on the lanslide area. Only slight crack has been confirmed on the retaining wall.	Slope	Landslide
35	Cavernous Area at Mgr Leen Avenue and Bassin	A cavity was reported during the house construction but it was filled with concrete. There is no further danger at this site.	Other	cavern
36	Morcellement Hermitage, Coromandel	At this slope, slope failure occurred in 2010, and a road was destroyed. After a retaining wall was made as a countermeasure, large-scale slope failures have not been found. However, the stone blocks from on top of the retaining wall have fallen down. This is likely caused by the ground behind the retaining wall sinking due to lack of compaction of the backfilling soil.	Slope	Slope failure
37	Montée S, GRNW	Weathered outcrops were detected on both sides of the bank. The erosion is remarkable in the rainy season.	Other	Stream erosion

Sources, Acknowledgements and References

The material and information obtained from these different sources and having made possible the preparation of this guidance is most gratefully acknowledged.

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