DEVELOPMENT CONTROLS FOR SENSITIVE SLOPES

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1 INTRODUCTION

In the past land was treated as a commodity which was bought, bartered or sold through the real estate market. When land was cheap, wetlands and hills were left alone, where land was expensive it was made buildable by flattening, draining or filling.

Experience however shows that land is a complicated resource and that the real estate market alone cannot handle all allocation considerations. These considerations now vest in the hands of planners.

Due to the public character of environmentally sensitive lands, government involvement has become necessary in the form of standards and regulations. The degradation of environmentally sensitive lands does not only imply the possible loss of some "intrinsic" environmental values, but a real social and economical loss to a community. These losses may take the form of (i) the creation of hazards such as flooding and landslides, or (ii) the destruction of public resources such as water supplies and water quality of lakes and rivers, or (iii) the wastage of productive lands and renewable resources. All these losses are directly coupled to an economic loss and lowering of the general welfare of the community.

Local regulation is, therefore, needed not only because of the public character of the resources, but also because the real estate market does not adequately consider these costs and the benefits of protecting these resources. A wetland, for example, which is filtering sediment and allowing water to enter a stream, cannot be evaluated in money terms.

2 SLOPES:

Due to the varied combination of soil, climate, vegetation and bedrock geology, each hillside slope is unique in its composition and should, therefore, be treated as such when proposed urban development is to take place on such a hillside. In order to protect the equilibrium which exists on a hillside slope certain regulatory measures have been introduced in the United States governing development on certain slopes by means of empirical standards related to the steepness of the slope.

There are certain natural constraints which must be considered when regulating new urban hillside development.

2.1 Mass Movement and Erosion

A loss in slope stability can cause increased erosion as result of the lowering of the stabilization effect of the soil on the prevailing root vegetation. Ever present is this downward movement of hillsides as a result of weathering in which new soil is being created, later to be deposited in the valley below as illustrated in Figure 1. See cover for illustrations.

Regarding urban development the concern is mainly directed to the mass movement of soil in the form of landslides and slumps. Soils on a steep slope can become saturated after a heavy rainfall and overcome the friction holding these soils to the bedrock, resulting in a landslide as shown in Figure 2. The disturbance of debris or the shoe of a slope by development or erosion can also cause a landslide as illustrated in Figure 2.

A similar oversaturation of soil on a slope can result in a slump or mudflow. Where the material is homogenous, such as clay soils, a slump can occur as shown in Figure 3. Mudflows occur in saturated heterogeneous materials, such as gravels and silt, and are common in arid areas during heavy rains.

Two phenomena clearly play a part in the disturbance of hillsides namely decreased stability and increased runoff.

2.2 Runoff and Drainage Patterns

The stabilization of hillsides for urban use is dependant on the development of a stable drainage system.

The nature of the slope, soil type, vegetation cover, bedrock-geology and rainfall pattern determines the form of streams and watercourses. In the natural environment slope drainage, due to vegetation cover, is relatively stable with slow erosion. However when cut and fill takes place to construct roads and sites across the slope, the runoff water seeks new channels resulting in gullays. The later construction of impervious structures such as roads, roofs and other covered surfaces increases the runoff and contributes to downstream flooding. Therefore hillside development must proceed from a firm knowledge of drainage systems.

2.3 Aesthetic Value of Hillsides

Hillsides are geological features and of great aesthetic value to a community, providing attractive settings for dwellings and serving as natural boundaries between communities. Futhermore hillsides offer a variety of dwelling construction possibilities and commanding views and are, therefore, sought after features in the property market. Examples in the Southern Cape Mountain Chain include Llandudno, Houtbay and Constantia. Figure 4 illustrates how the aesthetic value of a hillside can either be destroyed or used compatibly.

3 A REGULATORY APPROACH TO HILLSIDE DEVELOPMENT

Presently in the United States of America there are three approaches to hillside development control:

(i) Slope-density provisions, which decrease allowable densities as the slope increases.

(ii) Soil overlay provisions, which guide the development according to the nature of the soils on the slope.

(iii) A Guiding principles approach, which is relatively free of precise standards but advocates an indepth case by case evaluation.

3.1 Slope Density Provisions

The main purpose of this provision is to define the percentage of a particular parcel of land which can be developed on the basis of that parcel's average slope. The steeper the slope the less the parcel may be developed as shown in Figure 5.

By lowering the density as a function of the slope the potential for environmental degradation is decreased. The accumulative advantages of the provision include public safety, lowering of development costs and maintaining aesthetic values.

Another attractive feature of slope-density provisions is the substantial flexibility in setting exact standards, and these standards can be adapted to suit local conditions. For example, less restrictive controls may prevail in a region composed entirely of sloping areas, while more restrictive controls will prevail in an area where a history of steep-slope failures or extensive erosion is common.

There are three principal variations of the slope-density approach; namely slope-erf size, slope-natural state, and slope-dwelling units.

3.1.1 Slope-Erf size

Minimum erf size increases with increase in average slope, thus defining a relationship between average slope and required minimum erf size.

Table 1 compares the slope-erf size relationship for three American jurisdictions, namely Sante Fe in New Mexico, Phoenix in Arizona and Orange County in California. The table illustrates that on a 5 per cent average slope a minimum erf zise of 0,1 hectares is proposed in Sante Fe and on a 50 per cent average slope in Orange County a four hectare minimum erf size. Local conditions obviously play a key role in determining the minimum erf size.

There has also been regulatory response to the hazards of impervious surfaces. This comes forward in a maximum coverage regulation which specifies the amount of land on a slope that may be covered by impervious surface. The proposed Orange County regulations provides for a maximum coverage of 40 per cent on a 7 000 square foot minimum erf situated on a 20 per cent average slope.

When designing minimum erf-slope relationships it is important to bear in mind that liberal terracing and cut and fill allowances in steep-slope areas can lessen the effectiveness of such regulations.

Table 1 Slope-Erf Size Requirements

Percent Average Slope	Sante Fe, N.M. (Proposed)	Phoenix, A.Z.	Orange County, C.A. (Proposed)
	Hectare	*Hectare*	*Hectare*
5	0,1012	No Reg.	No Reg.
10	0,2024	0,2226	No Reg.
15	0,4048	0,3643	No Reg.
20	0,8097	0,5263	0,0647
25	2, 024	0,8097	0,0890
30	No Development	1,3481	0,1781
35+	No Devel.	2,0242	0,4048
40	No Devel.	2,0242	2,0242
50+	No Devel.	2,0242	4,0485

3.1.2 Slope-Natural state

The amount of land to be left in its natural or undisturbed state increases with the slope.

On such natural land, only uses which do not require topographical change or major construction, such as conservation or reacreation are permitted.

Table 2 compares the slope-natural state requirements of Chula Vista, Pacifica and Thousand Oaks jurisdiction in California, the variation reflecting local natural conditions.

Table 2 — Slope-Natural State Requirements

Per Cent Average Slope	*Per cent of site to remain in natural state* — *Chula Vista, CA*	*Pacifica, CA*	*Thousand Oaks, CA*
10	13,75	32	32,5
15	31,25	36	40,0
20	43,75	45	55,0
25	62,50	57	70,0
30	90,00	72	85,0
35	90,00	90	100,0
40	90,00	100	100,0

3.1.3 Slope-dwelling units

This is a specification of the number of dwelling units allowable according to the degree of the slope. The number of permissable dwelling units falls as the slope increases.

Table 3 illustrates a comparison of slope-dwelling unit requirements for three jurisdictions, namely Walnut Creek and Thousand Oaks in California and Phoenix in Arozona.

**Table 3 — Slope-dwelling unit requirements
Dwelling units per Hectare:**

Per cent Average slope	*Walnut Creek, CA*	*Phoenix A.Z.*	*Thousand Oaks, CA*
	Hectare	*Hectare*	*Hectare*
5	No regulation	No regulation	No regulation
10	8,65	4,45	4,94
15	7,41	2,72	3,95
20	6,18	1,73	2,96
25	4,94	1,24	1,98
30	3,71	0,74	0,99
35	2,47	0,49	0,25
40	1,24	0,49	0,25

From the abovementioned tables it can be seen that slope-density requirements are adaptable to local needs. Chula Vista in California has extended this concept into a regulation regarding the maximum area which may be graded as a function of slope.

The use of Slope-Density Requirements

The main source of information for slope-density provisions is a contour map which supplies all the necessary data.

The following formula is used to determine the average per cent slope of a parcel of land.

$$S = \frac{0{,}0001 \times I \times L}{A} \times 100$$

Where S = Average percent slope
0,0001 A conversion factor of m^2 to hectare
I = Contour interval

L = Total length of the contour lines within the land parcel in metres

A = Area in hectares of the subject parcel.

(To achieve accuracy within one percent, the contour interval must be 3 m or less).

In determining A (area of subject parcel) substract any area with a slope greater than that permitted by the particular regulation. For example, the regulation may exclude all land with a slope of greater than 30% from development.

The permitted number of dwelling units, minimum erf sizes and open space requirements can now be determined by using "S", the average slope percentage. In each case, the restriction on the slope, be it minimum erf size or percentage natural state, is determined empirically for each local authority or local condition. Existing developments on slopes are analized, and factors such as slope, bedrock geology, soil type, vegetation and rainfall are scrutinized in order to determine the restriction to development on the slope.

Survey and contour maps are a requirement when new township applications are lodged with local government, and the task of determining average slope is easily within the capabilities of planning authorities.

Shortcomings of the slope-density approach

The potential for degradation increases as a function of slope, but in the case of more gentle slopes, aspects such as erosion are sometimes more a function of soil type or vegetation. Although several factors influence the degradation of a slope, the main strength of the slope-density provisions is the relationship between slope and the potential for degradation.

Local communities with limited technical resources and the absence of site-specific information can make use op slope density regulations. If however, these provisions are combined with site specific information, they can be used by developers and local authorities in maintaining critical environmental values.

The method by which percent average slope is determined is a further possible shortcoming. While one corner of a parcel of land may be very steep and fall under restrictive regulations the rest of the parcel may be gentle sloping. The resultant average slope may thus be lowered enough to allow development of the entire parcel of land.

Regulations have been introduced to avoid this by specifying that any slope above a certain percentage cannot be developed and must therefore be excluded from the average slope equation.

3.2 Soil Overlays

A second approach to the regulation of hillside development is through the use of soil overlay maps. Such an overlay map indicated which areas are suitable for particular types of development based on soil content. Combining soils information with runoff and slope, possible erosion and landslide can be minimized.

3.3 The Guiding-Principles Approach

In this instance every situation is judged on its own merits when reviewing developmental proposals. Precise standards, such as slope-density provisions, can be applied in conjunction with the evaluation of visually significant slopes in their natural state or clustering developments into meaningful units, or the avoidance of mass grading of large pads and excessive terracing.

Furthermore a geology report and hydrological report should accompany developmental proposals.

4. The use of the above mentioned or similar methods to evaluate the sensitivity of slopes prior to development could aid municipalities and local governments in their decision-making process; as it is in sensitive areas such as slopes where these authorities can make an immediate and recognizable impact. But their work is often hampered by the lack of helpful information.

Acknowledgements:

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DESTRUCTIVE AND COMPATIBLE HILLSIDE DEVELOPMENT

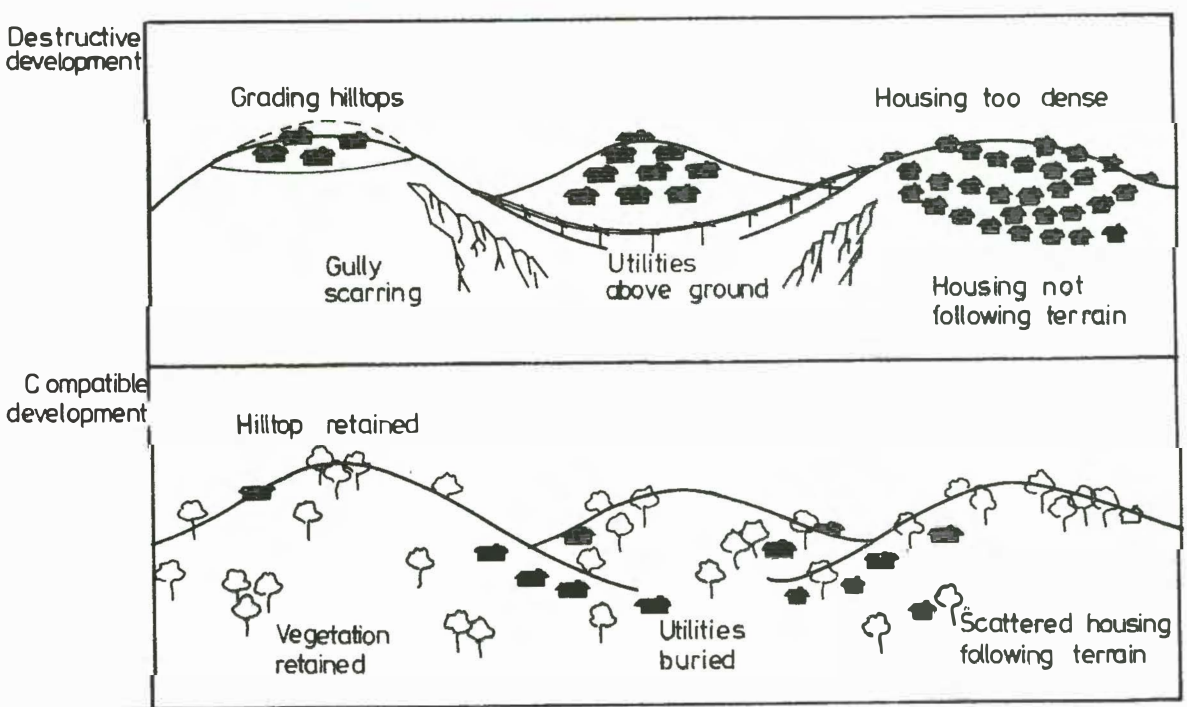

Figure 4

Fotoset deur CABO, Stellenbosch.