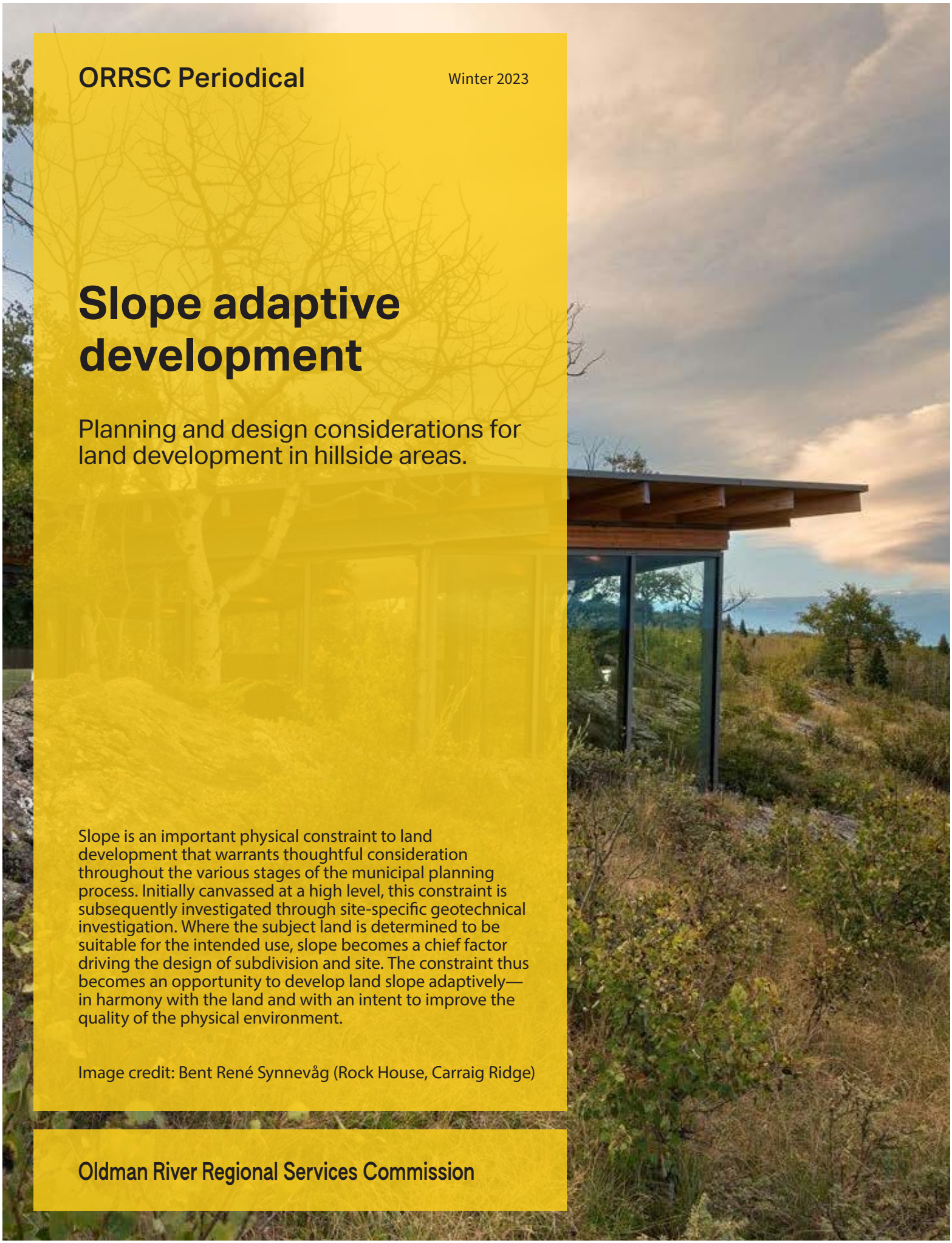
ORRSC Periodical

Winter 2023

Slope adaptive development

Planning and design considerations for land development in hillside areas.



Slope is an important physical constraint to land development that warrants thoughtful consideration throughout the various stages of the municipal planning process. Initially canvassed at a high level, this constraint is subsequently investigated through site-specific geotechnical investigation. Where the subject land is determined to be suitable for the intended use, slope becomes a chief factor driving the design of subdivision and site. The constraint thus becomes an opportunity to develop land slope adaptively—in harmony with the land and with an intent to improve the quality of the physical environment.

Image credit: Bent René Synnevåg (Rock House, Carraig Ridge)

Oldman River Regional Services Commission

Overview

Throughout history and across the globe, hillside areas have been popular locales for human settlement. Development in hillside areas should be "slope adaptive," meaning undertaken with an intent to safeguard against the risk of slope failure, retain high-value environmental features of the site, and contribute aesthetic quality to the area. This periodical will canvass the elements to consider when planning and developing land in "hillside areas," a term which is employed broadly to encompass all types of slopes across the southern Alberta landscape—from the vertical terrain of the Canadian Rockies to the coulee-dominated landforms of the Northern Great Plains.

"No house should ever be on a hill or on anything. It should be of the hill. Belonging to it. Hill and house should live together each the happier for the other."

- Frank Lloyd Wright

Slope mechanics

Slope is the ratio of vertical change ("rise") to horizontal change ("run") between two points on an inclined surface. In land use planning and related fields, it is most often expressed as a percentage rather than in degrees. The term is most frequently used in reference to natural inclines, whereas "grade" is used to describe the incline of roads, graded lots and other finished surfaces. "Gradient" is used interchangeably with both terms. Slope and grade also have colloquial meanings in planning: slope can mean hillside (i.e. slope stability), while grade can mean ground (i.e. direct access from grade).

The gradient of land is generally a determinant of slope stability. Other factors include groundwater conditions, and the load-bearing capacity and shear strength of the underlying geomaterials (soil and rock). Climate is also relevant: frost impacts soil conditions, and wind and rain are powerful natural agents that impact erosion. The relationship between slope and climate is reciprocal ("climate" actually derives from the Greek word for slope).

Various classifications exist for slope failure, but "mass wasting" is an all-encompassing term referring to any sudden or gradual collapse of the geomaterials. In the Rocky Mountains, mass wasting manifests primarily as rock avalanches or landslides concentrated along major faults. Slopes in the Foothills tend to be more stable since their underlying rocks have not been weakened by shear stress to the extent of those in the Rockies. In the river and stream valleys further east, rotational slumping can be a concern due to the erosion of valley banks underlain by weak substrata. The prevalence of country residential development near such valleys makes this last type of mass wasting especially relevant. In particular, the bank can become destabilised where the load-bearing capacity is exceeded, or where land disturbance undercuts the slope, steepens the bank, alters natural drainage patterns or destroys vegetation.

Slope percentage categories:

0–0.5	*level*
0.5–2	*nearly level*
2–5	*very gentle slopes*
5–9	*gentle slopes*
9–15	*moderate slopes*
15–30	*strong slopes*
30-45	*very strong slopes*
45-70	*steep slopes*
70-100	*very steep slopes*
> 100	*extreme slopes*

Source:
Lagro, James A. Jr. 2001. Site Analysis: Linking Program and Concept in Land Planning and Design. New York: John Wiley & Sons, Inc.

Macro-planning for sloped land

Where unstable slopes are developed, persons and property are put at risk.

Bank regression at Lake McGregor, Vulcan County

Along portions of the north and east shorelines of Lake McGregor in Vulcan County advanced bank regression has and continues to take place. Severe wave erosion due to high winds, fluctuating reservoir levels, and geotechnical instability is the mechanism that has caused the gently sloping shoreline lands to recede significantly (upwards of 200 m in some areas).

In recognition of the encroachment onto private property in shoreline communities and other concerns related to this occurrence, Alberta Environment commissioned an erosion study (Golder & Associates, 2014). Erosion projections within the document along with desired capital improvement projects (eg. bank armouring) assist in the review of subdivision proposals. Geotechnical reports supporting subdivision applications are to address recommended shoreline setbacks in addition to minimum setbacks to the reservoir in the County's Land Use Bylaw, as well as the recommendations in the provincial Reservoir Lands Guideline document.

Slope is therefore an important consideration for developing and maintaining safe and viable communities. Municipal planning is chiefly concerned with slopes under 35%. Beyond that threshold, technical feasibility, project economics and environmental integrity are easily frustrated.

An initial consideration of sloped lands may occur in the municipal development plan. In southern Alberta, this high-level analysis has been facilitated by the field surveys undertaken in association with a series of reports titled "Environmentally Significant Areas in the Oldman River Region." Slope-related policy within a municipal development plan will spotlight areas of unstable slope potential for further study. Because the usability of land is diminished where slopes are significant, policy should preclude the dedication of such land as municipal reserve. Conversely, sloped areas make excellent candidates for dedication as environmental reserve (more on this later). More detailed analysis can occur at the area structure plan level as part of a topographical analysis that takes into account development capacity, density, layout and servicing. Planning policy concerning slope may also exist outside of a statutory plan, as in the "Town of Canmore Guidelines for Subdivision and Development in Mountainous Terrain." In that document, an additional level of review is triggered for applications on land containing slopes of 15% or greater over a minimum horizontal distance of 15 m.

The land use bylaw offers various avenues to regulate the use and development of sloped land. Where the natural features are such that development would trigger a significant risk to persons and property, development should be prohibited altogether. Slope hazard areas may be redesignated to an open space district, where uses not qualifying as low-impact, passive recreation are prohibited. Where the land is redesignated for public use, s. 644 of the MGA compels the municipality to take steps to acquire the land within 6 months. Slope-specific development standards can be provided in an overlay district or in a separate schedule.

Many land use bylaws have incorporated the setbacks espoused in the "Interim Guidelines for the Subdivision of Land Adjacent to Steep Valley Banks," a Government of Alberta publication from the 1990s. These were intended to be subdivision standards (i.e. lot boundary setbacks applied through the subdivision process) but in some land use bylaws they are prescribed as development setbacks. The guidelines define "valley bank" as the area where slope exceeds 15%; "toe of slope" as the line of transition between a valley bank and the adjacent river terrace; and "valley crest" as the line of transition between a valley bank and the adjacent upland area. From the toe of slope, the recommended setback is 6 m or half the height of the valley bank, whichever is greater. Recommended setbacks from the valley crest vary from one to two times the height of the valley bank depending on the land gradient, the extent of existing surface disturbance, the anticipated surface disturbance associated with the intended use, and any visual signs of bank instability. Importantly, the guidelines are specific to river and stream valleys east of the mountains, and are not applicable to geographic contexts where rock landslides are the predominant type of mass wasting.

Site-specific investigation of slope

A site-specific study of slope is usually undertaken as part of a subdivision application, though it may occur at the land use redesignation or development permit stage. Within land use bylaws in southern Alberta, "geotechnical investigation" and "slope stability assessment" are two terms commonly used to describe this detailed study. Some bylaws use the terms interchangeably, yet clay-heavy soils and other challenging conditions that warrant geotechnical investigation can also exist on flat land. A more common method is to frame the assessment of slope stability as a component of a geotechnical investigation. A third option is to separate the two processes—step 1 being a preliminary geotechnical investigation and step 2, if necessary, being a slope stability assessment. This latter procedure is analogous to the tiers of environmental site assessment, where the requirement for subsequent levels of assessment is contingent on the findings at level 1. Requirements vary from municipality to municipality, but a detailed assessment of slope stability is typically only required where slopes exceed 15%, where a relaxation of the setback from the toe or crest of a valley is proposed, or where the Subdivision Authority is presented with evidence that an undue risk of slope failure exists.

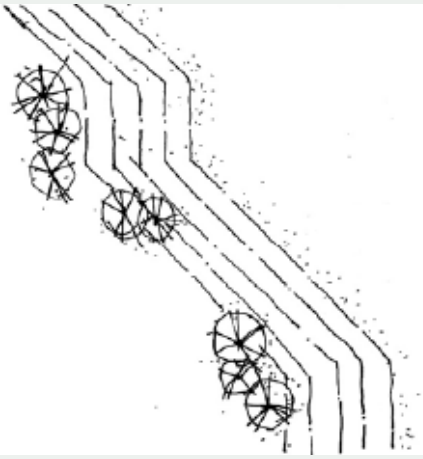
A geotechnical investigation is conducted by an accredited engineer or geoscientist. Its principal aims are to acquire knowledge of subsurface conditions, and predict how the geomaterials will behave in response to the structural loads associated with the proposed use. It begins with the review of existing maps and reports, followed by a visual survey to document physiographic features of interest: rock outcrops, vegetation communities, natural drainage patterns, areas of groundwater discharge, signs of erosion, etc. The on-site component includes drilling exploratory boreholes, sampling the soils, and measuring in-situ ground movements and underground water pressure. In the single-lot context where the intended use involves a limited number of permanent structures, a landowner can expect to pay somewhere in the neighbourhood of $6,000 to have a geotechnical investigation undertaken. Larger parcels intended for multi-lot subdivision warrant more extensive field drilling programs, which can cost upwards of $25,000.

The outcome of a geotechnical investigation is a report stating the impacts of subsurface conditions on the suitability of the subject land for the intended use. Where only a portion of the subject land has stable slopes, its areal extent will be mapped. Also included in the geotechnical report are select design recommendations for grading, retaining walls, foundations, weeping tile and frost protection. In Calgary, areas identified as unstable are flagged as undevelopable in a restrictive covenant entered into between the landowner and the city. Attached to the restrictive covenant is a plan of survey on which the developable and undevelopable areas are demarcated by a line of stability. The covenant is then registered against the titles of all affected properties by way of caveat pursuant to s. 651(1) of the MGA. The city imposes registration of the covenant as a condition of subdivision approval.

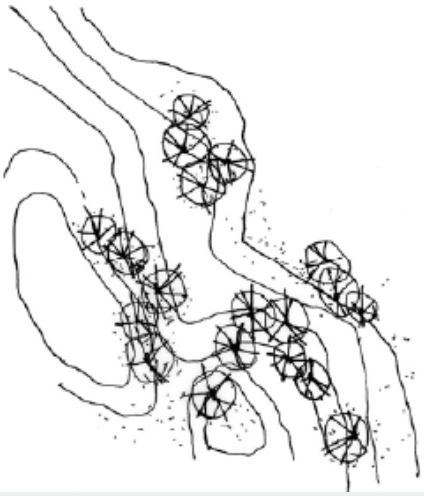
The popularity of 15% as a threshold for requiring a geotechnical investigation likely derives from the Environmental Reference Manual for the Review of Subdivisions in Alberta. Within this document, the "suitable development area" of a residential parcel is restricted to areas with slopes of 15% or less. The provincial "Land Use Policies" state that municipalities should refer to the Environmental Reference Manual when evaluating land use, subdivision and development in areas prone to mass wasting.

In engineering, geotechnical investigation primarily deals with subsurface conditions as they relate to supporting structural loads. From a planning perspective, a broader consideration of subsurface characteristics in the context of unserviced land will include the suitability for any proposed on-site sewage disposal system.

The process for determining septic suitability is articulated in the Alberta Private Sewage Systems Standard of Practice 2021, wherein it is referred to as a "site evaluation." Where a municipality adopts a broad, all-inclusive definition for geotechnical investigation, the component focused on soil-based wastewater treatment should include the opinion of a certified Private Sewage Treatment System (PSTS) installer. The Model Process for Subdivision Approval and Private Sewage recommends considering the opinion of a PSTS Installer in any site evaluation, even those involving more detailed and complex levels of assessment where the expertise of a registered engineering professional is also required.



Compared to the rigid earthwork geometry depicted above, the curvilinear contours in the sketch below illustrate site grading that is sensitive to the existing terrain. These contextual finished slopes become the canvas for slope adaptive development.



Source:

City of Calgary Slope Adaptive Development Policy and Guidelines

The legislative context for suitability

Emphasis on slope stability in determining the suitability of land for a particular use is embedded into the MGA. In particular, s. 654(1)(a) prohibits a Subdivision Authority from approving an application unless it is of the opinion—based on a legitimate planning reason—that the subject land is suitable for the intended purpose of the proposed subdivision. The slope-related factors that a Subdivision Authority must consider when determining suitability are specified in s. 9 of the *Matters Related to Subdivision and Development Regulation*.

Issues related to suitability are often the subject of subdivision and development appeals. In Hall v Clearwater County (Subdivision Authority), 2023 ABLPRT 558, the provincial Land and Property Rights Tribunal (LPRT) heard an appeal of two conditions that were imposed on an approval involving the subdivision of 3.6 acres for residential use as a first parcel out from 159 acres of agricultural land. One of the conditions being appealed was the requirement for a geotechnical report demonstrating the availability of a suitable development area, which the appellant argued was unnecessary because the proposed parcel contained abundant flat and gently sloping areas. The LPRT disagreed and revoked the subdivision approval, arguing that the sloped nature of the land warranted the submission of evidence establishing a suitable development area as part of the subdivision application. Had the decision not been overturned, and the subject land were to experience slope failure at some future date, the existing body of case law suggests that the municipality would assume at least some amount of liability due to a lack of reasonable care by its Subdivision Authority.

Subdivision design

Where subdivision approval in a hillside area is contemplated, the layout should be guided first and foremost by the existing topographical blueprint. In practical terms, this means the Subdivision Authority will require any land it believes to be unstable to be dedicated as environmental reserve (or made subject to an environmental reserve easement). Where environmental reserve is taken in respect of land that abuts the bed and shore of a water body, the strip of land must be at least 6 m wide. This statutory minimum is perhaps appropriate in the context of water bodies with relatively benign banks, but where banks are steeper its capacity to protect persons and property is questionable. A more sensible formula for calculating environmental reserve in the river and stream valley context will vary the width of land based on the height of the valley bank. This is the approach endorsed in the "Interim Guidelines for the Subdivision of Land Adjacent to Steep Valley Banks," as well as in the "Sustainable Resource Development Standard Recommendations to Municipal Subdivison Referrals." The latter provincial policy document suggests a more conservative width for environmental reserve equalling three times the height of the valley bank.

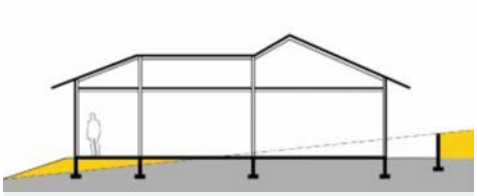
Upon deducting the undevelopable land as environmental reserve, and likewise satisfying the municipal reserve land requirements, roads are the next major factor driving the subdivision design. Roads should be laid out in curvilinear routes that parallel the existing contours, and moreover it may be practical to allow the minimum dimensional standards, which typically exist outside the land use bylaw in a policy manual, to be relaxed. This may include allowing an increased maximum road grade over short, straight stretches, or a reduced minimum road width to avoid large volumes of cut and fill. Similar allowances may be made for cul-de-sac radii, or these might even be eliminated altogether in favor of hammerhead road-end configurations. As the vast majority of hillside subdivisions will be located in the wildland–urban interface, it is critical to ensure that functional emergency access is not compromised where reduced or different dimensional standards for roads are contemplated. A secondary physical access to a hillside subdivision is also advisable, despite the increased land disturbance.

Grading of the lots should similarly aim for cuts and fills that complement the existing terrain. This helps preserve the natural drainage patterns, which is important since even minor terrain modifications can have major impacts on the flow of storm water—and in turn the effects of erosion. Naturally, runoff should be directed away from unstable slopes. Furthermore, in the multi-lot context, back-to-front drainage is preferred to side-to-side drainage, especially where lots are narrow.

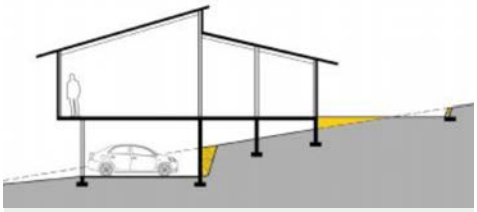
Where a subdivision is designed with slope adaptive principles, one strategy a municipality can utilize to ensure this spirit is likewise embodied at the development stage is to prescribe, on each lot, a buildable envelope for the principal building and driveway. This can be achieved by registering a restrictive covenant against the title to each lot. When implemented in conjunction with land use bylaw standards for maximum building height, a view corridor can be secured for each future residence. Other elements canvassed above, as well as the unique aesthetic considerations for buildings in a hillside area, can be regulated at the development stage through the land use bylaw. For example, in the Municipality of Crowsnest Pass, a development permit application may be deemed incomplete if it fails to incorporate slope adaptive building and site design principles.

Concluding remarks

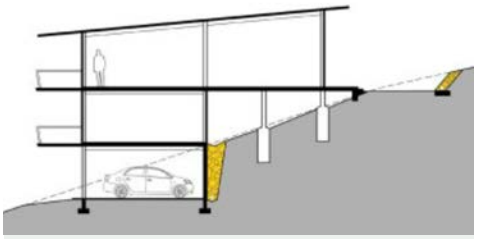
Landforms in southern Alberta have diverse bedrock geology, and for the most part have been sculpted by alpine or continental glaciers, or by both. Slope is thus a pervasive feature of the land throughout the region; one with various planning implications depending on the context. This physical constraint deserves high-level consideration, and subsequently site-specific investigation to learn how the geotechnical characteristics of the land impact its suitability. Where the findings of this (and other) due diligence supports a determination of suitability, slope should be a major influence on how the land is developed. By planning with, rather than against, the slope, an opportunity is revealed to develop adaptive built forms that complement the dramatic character of the southern Alberta landscape.



A single slab on grade is a viable building foundation option for slopes up to 7%.



Where slabs are used on slopes between 7% and 20%, they should step down the hillside.



Slopes between 20% and 33% warrant a stepped foundation (eg. stepped pier & beam, with potential for slab on lower level).

Source: Building on sloping sites (City of Gold Coast, Australia)

For more information on this topic contact admin@orrsc.com or visit our website at orrsc.com.

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