internal report **274**

Monitoring of gully erosion at ERA Ranger Uranium Mine Northern Territory, Australia

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January 1998

supervising scientist

Monitoring of gully erosion at ERA Ranger Uranium Mine Northern Territory, Australia.

by

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January 1998

File Reference: JR-05-210

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ENVIRONMENTAL RESEARCH INSTITUTE OF THE SUPERVISING SCIENTIST

Table of Contents

Executive Summary

As part of the proposed rehabilitation at Ranger Uranium Mine, ERARM, investigation into the long term erosional stability of the final design landforms is currently being conducted.

The steep batter slopes of the proposed landform are considered highly susceptible to erosion, with previous investigations highlighting possible problems caused by the development of gullies through the containment structure.

This project constitutes one aspect of this assessment process.

The aims of this project were to:

- Firstly, initiate a gully on the steep batter slopes of the Northern Waste Rock Dump.
- Secondly, to monitor the development of the gully, and hydrology of the gully catchment.

These two components constituted the field trial and were conducted with the assistance of the Office of the Supervising Scientist, ***eriss*** and ERA Ranger Mine.

- The third objective, was assessment of the capability of the landform evolution model SIBERIA to predict the extent, depth and width of gullies formed on the steep waste rock slopes,
- and finally, by comparison between observed and predicted landforms, ascertain dominant erosional processes, and assess implications of additional erosion modules on these predictions.

SIBERIA was adapted to represent the batter - gully catchment study site, and validated through direct comparison between predicted and observed landforms.

Modification of the homogenous initial landform to incorporate heterogeneity, increased catchment outlet width, and implementation of rudimentary armouring module, have encapsulated the dynamism of the development process observed on site.

Depths of erosion are comparable to those observed, and behaviour of gully development is mimicked by model simulations shown here.

1.0 Introduction

1.1 Background

Ranger Uranium Mine (ERARM) is located about 270km east of Darwin, surrounded by the Kakadu National Park, Northern Territory.

As part of the mine rehabilitation strategy, storage of mine tailings, a by-product of the uranium processing system, in existing facilities may be involved. Containment and isolation of this material will be required, with structural integrity of the containment structure of at least 1000 years.

The overall strategy employs engineered landforms designed to avert such potential hazards, with this investigation forming part of the assessment of the erosional stability of these landforms.

The above ground rehabilitation option involves a landform about 4 km^2 area, and rises to a height of 17m above the surrounding area, Figure 1.1.2.

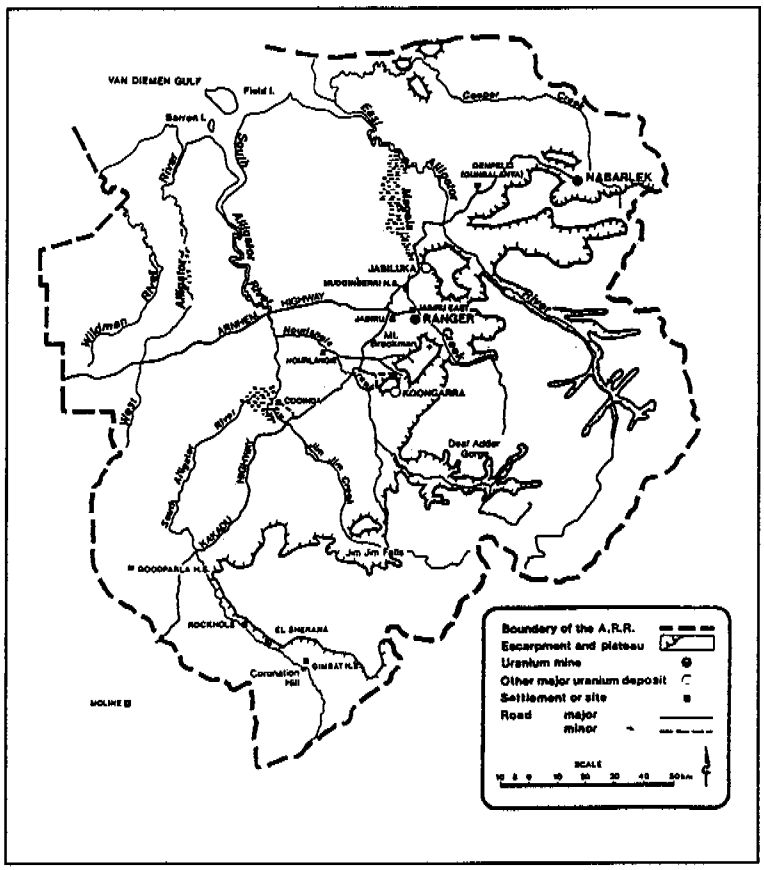


Figure 1.1.1: ERARM is located within the sensitive Kakadu National Park, Northern Territory.

The validation of predictions from the landform evolution model SIBERIA, used to assess the long term stability of these landforms, with a gully erosion study constitutes the major aims of this report.

Regions likely to suffer degradation are highlighted in Figure 1.1.2, where gullies are predicted to form along the batter slopes surrounding the proposed landform. Incision at the transition point between the long cap sites, and the steep batter slopes extenuate back into the structure under some simulation conditions investigated previously.

This project was conducted on the Northern Waste Rock Dump. These waste rock slopes have been exposed for several years, and were considered ideal for the relatively straightforward experimental component of this study.

The overall design for the landform is constrained by objectives not considered here, and the reader is directed to Willgoose and Riley, 1992 for further discussion.

This study concentrates on the development of an experimental regime, and modelling simulations conducted on a small section of this batter slope, with adaptation of the landform evolution model SIBERIA to validate predictions through direct comparison with observed development.

The section of batter slope chosen for this investigation has been exposed for several years, with Figure 1.1.3, and 1.1.4 offering a comparison between relatively freshly exposed material, and remnant fine material found on the study site.

The surrounding National Park is pictured in Figure 1.1.4, with monsoonal rains coming to the region between December and February. The intensity of the climate in the region has been well documented, with exposure to large temperature differentials, high humidity, and large monsoonal rainstorms providing idyllic conditions for rapid degradation of soil surface material by geochemical weathering mechanisms.

During the 96-97 Wet Season, many storm events were monitored with only a relatively few leading to significant alteration of the gully formation once it had been initiated.

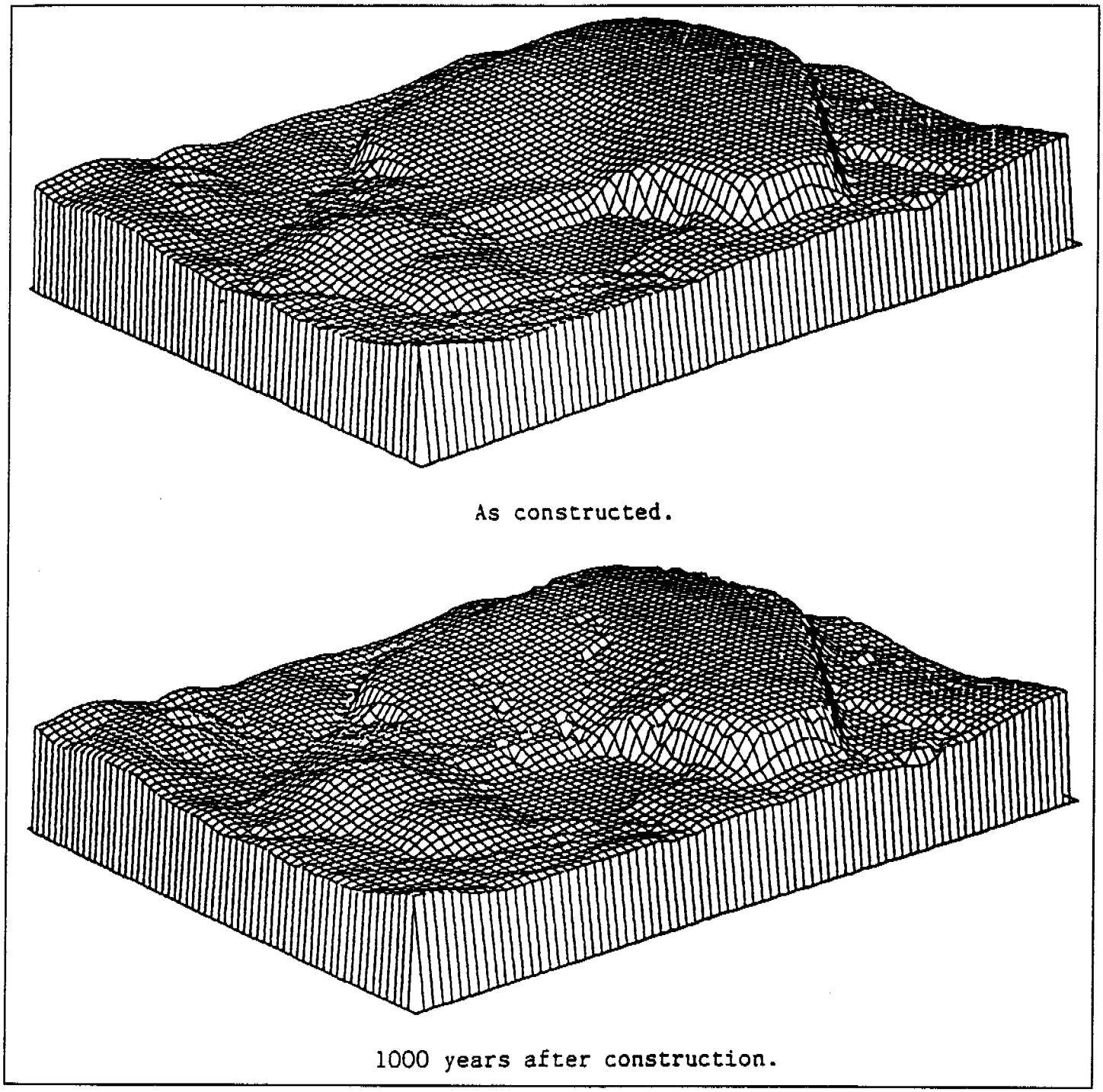


Figure 1.1.2: Regions likely to suffer from erosion are highlighted in this simulation of one of the proposed landforms. Gullies are predicted to form on the steep batter slopes surrounding the structure (Willgoose and Riley, 1993 Figure 4).

Figure 1.1.3: The Southern waste rock dump located about 2km east of the study site, with relatively recently exposed material being deposited.

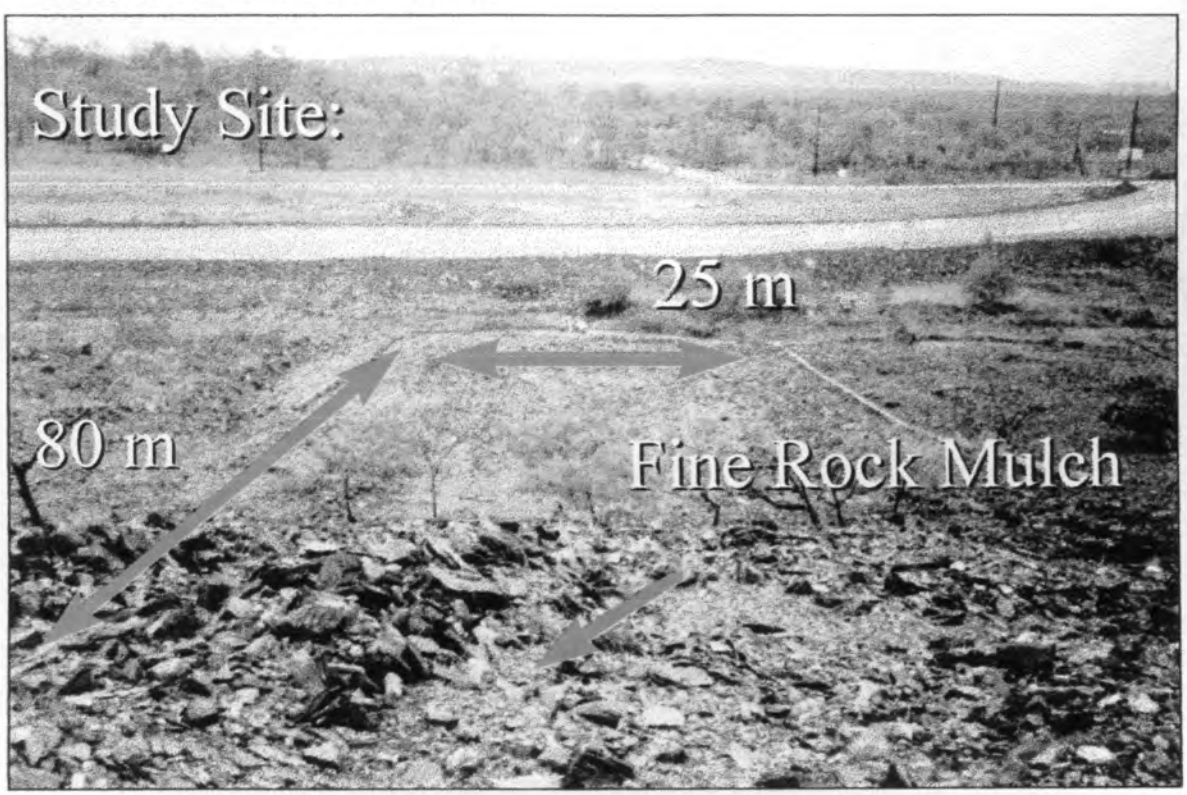


Figure 1.1.4: The batter slopes of the Northern waste rock dump has been exposed for a period of several years. Some natural re-vegetation had occurred, which was not considered to have any impact on the erosion study. It was also noted that relatively fine material has accumulated in the upper surface layers of the study site.

1.2 Objectives

The project constitutes one part of the continuing calibration and validation of the landform evolution model SIBERIA, used to predict erosional development of proposed rehabilitated landforms.

Amongst the objectives of this work, the implementation of a field trial involved the following:

- Construction a catchment on top of the WRD at ERARM, and establishment of monitoring regime necessary to monitor the hydrology of the constructed catchment, and the development of the gully on the waste rock slopes, once it had been instigated.
- Monitoring and recording the formation of the gullies on this slope, once initiated, and advise on the suitability of different measurement techniques, as well as the monitoring of hydrology of the gully catchment throughout the numerous storm events experienced during the 96-97 Wet Season.

Establishment of the field trial was conducted with the assistance of the geomorphology team at the Office of the Supervising Scientist ***eriss***, and ERA Ranger Mine. Development of monitoring regime to record hydrological and sediment loss estimation was conducted during the Wet Season, late November to March.

The next component of the project involved computational work conducted at the University of Newcastle as part of a final year environmental engineering project by the author, with the assistance of Dr G.R. Willgoose, author of the SIBERIA model. This work involved the following objectives:

- Adaptation of the landform evolution model SIBERIA to be representative of the gully catchment - batter slope study site,
- Assessment of different erosional mechanisms, by comparison between model simulations, through systematic implementation of an array of erosion modules,
- and, By comparison between predictions generated by the model and development observed on site, assess the capability of the model to predict the size and extent of gullies formed on the steep waste rock slopes.

1.3 Field Trial

Amongst the aims of this project, the construction of a catchment and the instigation of a gully on the batter slopes of the NWRD included the implementation of event monitoring equipment. Recommissioning of a previously established sheet flow erosion plot, with associated equipment and expertise supplied by ***eriss***, and earth moving equipment and labor supplied by ERA Ranger Mine to construct the catchment, constituted establishment of the field site.

Hydrology of numerous storm events encountered during the experimental period was devised using discharge-head relationship devised from hydraulic control structure attached to the small erosion plot, with rainfall tipping bucket gauge and water level sensor attached to electronic logging equipment for continuous monitoring.

The results from previous work conducted by ***eriss*** was used to determine on-site erosional characteristics and were incorporated into an estimate for the total sediment loss relationship, which constitutes one part of the input requirements for the landform evolution model SIBERIA, together with results from the rainfall-runoff hydrology model calibration.

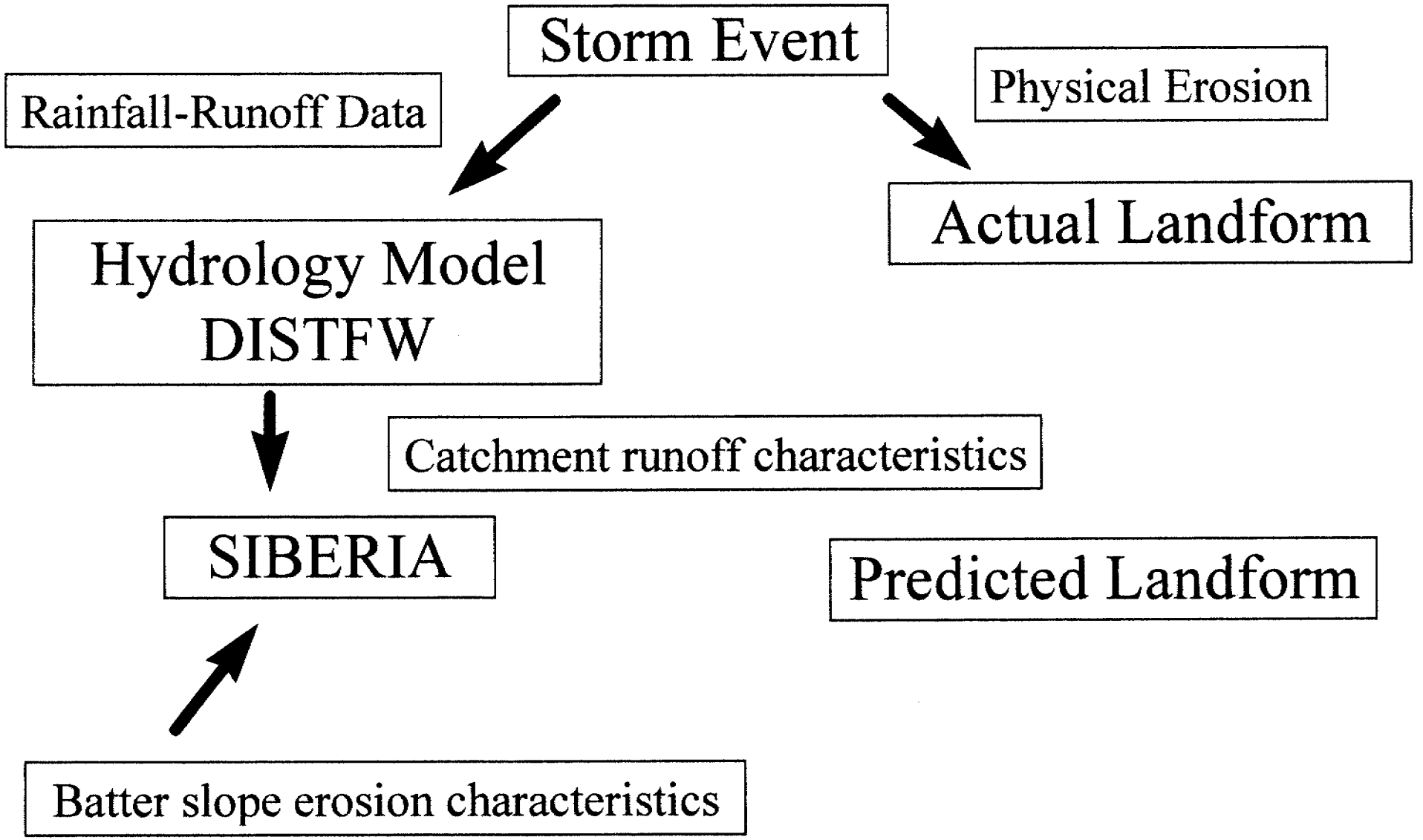
Figure 1.3.1 outlines the relationship between the fundamental components of the gully erosion study with discharge-runoff entrained within the constructed catchment funnelled over the side of the steep batter slopes.

These two major components summarise the calibration and input requirements of the SIBERIA model, with the relationship between catchment runoff and total sediment loss following typically adopted forms.

1.3.1 Hydrology Model

Runoff is the most important determinant in estimates of soil erosion, and consequently in the initiation and continuing development of gully erosion. (Willgoose *et al*, 1992). The hydrology model used to fit natural rainfall data from plots on top of the NWRD was based on kinematic wave flooding routing model DISTFW, incorporated within the non-linear regression fitting package NLFIT.

Experimental Methodology



igure 1.3.1: The gully catchment with the small scale monitoring plot supplied water for from an area of 7213m^2 to the steep batter slopes of the NWRD. The combination of hydrology and stimates of total sediment loss from the catchment, are used to calibrate the landform model SIBERIA, with direct comparison between observed and predicted landforms validating these herent assumptions.

The kinematic wave flood routing model, DISTFW is a distributed parameter generalised kinematic model (Willgoose, Kuczera, and Williams, 1995).

This model discretised the catchment into a number of sub-catchments connected together with a channel network, and was calibrated using natural rainfall-runoff data obtained from the cap site during the monitoring period.

The model simulates Hortonian runoff with Philips infiltration, with kinematic wave component influencing properties of the predicted runoff hydrograph from the gully catchment, whilst infiltration rates mainly influence of runoff volume.

The two kinematic wave parameters are Cr, and e_m that are defined by flow geometry and surface roughness respectively. The infiltration rate (Hortonian runoff with Philips infiltration) is a function of the cumulative infiltration and the two parameters in this case are S_ϕ and ϕ, Sorptivity and Long term infiltration respectively. Further detail of assumptions, conclusions and description of model basis are found in Evans, in prep., and Willgoose *et al*, 1995.

As outlined below, values adopted for calibration of user defined runoff module used in SIBERIA landform model reflect accumulated data from work conducted at ERARM.

The calibration procedure used for fitting of parameters using the non-linear regression package NLFIT involved the following procedure:

- Fit Cr and ϕ (approximate fitting of timing, and volume of hydrograph)
- Fit S_ϕ and ϕ (more exact fitting of volume)
- Fit Cr and e_m (routing behaviour)
- Fit all 4 parameters (for exactness)

Although Kuczera notes that this sheetflow assumption is widely discredited, except under ideal conditions, parameters for infiltration and conveyance characterise the hydrological behaviour of each of these storm events, with these issues considered in Evans, in prep.

1.3.2 SIBERIA evolution model

Computer models used to simulate the changes of landforms over time provide a link between the study of process, and the study of landforms.

A landform evolution model using runoff and erosion physics to simulate the changing form of a catchment with time has been developed. Such aspects of computer modelling for the longer term timescale, that operate in geomorphology, can rarely be substantiated with short term measurements. The combination of time and space, usually physically based of continuity of mass, provide a predictive tool with forecast capability as well as a tool for improved understanding, (Kirkby, 1996).

The simplicity of any simulation model is an important characteristic, with field observation consistent with the theoretical explanation of landscape processes.

The computer model SIBERIA (Willgoose, Bras, and Rodriguez-Iturbe, 1991a-d) is amongst these simulation models capable of prediction of landscape forms in the longer term, and is used to study the erosional development of catchments and their channel networks.

Elevation changes within the catchment are simulated using a mass transport continuity equation applied over geologic time (Willgoose *et al*, 1993). If more material enters a region than leaves then elevations rise and vice versa, with the model averaging the mass transport process over time. The mass continuity equation used consists of two major component, fluvial sediment transport and diffusive mass movement mechanisms such as soil creep, rainsplash, and landslide.

Other significant aspects of the erosional development of the catchment include the differentiation between processes occurring on hillslopes and those occurring in channels.

Channelisation is simulated using another governing equation, once a channel initiation threshold is exceeded (a value beyond which a channel is initiated). This threshold represents a transition in the dominant erosion mechanism, with this second component of the model not being considered in this study (Willgoose *et al*, 1991a-d).

The governing equation of elevations within the catchment model is expressed as:

$$\frac{\partial z}{\partial t} = C_o + \frac{\nabla q_s}{\rho_s(1-n)} + D\left(\frac{\partial^2 z}{\partial x^2} + \frac{\partial^2 z}{\partial y^2}\right) \text{ (Willgoose } et\ al\text{, 1992)} \qquad (1.3.1)$$

where

z = elevation
C_o = tectonic uplift (this term neglected over short term)
q_s = sediment transport per unit width,
$\rho_s(1-n)$ = bulk density of sediment

Validation of the evolution model SIBERIA, is presently being conducted with experimental laboratory analysis and field trials such as this one.

The characteristic of the natural catchment once formed, is substantially different to that proposed in the rehabilitation, with long hillslopes contributing flow to the tops of the batter slopes considered likely to trigger erosional degradation of these slopes.

The validation of predictions from the landform model is at the heart of this investigation, with preliminary field trial estimate the physical characteristics of a gully formed on the batter slopes.

By assessing the outcomes of this modelling analysis insight can be gained into the other factors contributing to the formation of gullies on the batter slopes, that are not presently not fully implemented in the model.

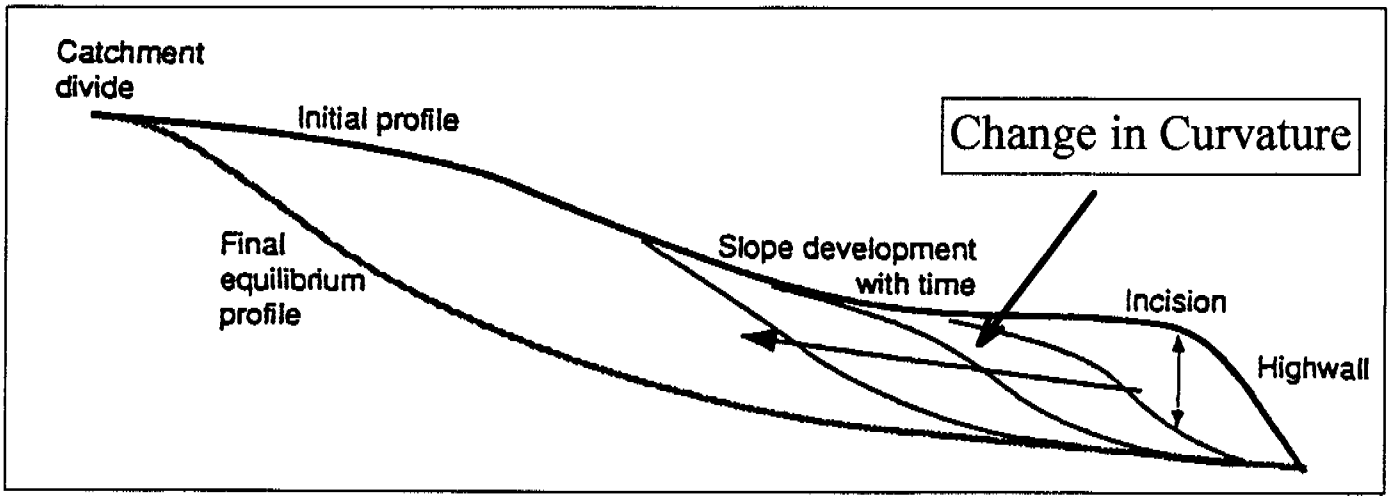


Figure 1.3.2: The schematic diagram of initial landform is considered far from equilibrium profile (Willgoose *etal*, 1992 Figure 6.1)

2.0 Experimental

The field trial involved monitoring hydrologic behaviour of the gully catchment (using the small scale erosion plot), and intensive measurement of the dimensions, size and extent of the gully once formed on the steep waste rock slopes.

Cap Site

From previous work conducted by ***eriss*** at ERARM, a small scale erosion plot remained centrally located on top of the NWRD.

The plot consisted of an isolated area bounded by damp coarse bituminised aluminium, with a 250mm diameter PVC sewer pipe located at the downstream end. This plot was of standard size to those used previously, at 20m by 30m (591m^2), constructed on relatively flat ground of 1-2% slope, consisting of relatively undisturbed, unvegetated waste rock surface material.

The downstream sewer half pipe was set into the ground at surface level. Sediment-laden overland flow could deposit larger sized particles along this pipe referred to as bed load, whilst suspended material was transported through the hydraulic control structure, although these devices were only used to measure rainfall and runoff for the cap site within this study.

A standard 150mm RBC flume was recommissioned, with a discharge-head relationship assumed from previously constructed devices:

$$Q(L/s) = 18.4 * H + 940H^2 \qquad (2.1.1)$$

where

H = height of water or head, m
Q = flow discharge, L/s

The stilling basin served dual purposes; reduction of surging of flow discharge leading to erroneous results, and to provide a collection point for bed load material, for continuous monitoring.

Figure 2.1: A standard 150mm flume was re-commissioned and used for monitoring hydrological data for the study site. Discharge recorded from the cap site area 591m^2, together with cumulative rainfall was used to calibrate the hydrology model DIST-FW, and hence characterise each of the storm events.

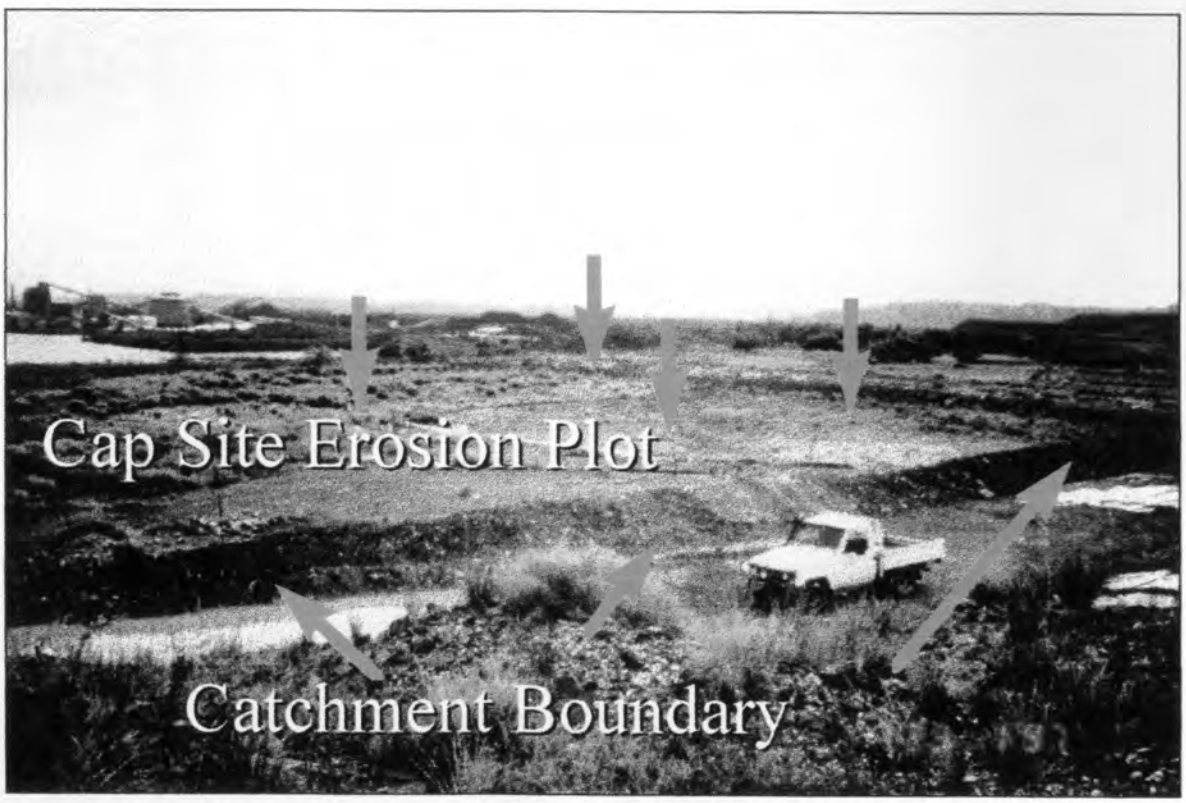


Figure 2.2: Monitoring equipment was attached to the recommissioned erosion plot located centrally in this figure, within the constructed gully catchment of area 7213m^2.

A drainage channel was also constructed downstream from the cap site to dissipate flow discharge and prevent backing up of the monitoring site during large storm events. This experimental design has been in previous site investigations, and reference is made to other studies for construction details (Moliere, Evans, Riley and Willgoose, 1997).

The DISTFW rainfall-runoff hydrology model was then used to evaluate each of the significant storm events, with the catchment discretisation described Figure 2.3, with model catchment description detailed in Appendix A.

Gully Catchment

ERARM constructed a catchment with large earth moving equipment to create an irregularly shaped soft earthen bund wall, which was used to generate a large water supply for the study site.

The surface material disturbed by the construction of this catchment appeared as red-brown sediment during the preliminary storm events, however this material tended to subside in concentration over time, although was still evident at the conclusion of the monitoring period.

The bund wall reached a height of 1m and effectively captured all rain falling within the gully catchment, and directed it through a notch at the downstream end to the batter slope, illustrated in Figure 2.2. The site was relatively flat, with slope ranging between 1 and 2%, slope length of 110m, with an area of 7213m^2. Although a relatively uniform surface, some sections were depressed, leading to regions pooling during large storm events.

During the construction of the gully catchment, a small reservoir was inadvertently created along the upstream side of the entrance to the batter slope. This reservoir effectively shielded the batter slope from high surface flow velocities, and buffered the impact of all but large events on the slope, once the gully was initiated. Runoff collected during a rainfall event was subsequently released slowly, well after the end of storm activity.

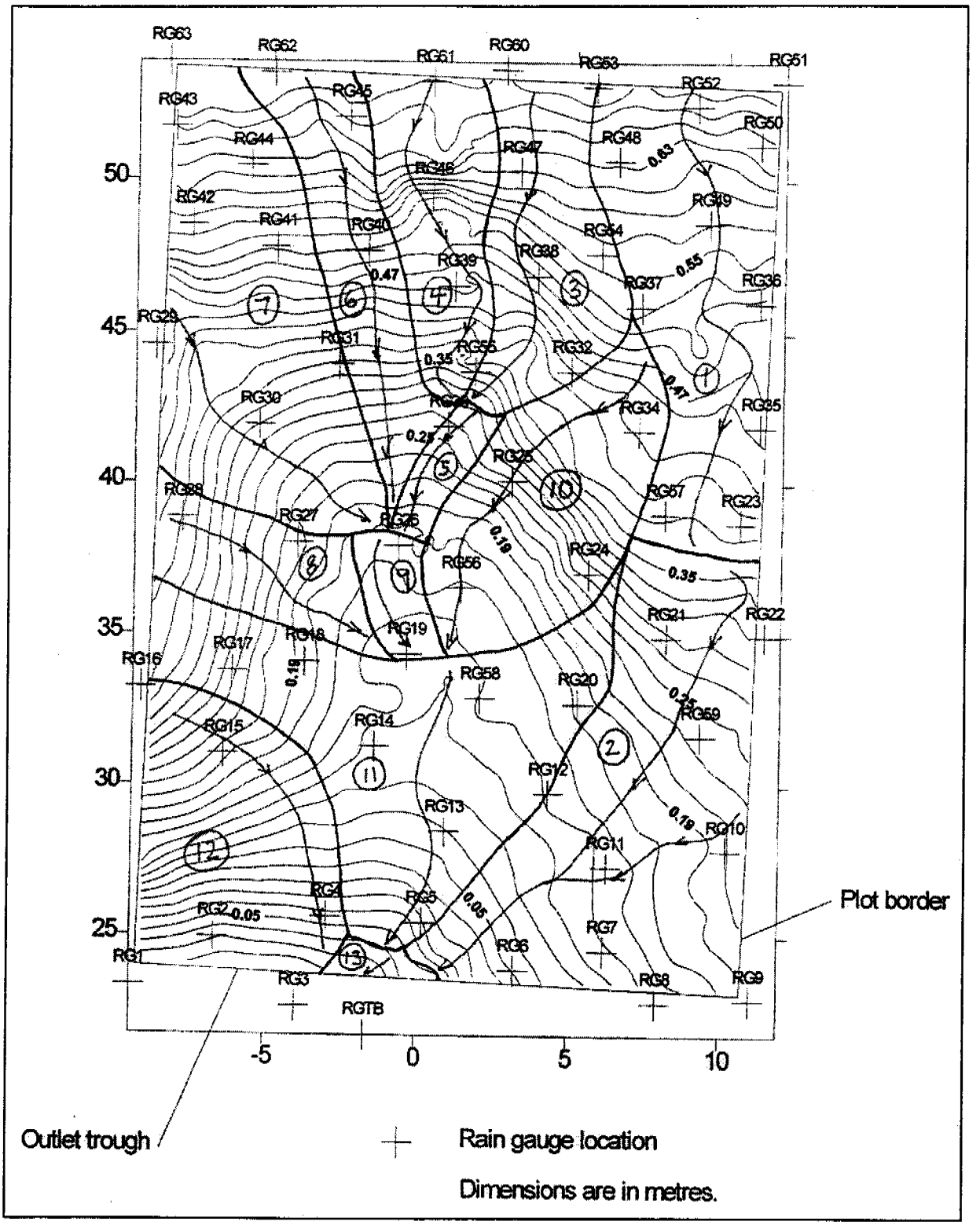


Figure 2.3: Cap site subcatchment discretisation, noting that kinematic wave routing model evaluates each of this subcatchment using Hortonian overland flow with Philips infiltration, Evans *etal*, in prep.

Intensive investigation of the response of the gully catchment may be conducted in the future, although the reservoir was neglected given the method of implementation of the hydrology model into the landform model SIBERIA, with Figure 2.4 illustrating the subcatchment discretisation for this site.

Calibration of the DIST-FW hydrology model to include these storage effects was neglected, as pooling did not seem to significantly affect the passage of large storm events, where reservoir water level exceeded the weir height and rapid moving water cascaded directly into the gully network.

These measurements together with the catchment analysis outlined in Figure 2.3, and Figure 2.4 below, constitute the input requirements for the hydrology model. Appendix A contains estimates of slope length, and area, as well as with for each of the elements incorporated in the catchment description file *.fw.

For the purposes of modelling discharge-runoff-sediment transport relationship, such factors as discrepancies between small and large scale catchment response have been neglected, with assumption that behaviour of cap site could be scaled up to represent the whole catchment. Of the many components in operation on site, large pooling leading to excessive infiltration, ponding in reservoir behind leading edge of bund wall leading to filling of this storage area before commencement of flow in the gully, have been neglected considering the magnitude of erosional development of the batter slope.

The model was calibrated using hydrology data extracted from the cap site using 3 separate storm events. These events were considered significantly large and were noteworthy because of changes in the size and dimension of the gully.

Once calibrated comparison between small scale erosion plot and gully catchment could be made using area-discharge scaling factor of ~12.204 ($7213m^2$ / $591m^2$).

Batter Slope

The batter slope regions of the proposed landform are considered highly susceptible to erosion. The study site is located adjacent to a previously eroded surface which had been triggered during intense monsoonal activity 95-96 Wet Season.

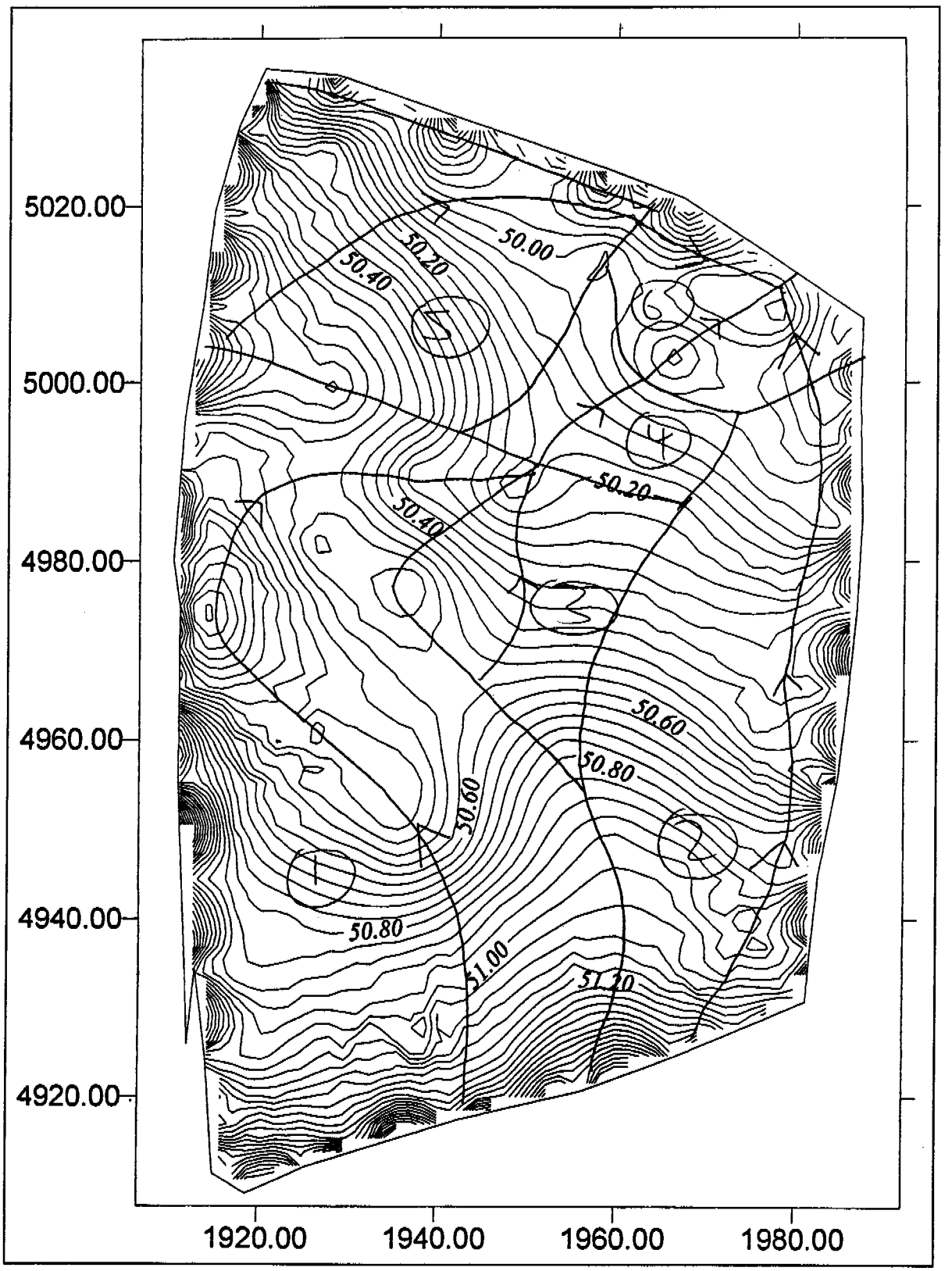
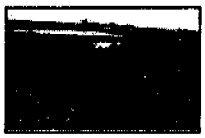


Figure 2.4: Gully Catchment was discretised into a number of subcatchment for implementation into the DISTFW hydrology model. Although some areas of the site were depressed leading to pooling, and the existence of the buffering reservoir, these were neglected given the method of implementation into the modelling package SIBERIA outlined below.



Monitoring Gully Formation

The slope is complex, changing profile from 1:3 through to 1:8, concave in upper sections and convex in lower sections. From previous work conducted by eriss, a large scale concrete apron and flume remained at the base of this slope. Extensive survey details were undertaken prior to the commencement of monitoring, as well as mid-way through the Wet Season, and after the completion of monitoring. Figure 2.6 highlights the complex nature of the slope profile, with measurement transects taken at a series of 10 points along the slope. Erosion pins were also utilised in an attempt to monitor changes in surface profile following each storm event.

Measurements were taken form within the gully, once it had formed, with fluorescent lead-pigment paint used to delineate active sections of the slope, Figure 2.5. Intensive analysis of gully formation has been determined to be relatively futile, with overall behaviour and erosion depths considered to be the most important findings from this study. The purpose of transect measurements were initially to determine the cross-sectional area of the gully at various points down slope. Conversion of these measurements to surface elevations involved estimation of height of string elevation, assumed to be horizontal across slope, and subtracting the recorded vertical height between string and surface. The volumetric difference between each of the 3 significant storm events could then be determined using a numerical mapping package.

Erosion pins were 50cm long, and sunk about 25cm to 35cm into the batter slope surface. An extensive measurement regime is included in Appendix B, although it is noted that measurements taken involved large discrepancies due to the nature of waste rock material. Detailed measurements taken for each of the cross-sectional areas, as well as widths of gully at different locations are also are summarised in Appendix B.

Reference is made to the use of survey equipment for future analysis on site, given the medium time scale expected for erosional development. According to the experimental method, the movement of material out of transect lines constituted a significantly eroded section, even though only one or two boulders may have been dislodged. This is evident in Figure 2.5, where removal of fine material has left large rock fragments exposed.

The geological characteristic of the layers of the batter slope were considered important, as pictured in Figure 2.7, with variability in erosion behaviour, particle grain size, resistance to scouring adding complexity to the overall behaviour of the material. Implementation of an approximate armouring erosion module to the landform model involved conservative estimation of the erodibility of this material based on mean particle diameter, d_{50}.

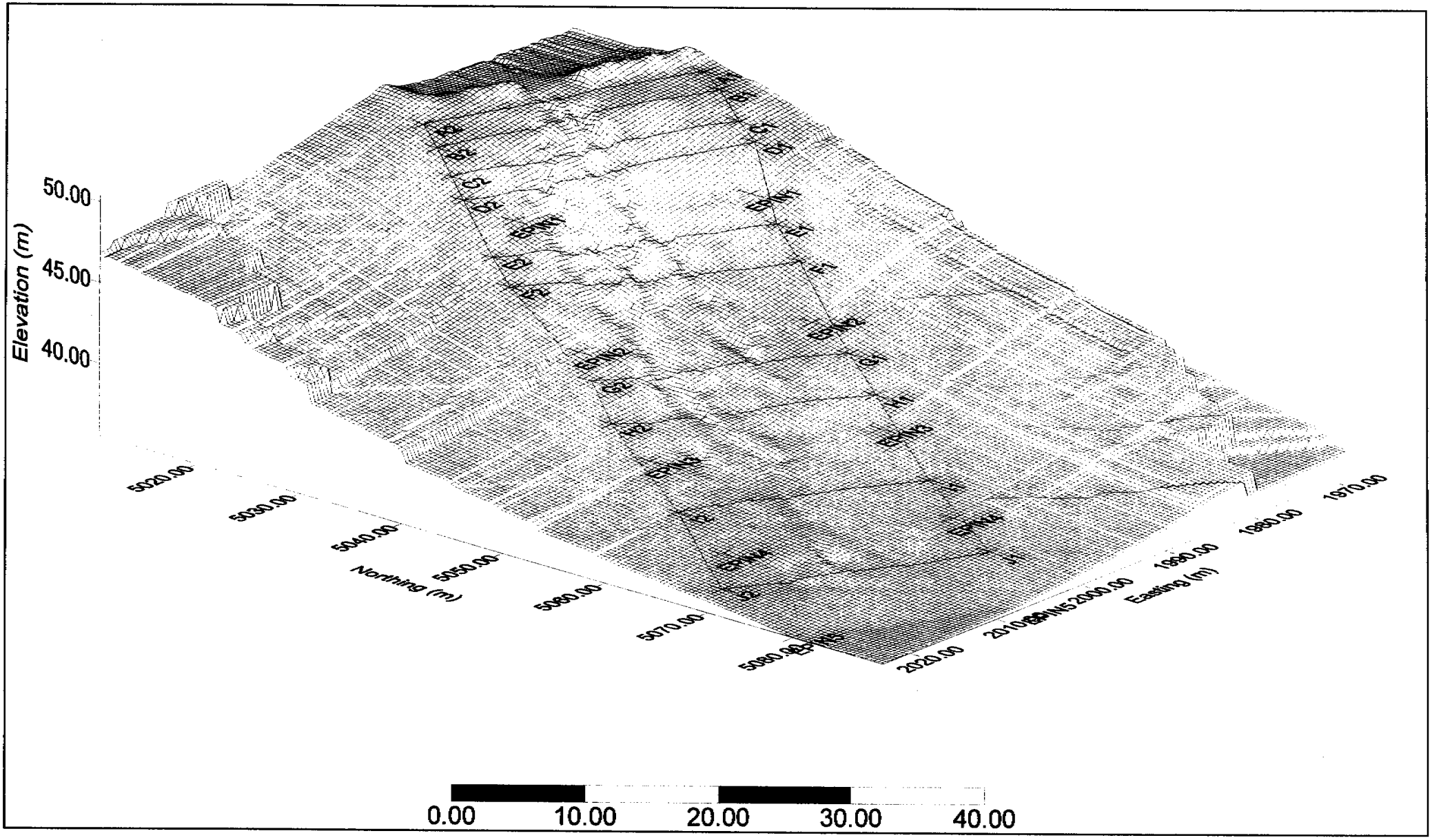


Figure 2.6: The batter slope study site was examined using a series of measurement transects located at 10 positions along the slope, with residual series of erosion pins from previous studies also used, but found to be unsuitable in this application.

Figure 2.5: Measurements were taken using twine strung across two starposts at 10 positions along the hillslope. Although considered a crude method of measurement, the inherent variability of rock material dictated that approximations could only suffice.

Figure 2.7: The erodibility of the waste rock material was dependent on the mean grain size, relative weathering and overall rock consistency. Erosion pins used, were considered ineffective, with excavation of gully reaching 50 to 60cm in places removing these devices.

3.0 Field Trial Results

3.1 Hydrology

Rainfall-runoff data from the cap site, for the three storm events occurring on 261296, 010197, and 230197 were used to calibrate the DISTFW model using the non-linear regression package NLFIT. The parameters Cr and ϕ, S_ϕ and ϕ, and Cr and e_m were fitted firstly, with Sorptivity found to be effectively zero for all calibration runs, and was set to be zero for subsequent investigations. Hydrographs, and cumulative rainfall for each of these 3 significant events are presented in Figure 3.1.1.

The parameters were calibrated using individual storm events, whilst the next stage incorporated calibration of multiple storm events (using all three of these storms together). The purpose of multiple regression analysis was to characterise an average hydrologic behaviour for the cap site, and consequently the gully catchment.

The data appears well fitted with error in the estimation of Cr ranging between 17 and 27%, whilst em ranged between 3.8 to 4.9%, and ϕ between 5.6 and 15% appear to be within acceptable ranges.

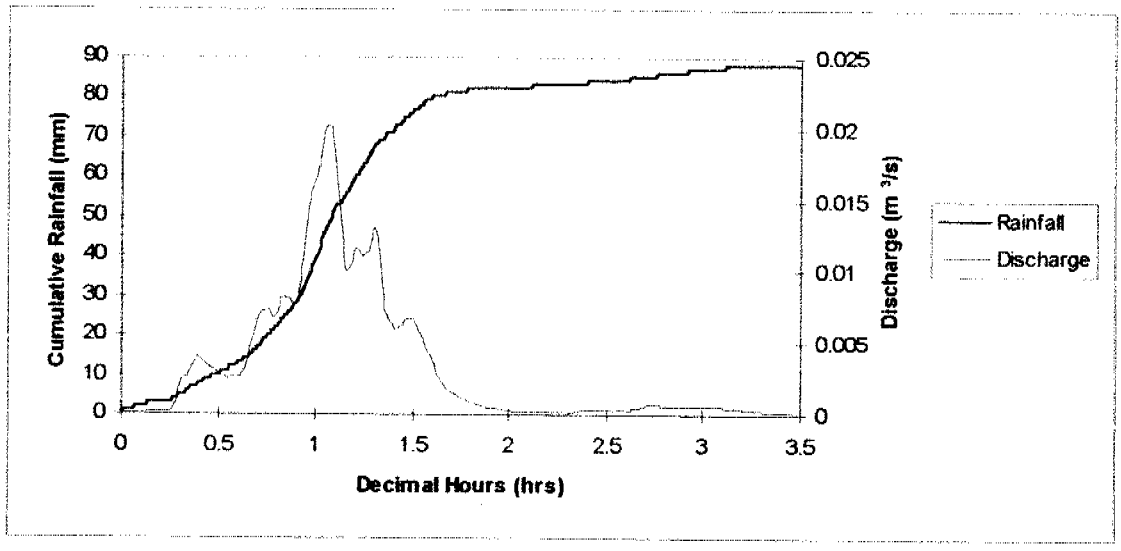
Prospective errors in estimation of Cr, em and ϕ are: 15.2%, 3.5%, and 6.8% respectively, suggesting additional two storm events provide marginal improvement in estimating parameter values.

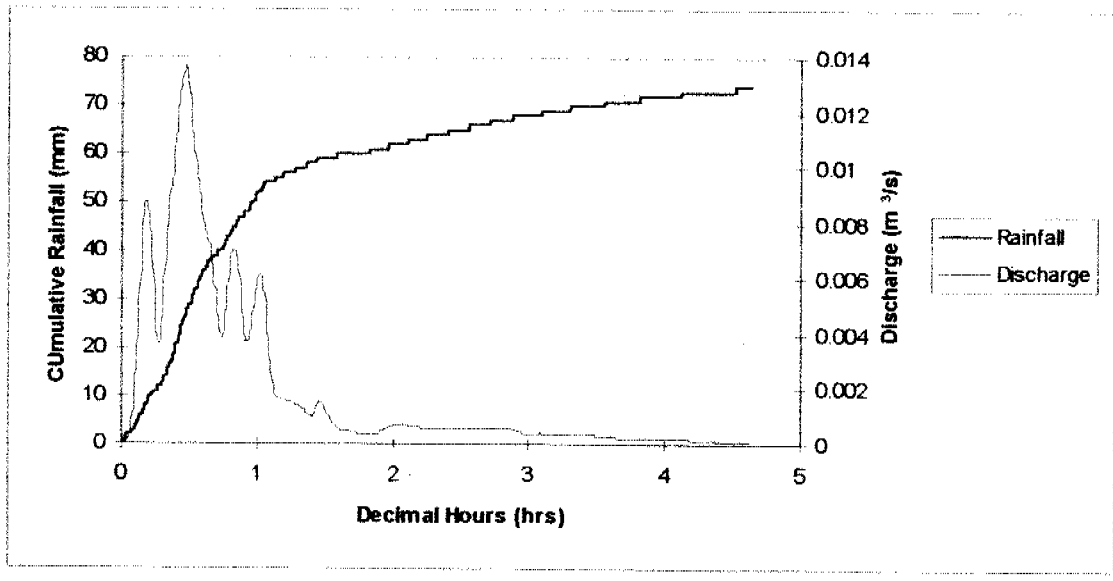
Table 3.1.1: Calibration results for cap site for individually fitted storm events: 261296, 010197, and 230197. Calibrated value and standard deviation is expressed.

Event	Cr ($mm/hr^{0.5}$)	e_m	ϕ (mm/hr)
261296	25.59 ± 6.92	2.52 ± 0.12	7.27 ± 1.05
010197	5.61 ± 0.95	1.55 ± 0.06	16.34 ± 0.92
230197	5.44 ± 0.70	1.27 ± 0.05	6.57 ± 0.99

Table 3.1.2: Joint calibration results for the cap site for the three designated storm events (mean ± s.d.).

Event	Cr ($mm/hr^{0.5}$)	e_m	ϕ (mm/hr)
average	7.90 ± 1.20	1.72 ± 0.06	11.74 ± 0.80





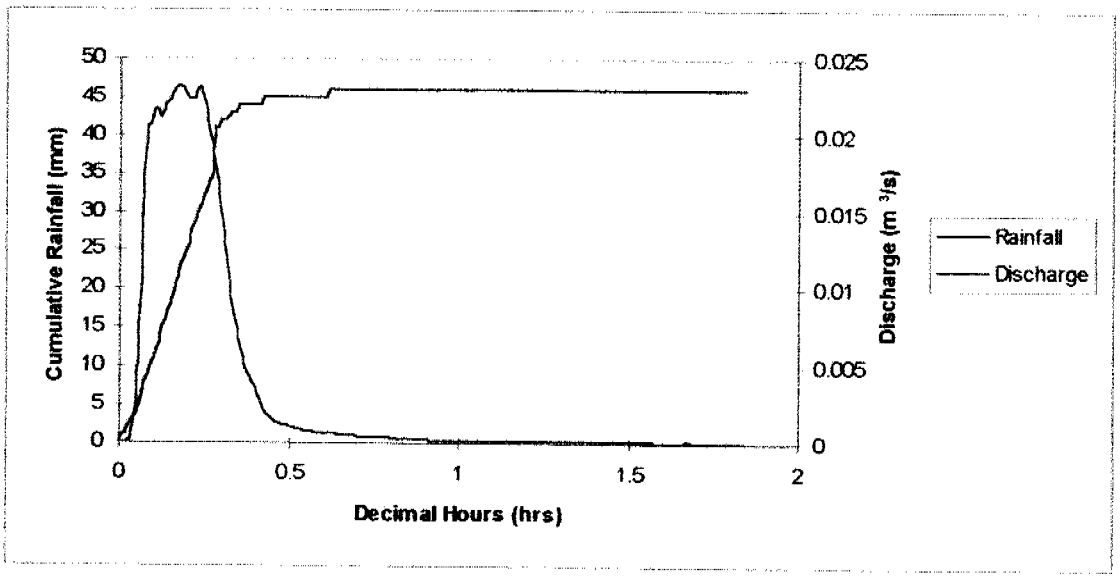


Figure 3.1.1: Observed runoff hydrographs and cumulative rainfall plots for cap site storm events monitored on: a) 261296, b) 010197, and c) 230197.

Table 3.1.3: Calibration results for gully catchment using individual storm events (mean ± s.d.).

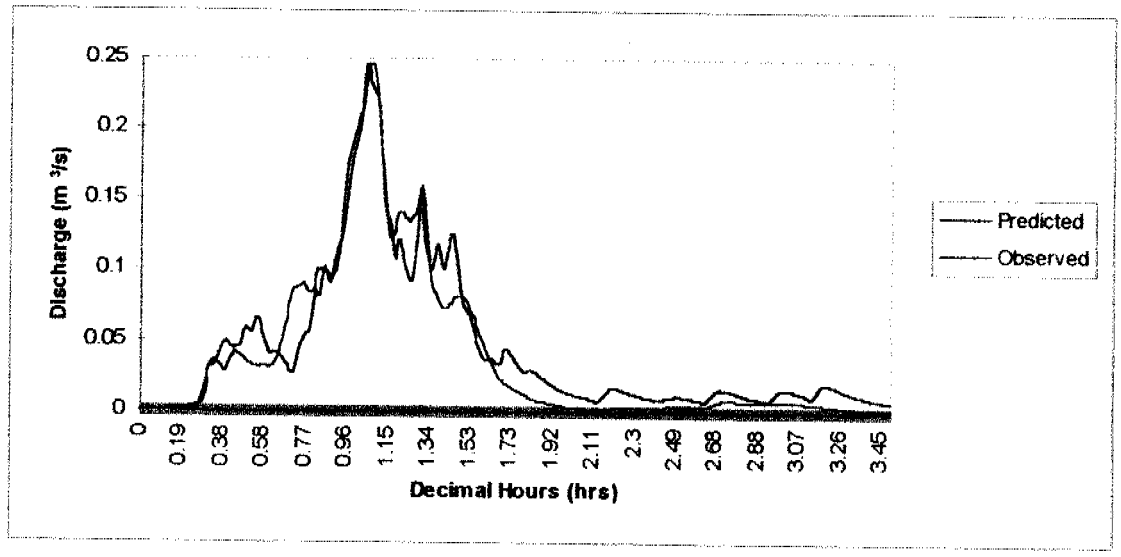
Event	Cr ($mm/hr^{0.5}$)	e_m	ϕ (mm/hr)
261296	35.29 ± 3.33	2.67 ± 0.12	6.59 ± 1.09
010197	67.45 ± 7.15	1.78 ± 0.08	29.64 ± 1.00
230197	82.42 ± 5.19	1.36 ± 0.06	5.18 ± 1.18

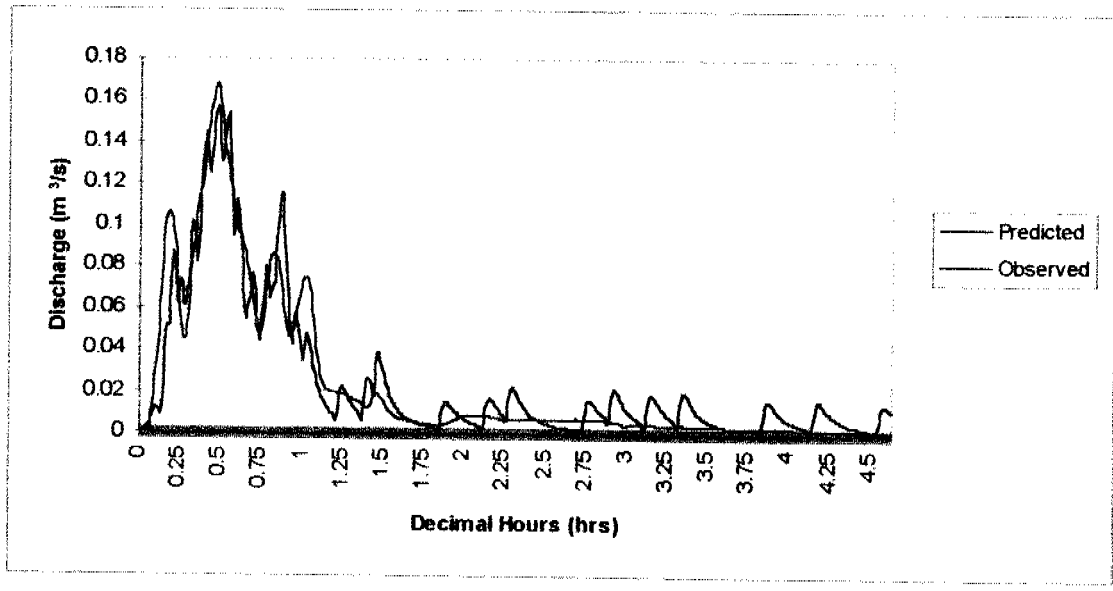
Table 3.1.4: Calibration results for the catchment, for runoff events fitted simultaneously (mean ± s.d.).

Event	Cr ($mm/hr^{0.5}$)	e_m	ϕ (mm/hr)
average	85.87 ± 6.55	1.84 ± 0.06	24.74 ± 0.79

The next stage of the rainfall-runoff calibration involved approximating the discharge from the gully catchment itself. As outlined above, an approximate scaling was employed, as installation of monitoring equipment at the head of the gully network would have disturbed water flow. Adjustments were made to the catchment description file *.fw, and a multiplier factor of 12.204 was used for each of the runoff (*.ro) files. The model parameters Cr, em and ϕ were fitted once again, with Sorptivity S_ϕ again found to be effectively zero. From Table 3.1.3, the error in estimate of Cr, em and ϕ were (6.3% to 10.6%), (4.4% to 5.5%), and (3% to 22.8%) respectively. These values compare well with Table 3.1.1, noting that error bounds are only exceeded for ϕ, with event 230197. Errors in estimation of Cr, em and ϕ are 7.6%, 3.3%, and 3.2% compare favourably with results from Table 3.1.2. Assumptions regarding the effect of scaling up of discharge-runoff data from cap site to be representative of gully catchment seems to have been a reasonable one. The hydrographs and corresponding predictions for gully catchment are illustrated in Figure 3.1.2 below, with these events adopted for calibration of storm events into the SIBERIA landform model, representative if the catchment batter study site.

Further investigation and comparison may be made with results from previous hydrology studies conducted on the cap site, Evans in prep., however these considerations are beyond the focus of this study. It is noted from Table 3.1.1, the variation between values of ϕ, and em are replicated in fitting for cap site against the gully catchment. However conveyance (flow geometry, Cr) for the first event seems to remain small, characteristic of the nature of the storm event observed in Figure 3.1.1a. An estimate for e_m of 1.72, and 1.84 for cap site and gully catchment, is consistent with theoretical interpretation of surface roughness of the two sites.





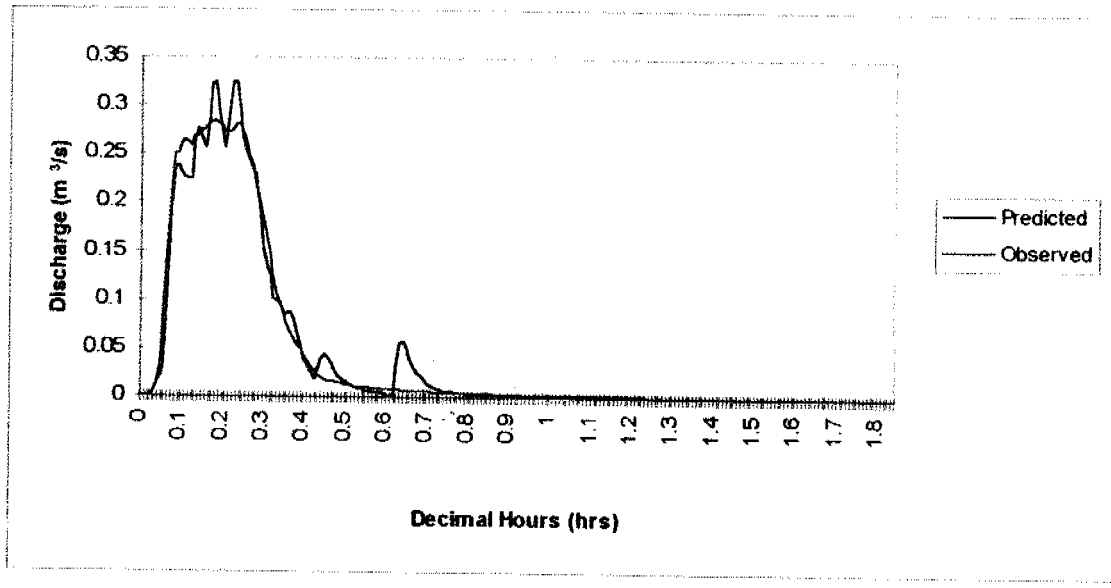


Figure 3.1.2: Gully Catchment hydrographs and predictions from the multiple regression fitting of all three significant storm events; a) 261296, b) 010197, and c) 230197.

3.2 Gully Development

Formation of a gully on the steep batter slopes of the NWRD was monitored during the 96-97 Wet Season. Analysis of the characteristic and nature of the initiation and development of the gully provides a field basis for continuing validation of the SIBERIA model.

The original topography of the site is described in detail above, with an inherent large degree of complexity in both form and constituency. The spatial variability in the waste rock material, illustrated in Figure 2.7 was significant, with the site being exposed and undisturbed for the past several years. Geochemical weathering processes which by their nature, are extremely significant in the region, were considered dominant factors in formation of the soil type material found on the upper surfaces of the slope. The fine particle material on the upper slopes was expected to erode quickly, exposing the coarser grade material below. The upper section of the slope Rows A to C had a very thin layer of fine material compared to between Rows E to F to G, where accumulation of 40cm of fine mulch had occurred. This may have been a product of the construction process of the rock dump, or dependent on the nature of weathering that has occurred.

The erodibility of the waste rock material was expected to be highly differential, with spatial heterogeneity having dramatic consequences on the final shape and form of the instigated gully network. The site characteristics were segregated into the following categories: heterogeneity, differential erodibility with depth and impact of inlet width at the top of the batter slope. The impact of these site characteristics will be the subject of these investigations, with incorporation of these factors into consequent prediction efforts.

The geometry of the batter site is complex with concavo-convex slope. A change in curvature occurs between Row H - Row I, as illustrated in Figure 2.6. Results from field trial observations with excavation on the upper sections and deposition onto lower sections followed expected theoretical behaviour mechanisms. Initial profiles of the batter site also suggested that incision of the top slopes of the highwall

would occur. The degree of erosion at this transition point between the gully catchment and the batter slope was influenced by the relatively thin layer of fine material in this region, and the larger reservoir inadvertently created behind the leading bund wall. This reservoir effectively raised the entry notch about 30cm before runoff from the catchment could enter the gully, with only relatively intense storm events of significant magnitude generating enough runoff for erosion to occur.

Figure 1.3.2 above outlines the nature of the equilibrium slope formation, far removed from the initial study site characteristics. However the physical attributes of the site are dictated, and hence the location of batter slopes, by the character of the final design solution.

During the monitoring period there were numerous storm events, with many averaging 20 to 30 mm in total. Other studies conducted during the Wet Season, (Bell, 1997) examine these numerous storm events in greater detail.

Three storm events were considered to be significantly large, instigating and directly altering the dimension, depth and length of the gully once formed. As described in Section 3.1 above, these events totalled 89mm, 79mm and 45mm respectively and occurred on 261296, 010197, and 230197 respectively.

The inlet and outlet points of the gully were significant with discharge runoff entering the gully from the 7200 m^2 catchment area above, and exiting the gully site via a flume located at the base of the slope. Measurements of suspended sediment concentration were taken at the base of the batter slope from the large flume remaining from previous erosion studies, although these samples proved inconsequential to this study. Hydrological data from the cap site, was monitored electronically with average discharge entering the gully estimated and incorporated in calibration of the landform model.

Two measurement techniques were used to ascertain the amount of material shifted proceeding each significant storm event. The intensive monitoring of cross-sectional areas at each of the 10 designated transects was used to generate an approximate picture of the gully form.

An extensive survey regime of the site during the middle of the Wet Season, and a complimentary survey of the site before and after the completion of the monitoring period was used to support findings from the cross-sectional area analysis. From the measurement techniques used on the site, the characteristic of gully formation, with areas of deposition and erosion, was determined.

Inherent difficulty in interpretation of results from this study included erosional development between monitoring rows, and smothering of erosion pins on the lower sections. Problems associated with the use of the erosion pins are highlighted above, with results devised from these dependent on the survey work conducted before the commencement of monitoring period and were not considered of high importance.

Other aspects of the field trial that were not incorporated included the assessment of mean particle diameter as a function of depth as the gully evolved. Estimates of the depth-erodibility relationship coefficients were conservative based on these incomplete estimations from Figure 4.3.7 and alike.

Table 3.2.1 below, summarises the findings from this intensive study, with estimates of the amount of material mobilised from each storm event determined from difference between surface profiles for each of the 3 storm events. Maximum erosion depths and overall profile development are however considered the most important findings in this study. The width of the gully and distance between rows is presented in Table 3.2.2 below, with little development in the upper sections once the gully was initiated. The following figures also attempt to highlight the characteristic of the evolution of the batter slope profile to its' present form.

Figure 3.2.1, 3.2.2, and 3.2.3 illustrate the results of the survey study conducted before the commencement of the Wet Season, during the Wet Season (January 16th) and after the cessation of monitoring period (April 97).

Figures 3.2.4, 3.2.5 and 3.2.6 were derived from the cross-sectional analysis. These surfaces were then used in comparison to original topography, and each consequent event, with the difference between consecutive events indicating regions of deposition

Surface Topography: Pre-Wet Season

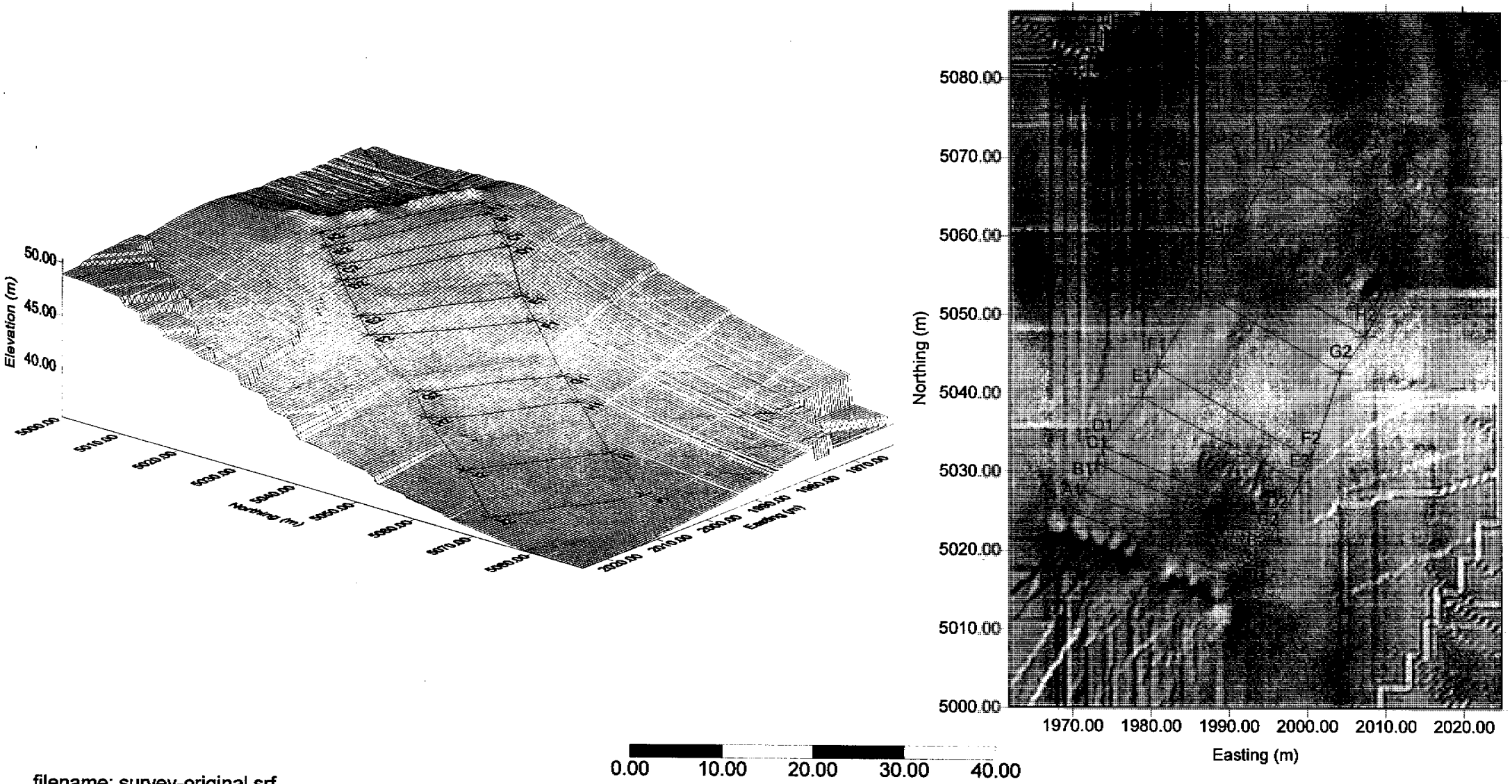


Figure 3.2.1: Three surveys were conducted during the field trial phase of this investigation. The first survey represents the batter slope before the commencement of gulling and was conducted before the start of the Wet Season.

Surface Topography: Mid-Wet Season

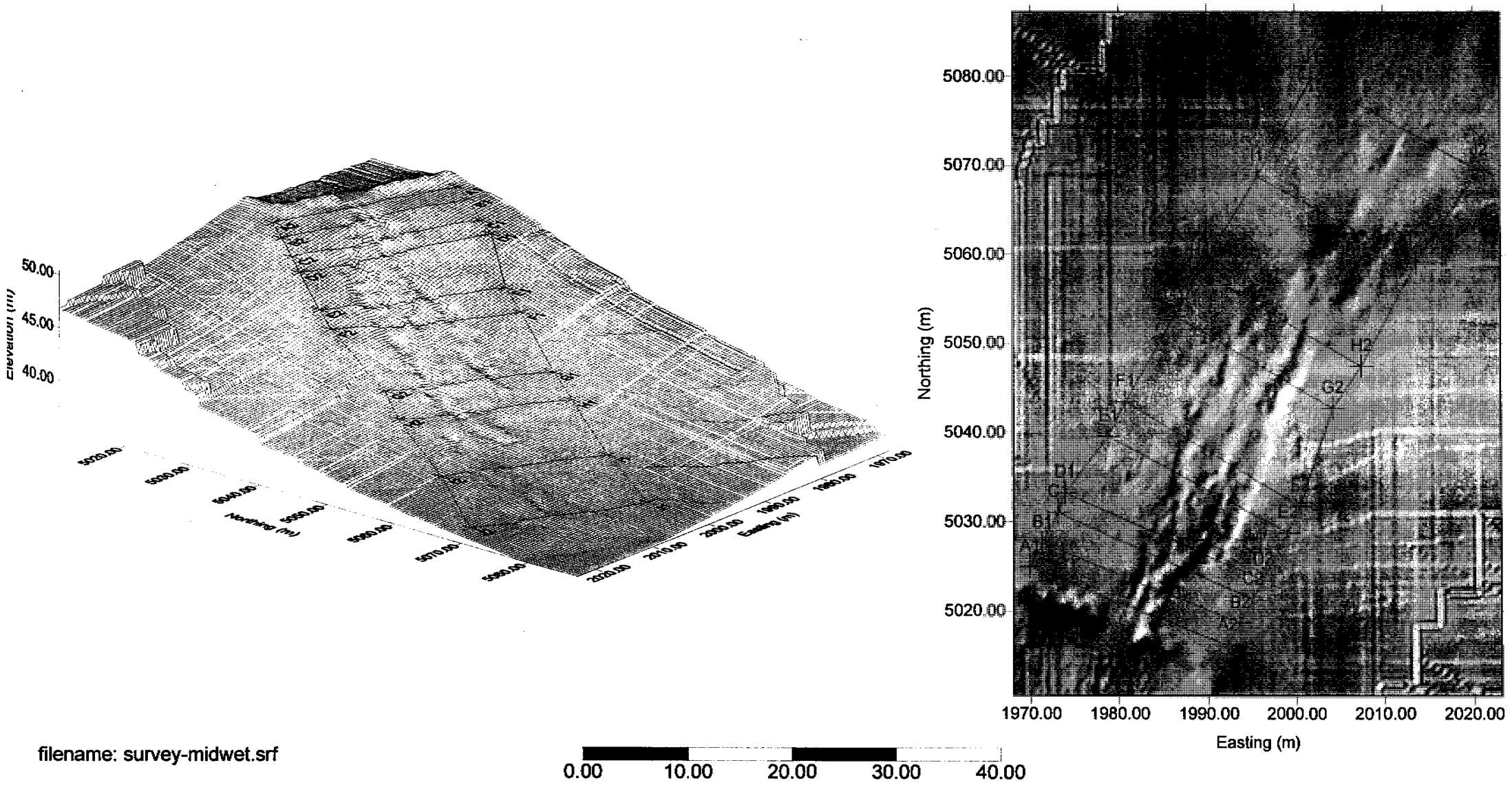


Figure 3.2.2: The next survey was conducted mid-way through the monitoring period on 16th January, where the first two storm events are compared to this landscape.

Surface Topography: Dry Season

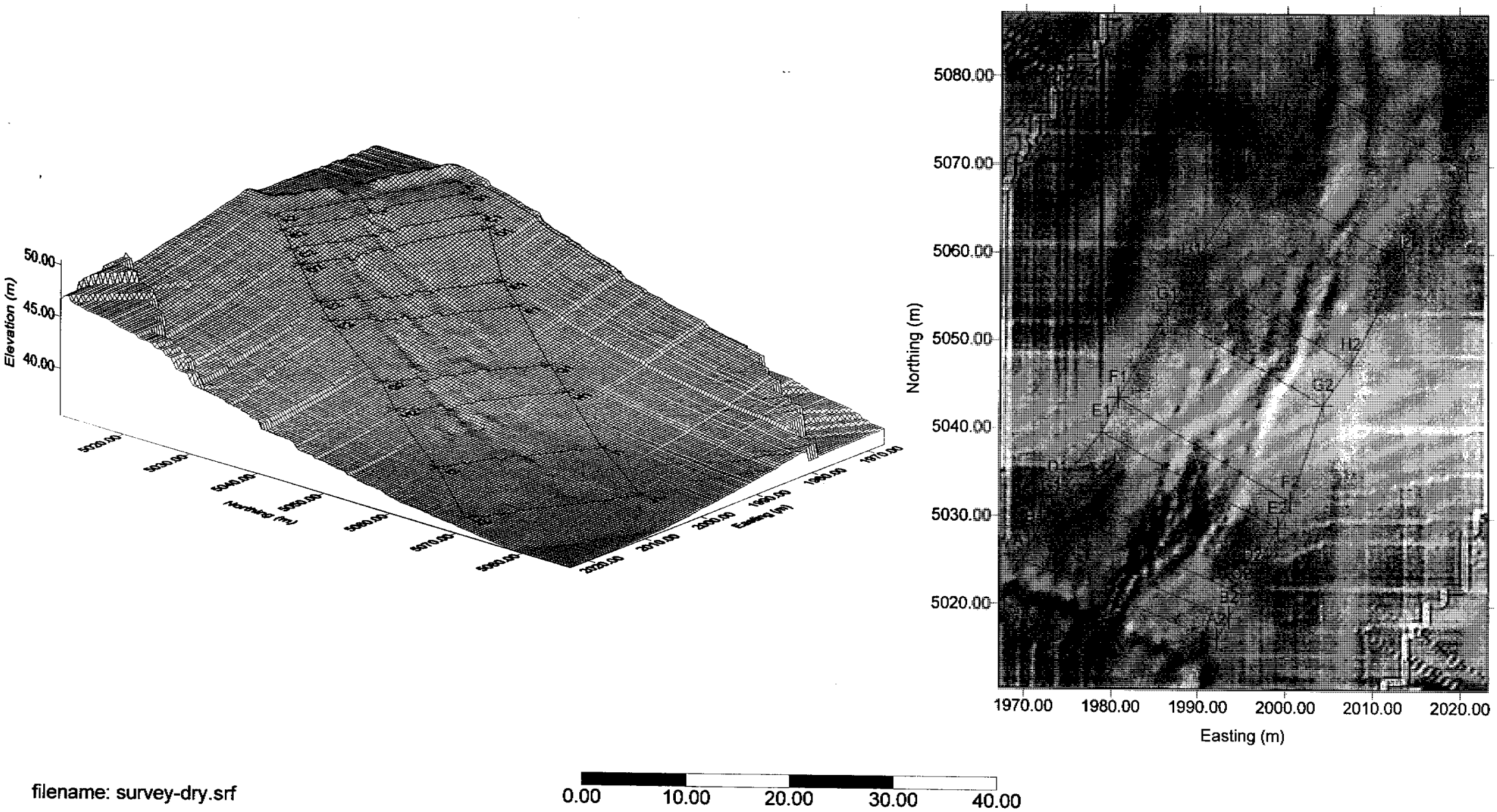


Figure 3.2.3: The final survey was conducted after the cessation of monitoring at the end of the Wet Season, although the detail of this survey was less than that seen in Figure 3.2.2, the continuing development of the gully can be observed to the bottom of the batter slope.

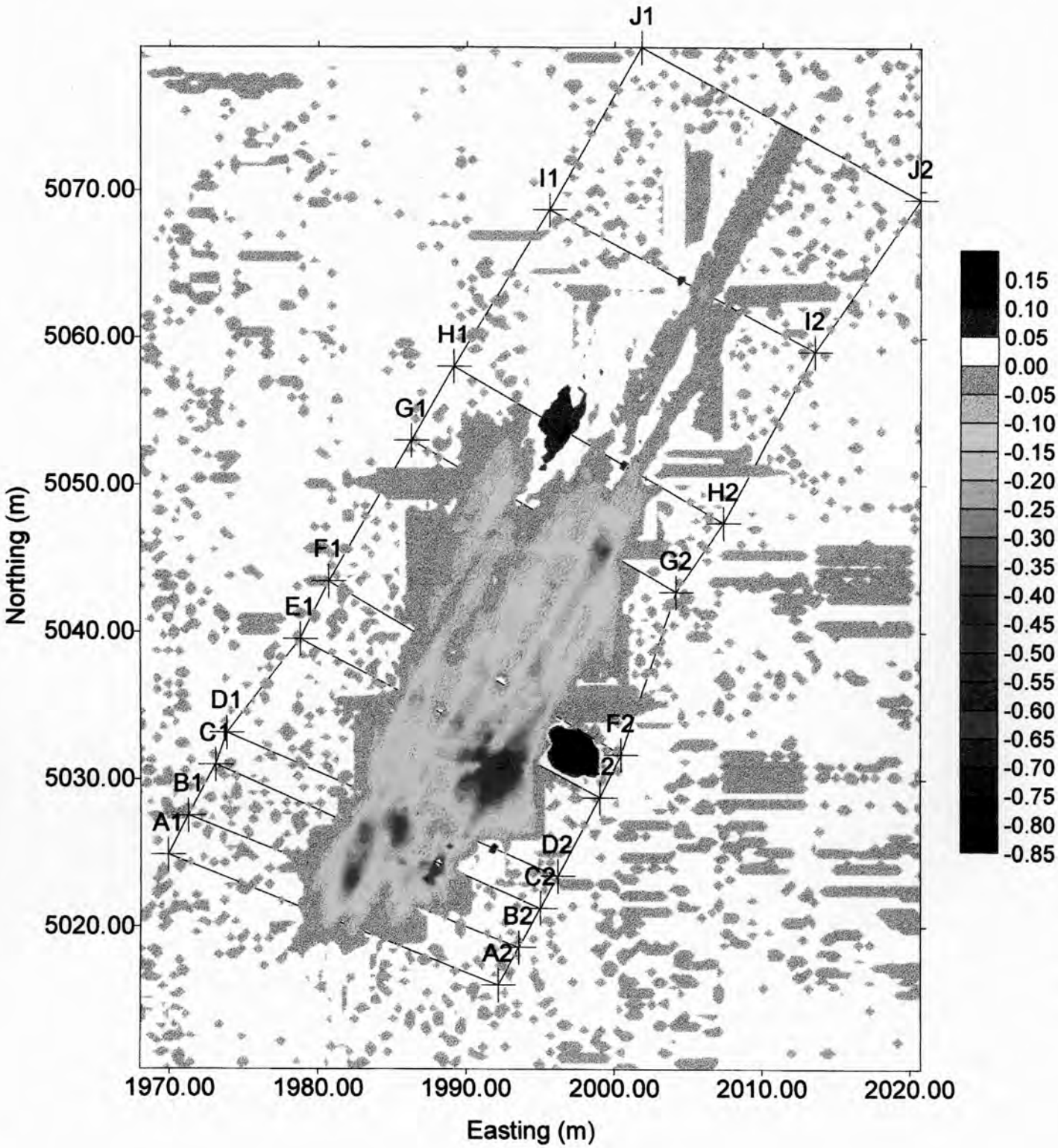


Figure 3.2.4: The results of the intensive cross-sectional analysis based on the 10 transects were translated to elevation data and used to evaluate the difference between measurements taken after each storm event. This figure illustrates the morphology of the batter slope from the initial surface to the storm event 261296, where erosion is represented on negative scale, whilst deposition is positive scale.

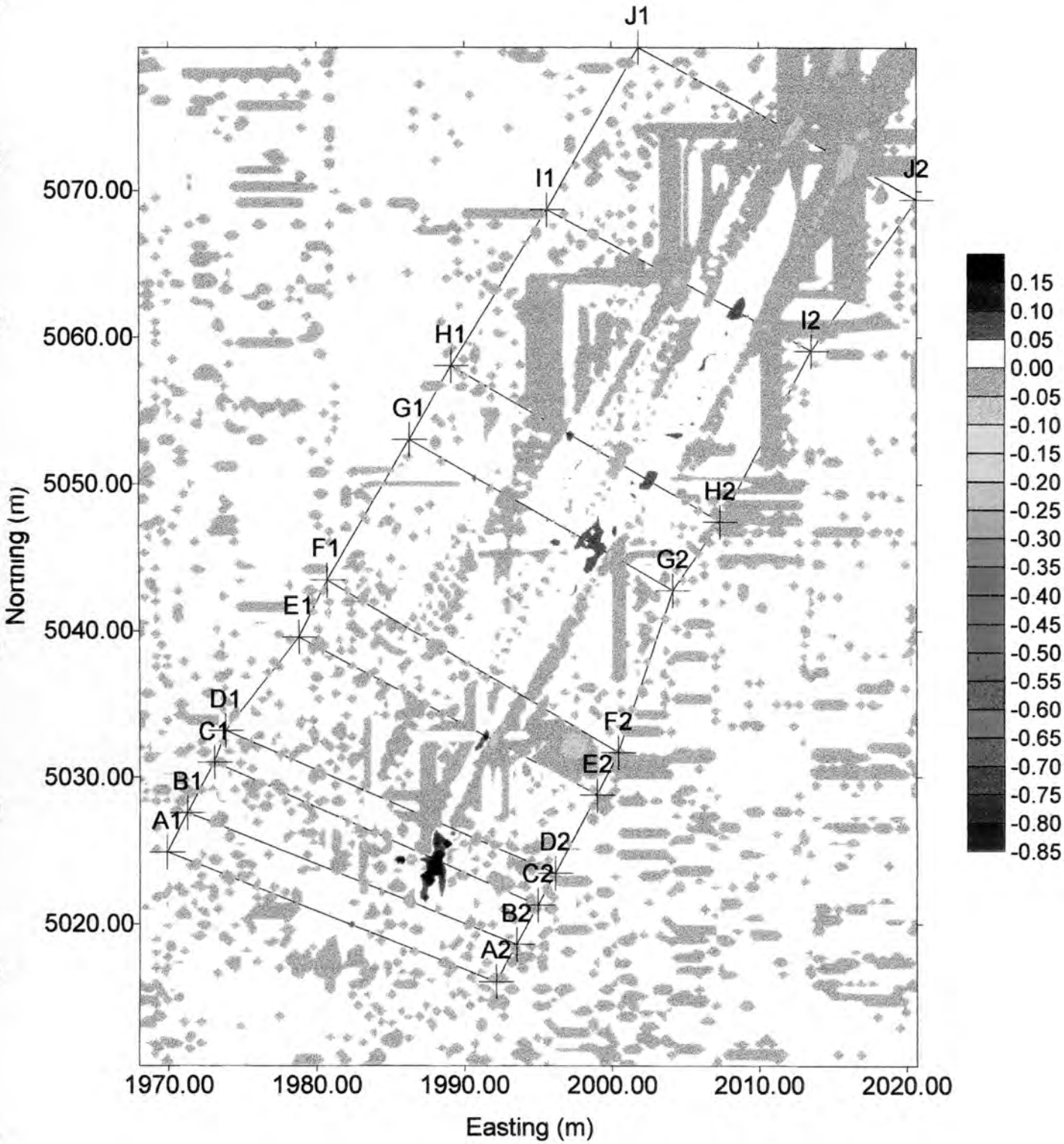


Figure 3.2.5: The difference between the surface profile at 261296, and 010197, where erosion is represented as positive values, and erosion as negative values. There was little alteration in the gully formation was associated with this storm event.

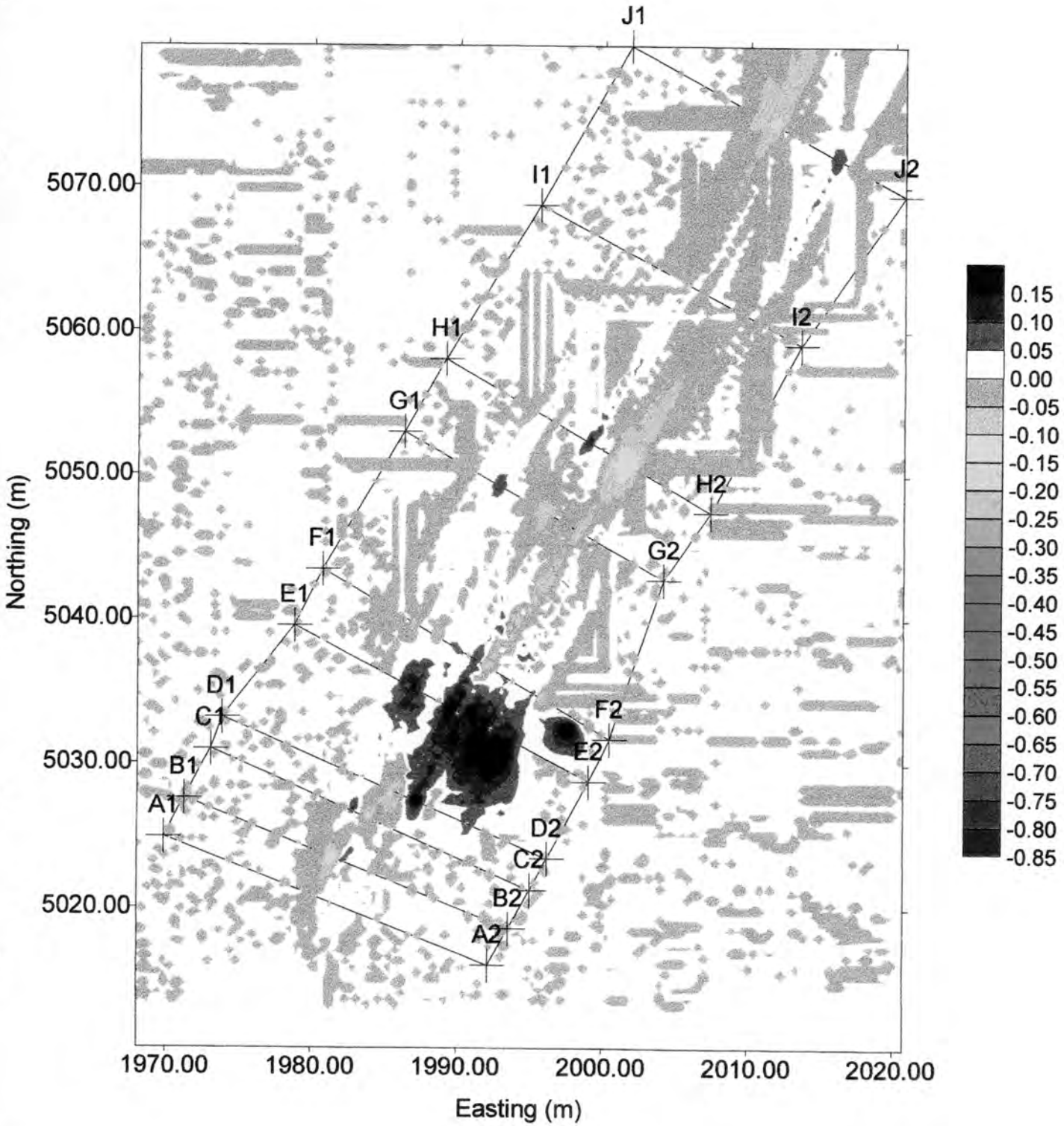


Figure 3.2.6: The difference between surface profile at 010197, and 230197. Erosion is once again represented on negative scale, whilst deposition is represented on positive scale.

Due to the large scale of mechanisms in operation, and as modelling discretisation consisted of a 20m by 60m grid (1m grid space) due to computational limitations, this was not considered beneficial.

Survey positions were taken at numerous random points in an attempt to enhance the findings from this aspect of the study, with a slightly better approximation being obtained in Figure 3.2.2, however it can be seen from the survey results conducted at the conclusion of the study that with approximately half the number of points recorded, a lot of detail was lost.

A physical description of the evolution of the gully helps to reaffirm those observations construed from the survey and cross-sectional analysis, with the characteristics of the formation of the gully remaining the most important aspects of the field study. Incorporation of other crucial sediment transport properties such as armouring can be identified readily in the upper sections of the gully after the initial event labelled 010197, with little movement occurring in these sections.

Figure 1.3.2 outlines the likely natural evolution of the steep batter slopes, with predictions based on work by Willgoose *et al*, 1992 suggesting that areas of deposition could be expected within 150 to 200m of the batter slopes, with depths of deposition up to 5m over the 1000 year time period.

From Figure 3.2.1, the initial excavation of the upper sections of the gully from Row A to Row C splits into two major arms, with accompanying deposition onto the divide between these arms, between sections Row D and Row E.

The actual initiation of the gully commenced a few days before the establishment of monitoring methods, with little data obtained and hydrological information about this storm event also being lost.

The first major event occurred on the 261296, with the event illustrated in Figure 3.2.7 occurring on the 191296. This event on 191296 was considered typical of the average storm events encountered during the monitoring period, with relatively even rainfall intensity and total rainfall level reaching 30 to 40mm.

However once the gully was instigated, erosion due to these relatively insignificant storm events was minimal. Although relatively little material was displaced by the preliminary event, the highly erodible upper surface material was quickly reduced about 10 to 20cm in some places. This was noteworthy due to the removal of almost all the finer material from the surface after the formation of the gully following the significant storm event occurring on 261296.

Figure 3.2.7 illustrates cross section located at the point now described as Row D. Although little material was mobilised from the upper surface of the batter slope, the earthworks in development of the catchment boundary wall and the channel linking the cap site to the remainder of the catchment, provided excess sediment during these initial events which was conveyed by the developing gully.

Figure 3.2.7 is compared with Figure 1.1.4, illustrating the batter slope before commencement of monitoring. The layout of the slope was relatively uniform, with little difference in elevation across the traverse. The inherent variability in the erodibility of the waste rock material is also indicated by this figure, material susceptible to geochemical weathering generated the material that was rapidly eroded once gully development commenced.

Other considerations included the nature of the pathway of the gully adopted, defined as the thalweg, minimal elevation point of the gully. This initial event dictated the shape of the formation of the gully during the remainder of the monitoring period. The consequent event, designated as the first major event excavated this cross-section dramatically, with little resemblance between the two surfaces.

Figure 3.2.9 illustrates the divide between each of the two major arms of the gully after the first major storm event, due to nature of inlet point, and armouring encountered within several centimetres of the upper surface.

The establishment of the reservoir above the entrance to the gully network contributed significantly to reducing the velocity of water in the upper sections of the gully. As the water reached the middle sections, the momentum had increased to such as extent that more significant amounts of material could be mobilised.

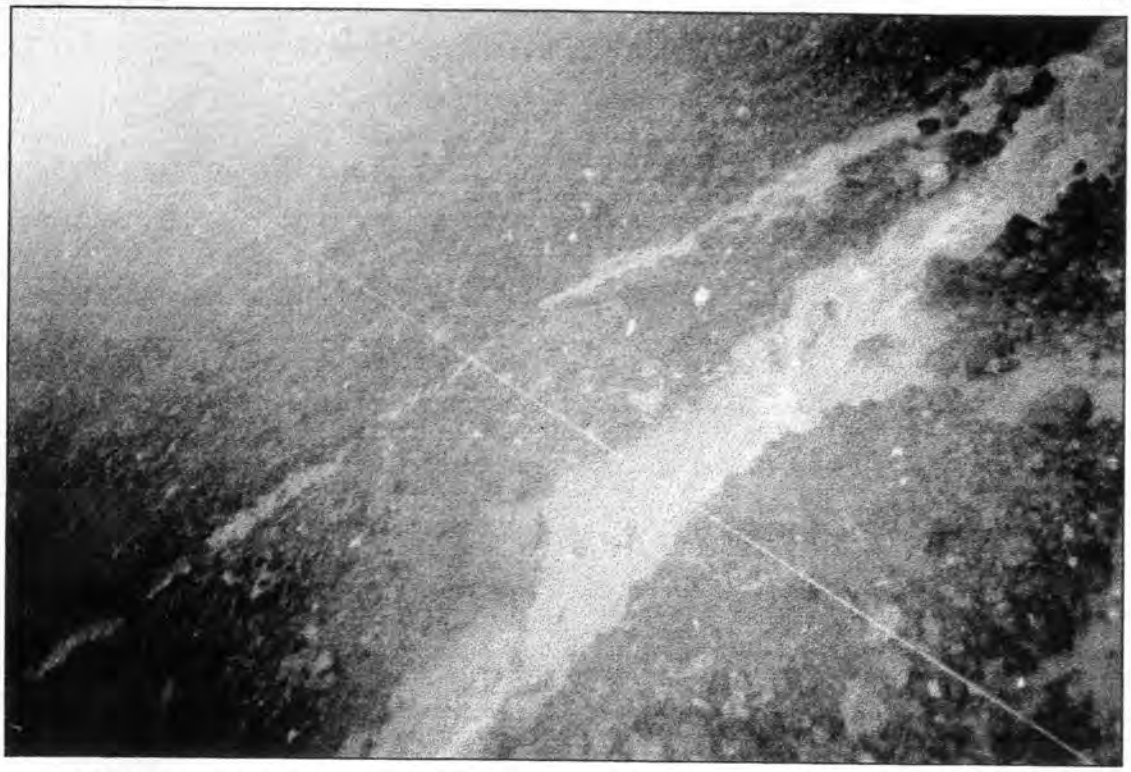


Figure 3.2.7: This cross-section was located at the point now labelled as Row D, with excavation of the loose upper surface material to some 10 to 20cm in depth. At this time little of the monitoring equipment had been established. It is also noted that this profile is not vertical, with the starpost in the upper left corner indicating the degree of elevation.

Figure 3.2.8: The first storm was estimated to be 30 to 40 mm, in total with incomplete installation of monitoring equipment resulting in no hydrological data obtained. However little emphasis was placed on this event, given the magnitude of the first significant event on 261296.

Although the constraint of the artificial reservoir may misrepresent what may happen considering the final design landform, the modelling process does not take into account the initial water velocity regardless, making this discrepancy less significant.

The nature of the waste rock material below the finer grade of material is evident in Figure 3.2.8 and Figure 3.2.9, with the relatively finer material seen centrally. The two arms of the gully were separated at the top of the batter slope due to the very large rock fragments encountered only several centimetres below the surface. The paths of the two arms crossed again below Row D with another tributary to the right of Figure 3.2.10.

Substantial deposition of 10 to 20cm in places at the forefront of the advancing major tributary continued until the end of this event. With large amounts of fine material deposited between Row G and Row H, which was consequently excavated in some degree by the more minor event on the 010197.

The gully extended to Row H during this event and is illustrated in Figure 3.2.11, and Figure 3.2.12, with the pathway becoming indistinct below Row I with deposited material (over erosion pin row 3) relatively easily erodible. It was noted that this event has a peak discharge of 21L/s, with rainfall continuing for approximately 1.5 hours, eroding the material transported initially.

The minor tributary on the right hand side of the slope encountered slightly less erodible material with mean particle diameter approximately twice that of the left hand side. The excavation of the gully halted about Row F to G for the major arm, and Row E to F for the minor arm. It was also noted that the paths of the two thalwegs crossed, and material deposited contributed to the overburden from the excavation of the sections above, as seen in Figure 3.2.11. This was also evident in Figure 3.2.5, with excavation divided between the two major arms, being clearly delineated. Overburden us highlighted in this figure, with minor disturbance of about 10 to 20cm being widespread between Row G and Row H.

Figure 3.2.9: The profile of the upper section was established by the first major storm event. Complete removal of fine material is evident in this figure and comparison is made to Figure 3.2.8 above.

Figure 3.2.10: The two main tributaries were separated between Row A to Row D, with thalwegs crossing below Row D as pictured here. Another tributary developed to the right of this photo, which crossed again below Row E to Row F in consequent events.

Figure 3.2.11: The removal of fine material was more widespread below Row D, as seen by the painted fluorescent lines across the slope. Both channels combined, and the gully pathway was not easily discernible.

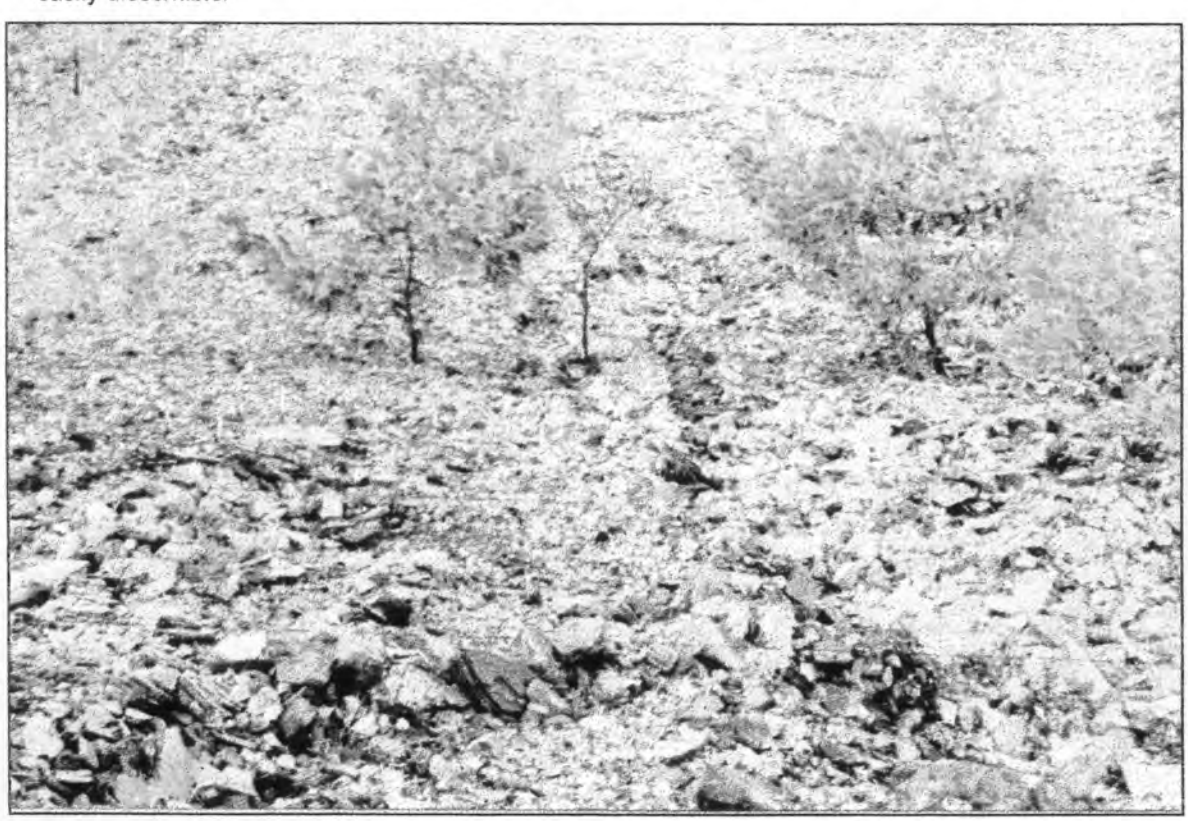


Figure 3.2.12: The left tributary also continued down the hillslope with relatively easily erodible material deposited between Row H and Row I making the pathway adopted distinct in the background of this photo.

The diversion of flow into the major gully from the divide pictured in the upper sections of the slope, resulted in significantly more erosion on this side, below Section F2 to Section G2. About one third of the flow was diverted to this path, with this gully ceasing to advance once past the intersection between the concave and convex parts of the batter slope, the point of change in curvature.

The next rainfall event occurred in 010197 with total rainfall of 60mm, and peak discharge entering the gully at 13 L/s, with average 4 L/s. This storm was monitored with a photographic record available. The amount of material moved by this event was considerably less due to the reduced intensity, as well as extensive armouring exhibited in the upper regions from initial activity.

Although the catchment had been constructed for same time, since the first event on 191296, the remnant brown mud sediment is evident in the suspended flow entering the gully in Figure 3.2.12. The buffering effect of the gully is also evident in this figure with flow diverging into the two main arteries. The accumulation of water behind the leading edge of bund wall supplied water to the gully for several hours after the rain had ceased, effectively minimising initial discharge velocity.

The divide between the two main tributaries is still evident in Figure 3.2.13, with coalescing of gully pathways below Row D to Row E pictured in Figure 3.2.14. The fluorescent paint used to delineate the previously eroded sections and was particularly useful in outlining the pathway of the gully as it developed.

The survey results pictured in Figure 3.2.2, were used to derive a directional derivative approximation of the drainage network for the gully, and this appears in Figure 3.2.15.

The third and final significant storm event occurred on 230197, with total rainfall of 45mm, over a period of only 30 mins, with peak discharge 29L/s.

Although Figures 3.2.4, Figure 3.2.5, and Figure 3.2.6 represent a morphology of the landform over a small duration, the inherent lack of detail devised from the cross-sectional analysis allows only generalisations to be made. Extrapolation of the cross-section of the gully at the transects located at both Row F and Row G by the mapping

Figure 3.2.13. The inlet point of the catchment extended ~ 3m with approximates of 2m and 4m used during the modelling process.

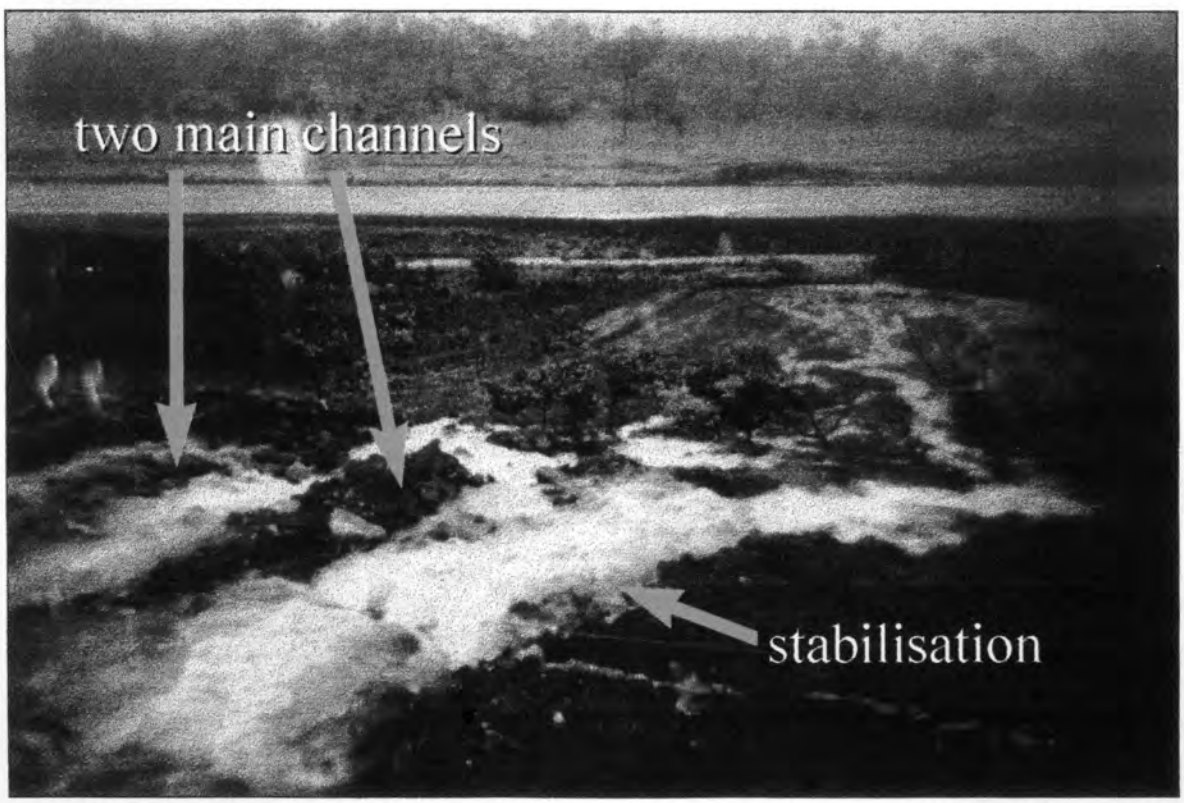


Figure 3.2.14. The pathway of the gully can be delineated by the fluorescent paint markings, indicating regions that were eroded on deposited between each storm event.

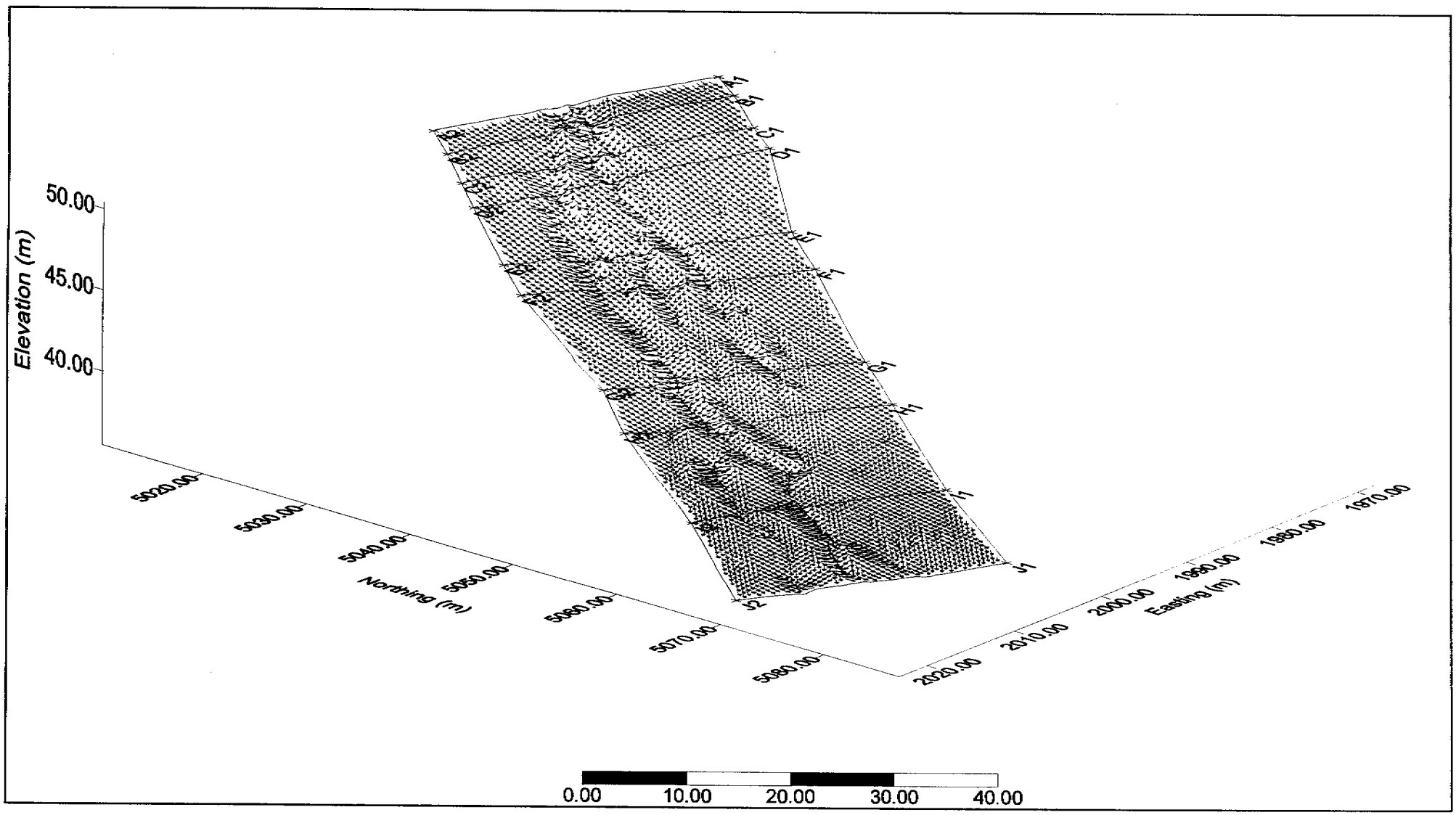


Figure 3.2.15: The survey conducted mid-way through the monitoring period was used to generate a directional derivative schematic of the drainage pattern for the gully.

Monitoring Gully Formation

Table 3.2.1: The amount of material excavated or deposited by each event was approximated by the subtraction of the upper surface from the lower surface. Estimates of net deposition can be seen in the events at the end of the monitoring period.

Description	*Erosion Volume (m^3)*	*Deposition Volume (m^3)*	*Morphology (m^3)*
Transect-261296	52.29	5.55	46.74
Transect-010197	5.25	6.94	-1.68
Transect-230197	8.42	13.93	-5.51
Survey-160197	68.90	30.14	38.76

Table 3.2.2: The width of the gully as it developed, is noted not to change significantly due to the extensive armouring experienced at the top of the batter slope, and the low initial velocity due to the artificial reservoir.

ROW : dated 28/12/96.	*Width (m)*	*Location (m..m).*
R1-R2 (2.9m)		Using R1
At 1m from R1	2.05m	10.55m to 12.60m
	1.60m	13.20m to 14.80m
At 2m from R1	1.95m	10.60m to 12.55m
	1.95m	13.15m to 15.10m
R2-R3(3.4m)		Using R2
At 1m from R2	0.55m	10.00m to 10.55m
	2.37m	11.35m to 13.72m
	1.30m	15.20m to 17.00m
At 2m from R2	0.35m	10.00m to 10.35m
	2.40m	10.90m to 12.30m
	1.00m	12.70m to 13.70m
	1.80m	15.20m to 17.00m
R3-R4(2.6m)		Using R3
At 1m from R3	4.45m	10.55m to 15.00m
	1.70m	16.10m to 17.80m
R4-EP1 (3m)		Using R4
At 1.5m from R4	1.15m	11.65m to 12.80m
	1.55m	13.70m to 15.25m
	1.75m	15.65m to 17.40m
	2.70m	18.00m to 20.70m
EP1-R5 (3.6m)		Using R5
At 2m from EP1	1.85m	8.75m to 10.60m
	1.80m	11.20m to 12.00m
	3.40m	13.30m to 16.70m
R5-R6 (3.6m)		Using R5
At 2m from R5	1.10m	8.00m to 9.10m
	1.30m	11.70m to 13.00m
	1.70m	13.30m to 15.00m
	2.20m	15.40m to 17.60m
R6-EP2 (7.9m)		Using R6
At 3m from R6	1.40m	6.60m to 8.00m
	1.70m	8.30m to 9.00m
	1.90m	10.20m to 12.10m
At 6m from R6	0.75m	6.80m to 7.55m
	1.75m	8.45m to 10.30m
	2.20m	10.80m to 13.00m
	3.20m	14.10m to 17.30m
EP2-R7 (3.8m)		Using R7
At 2m from EP2	1.10m	5.00m to 6.10m
	1.45m	7.20m to 8.65m
	1.10m	14.10m to 15.20m
R7-R8(5.7m)		Using R7
At 3m from R7		7.35m to 8.50m
		11.60m to 13.00m
		14.00m to 16.00m
R8-EP3 (5.2m)		Using R8
At 3m	1.00m	7.50m to 8.50m
	1.70m	9.20m to 10.90m
	3.60m	11.70m to 14.30m
EP3-R9 (7.8m)		no
R9-EP4 (6.9m)		significant
EP4-R10 (5.7m)		formations
R10-EP5 (9.2m)		here as yet.

package tended to conceal the complex nature of activity in those sections. From Figure 3.2.4, the areas of deposition are less clear, however with comparison with the results presented in Figure 3.2.2 the sections from Row F to Row G allows insight into the nature of this mechanism.

The disturbed sections of the batter slope were cleared of fine particles, resulting in dramatically reduced erodibility. From Figure 3.2.8, the disturbed material could be used to easily identify the path of the minor tributary, with erosion pins dislodged and transported downstream below transect Row D. Below the trees in the middle ground of the photo, a pathway linking the two major arms of the gully crosses. Overburden from this intersection deposited during the end of the initial event, as well as that of the 010197 storm event, with significant scouring observed during the final event.

The layering of fine mulch is of concern in future investigations, with depth in Row G to H about 50 to 60cm, revealed by examination of sidewall of the main gully. The relative heterogenous nature of fine particles is observed in photographic series in Figure 3.2.16 to Figure 3.2.19, where a 30cm ruler is highlighted in the centre of most of these figures.

Some sections of the gully, once breached eroded quickly with soft earthen material excavated from just above the mined ore, being exposed in Figure 3.2.8. A combination of surface layers has been used to design the batter slope, (pers com. Willgoose, 1997) making excavation to this depth, of some concern.

Further evaluation of the role of rapid geochemical weathering, and impact of diffusive mechanisms on modelling simulations may need to be conducted.

Figure 3.2.16: Excavation of sidewall material slowly increased the width of the gully, with residual layer of fine material about 45cm accumulating at this point.

Figure 3.2.17: The depth of erosion reached 60cm in some places, revealing the heavily armoured rock fragment layer. The differential erodibility of these surfaces is considered with the soft earthen material extracted from above the mined ore seen as brown colour. Depth-erodibility relationships for this slope would therefore be complex, once the protective layer is breached.

Figure 3.2.18: The excavation of material from Row H to Row I, reaches a depth of 60cm with large rock fragments armouring further incised.

Figure 3.2.19: The gully extends to Row I with depth of 20cm to 30cm, whilst almost reaching the concrete apron of the flume pictured in background.

4.0 Model Calibration and Predictions

4.1 Theory

The computer model SIBERIA was developed to study the link between physical process and the development of catchments. The distinction between hillslope and channel based processes is considered some of the most important aspects of this model.

As outlined above, the major components of the model focussed on in this study simulates the evolution of catchment elevations over time by continuity of mass, in this case the batter slope.

Fluvial erosion processes, modelled according to standard forms, is incorporated into influx and outflux of regions within the catchment over time.

Average elevations are therefore determined over monitoring period based on the following governing equation.

$$\frac{\partial z}{\partial t} = \frac{\nabla q_s}{\rho_s(1-n)} + D.\nabla^2 z \qquad \text{(adapted from 1.3.1)} \qquad (4.1.1)$$

where

z = elevation,
t = time,
q_s = sediment transport per unit width,
$\rho_s(1\text{-}n)$ = bulk density of sediment
D = diffusivity of diffusive transport (rainsplash, landslide)

The differential equation is described as a continuity of sediment transport over time, with other components of the governing equation such as tectonic uplift and diffusion terms were neglected for this study. This was considered reasonable since the monitoring period was short, and surface wash erosion was the most commonly observed mechanism. Only the exposed sidewalls of the lower sections of the gully were sufficiently high for landslip mechanisms to occur, and these areas were not considered important for simplification of modelling process.

The more sophisticated methods of diffusion such as soil creep, landslide and rainsplash were considered negligible, as mass transport processes observed were almost entirely dependent on fluvial transport.

The sediment transport process q_s, is modelled by the second term in equation 4.1.1, and can be represented in a number of ways

$$q_s = f\left(S^n, q_w{}^m\right) \tag{4.1.2}$$

where

q_s = sediment flux, g/s
q_w = discharge, L/s
m, n = derived exponents
S = Slope, m/m

with equation 4.1.2 reflecting findings from both field and laboratory observations by soil scientist and geomorphologists. The general form of this model is:

$$q_s = \beta_1 q^{m_1} S^{n_1}\left(\tau - \tau_c\right) \tag{4.1.3}$$

where

q = discharge per unit width,
β_1 = rate constant for sediment transport, function of sediment grain size,
m_1, n_1 = derived exponents,
τ = bottom shear stress for the flow,
τ_c = shear stress threshold (critical shear stress)

However for the material from the waste rock dump the critical shear stress has been attempted to be identified Willgoose *etal*, 1993, and their conclusions were that its value was indistinguishable from zero, with this conclusion adopted in parameter estimation.

Implications as to the nature of the rehabilitation design adopted will incorporate extensive revegetation, in doing so will reduce the erosional force of surface flow significantly. Plants provide protection of the surface by cohesion, and binding of soil particles, increasing the resistance to scouring. Prosser, 1996 suggests that the critical threshold for incision can be several times higher on vegetated surfaces compared to that of bare surfaces, although as stated, this is not considered in this study with minimal vegetation evident on either study site.

Equation 4.1.3 parameterises the total sediment transport, including bed load and suspended sediment loads (as defined above).

Exact values for these parameters has been the focus of previous studies conducted on site such as Willgoose *etal*, 1992, and Evans in prep.

Natural rainfall runoff events and simulated rainfall catchments (largest area ~ $100m^2$) were used to calibrate the fluvial sediment transport equation (equation 4.3.2) and were shown to be least dominated by diffusion processes (as assumed above). These small scale erosion plots were located on the Northern WRD adjacent to the cap site as described in Section 2.2, with other study sites on the batter slope itself, Willgoose *etal*, 1993.

The parameters fitted to equation 4.1.3 were n_1, m_1, and β_1, where m_1 and β_1 relate directly to estimates of sediment loss for monitored fluvial erosion studies. The exponent n_1 of the slope term S is derived using the following relationship (Evans, Willgoose, and Riley, 1995):

$$q_s \propto 1/d^{3/2} \tag{4.1.4}$$

where
d = median sediment grain diameter (mm)

Evans *et al*, 1995 suggests that this function of Einstein-Brown relationship can be adapted to determine a value for the WRD,

$$\left(S_{Cap}/S_{Batter}\right)^{n_1} = \left(d_{Cap}/d_{Batter}\right)^{1.5} \tag{4.1.5}$$

where
S_{Cap} = cap site slope from previous studies (S_{Cap} = 0.028),
S_{Batter} = batter site slope (S_{Batter} = 0.207),
d_{Cap} = mean diameter size (d_{50} Cap: 0.54mm),
d_{Batter} = mean diameter size (d_{50} Batter: 1.39mm).

Estimate of n_1 based on these values is 0.71 (with 0.69 from Willgoose *etal*, 1993).

This value for n_1 is then adopted and included in the multiple regression analysis used to determine m_1, and β_1 as described by Evans *et al*, 1995.

$$\log T = \log \beta_1 S^{n_1} + x.\log \int Q^{m_1} dt \text{ (Evans } etal\text{, 1995 equation 11)} \qquad (4.1.6)$$

For this case, the value of n_1 is considered susceptible, since the mean particle diameter, d_{50} varies dramatically once erosion commences.

For sediment transport according to the Einstein-Brown equation in a wide channel, the parameter values for m_1 and n_1 are 1.8 and 2.1 respectively. Investigation into the sensitivity of the estimate of the exponent on the slope component n_1 is conducted below, although a value of 2.1 is initially adopted due to the stability of preliminary modelling results.

From equation 4.1.6 above, the regression analysis is used to determine all the components of the sediment transport equation. By taking S^{n_1} as a known value, the parameter β_1 can be determined, as the *log K* term is devised from the analysis process. Thus the estimate of the parameter n_1 influences the erodibility of the material in parameter β_1 as well as the contribution to total sediment loss within the slope component.

Evans *etal*, 1995 noted that regression analysis for total sediment loss of:

$$T_B \text{ (batter)} = 3.34\, S^{0.71} w^{-0.8} \int Q^{1.8} dt \ (R^2 = 0.53;\ df = 11;\ p < 0.01), \text{ and}$$
$$T_C \text{ (cap)} = 13.8\, S^{0.71} w^{-0.8} \int Q^{1.8} dt \ (R^2 = 0.53;\ df = 11;\ p < 0.01). \qquad (4.1.7)$$

with erroneous data points removed, this relationship was analysed again.

$$T_B \text{ (batter)} = 5.05\, S^{0.71} w^{-1.8} \int Q^{2.8} dt \ (R^2 = 0.93;\ df = 9;\ p < 0.001), \text{ and}$$
$$T_C \text{ (cap)} = 20.9\, S^{0.71} w^{-1.8} \int Q^{2.8} dt \ (R^2 = 0.93;\ df = 9;\ p < 0.001). \qquad (4.1.8)$$

where

$$T(g) = \beta_1 . S^{n_1} . w^{(1-m_1)} . \int Q^{m_1} dt$$

with $\int Q^{m}{}_1$ = Cumulative value of duration of event,
T(g) = Total sediment loss.

Evans *etal*, 1995 notes that the value suggested for the exponent m_1 at 2.8 does not compare well with previous studies by Willgoose *etal*, 1993 with their estimate of m_1 at 1.68. The estimated value for parameter exponent n_1 from equations 4.1.8 was 0.71 and compares well with previous studies, with a value of 0.69 being determined.

The results of this process, conducted previously by Willgoose *etal*, 1993, is expressed in the following fitted relationship ($r^2 = 0.64$),

$$c = 3.59\, q^{0.68} S^{0.69} + \frac{0.178RS}{q} \qquad \text{(Willgoose } etal\text{, 1993 equation 5)} \quad (4.1.9)$$

where

c = sediment concentration = q_s / q, (g/L)
q = discharge = $f(q, S, Area)$, (L/s),
q_s = sediment flux, (g/s).

From equation 4.1.9 and above, the fitted parameter values adopted were $\beta_1 = 3.59$, $m_1 = 1.68$, and $n_1 = 0.69$, (and 2.1 for comparison). Rainsplash diffusivity was neglected and these results were considered consisted with other field data accumulated by the geomorphology group at ***eriss***.

The next important component of the calibration and adaptation process is the derivation of discharge, **q** in equation 4.1.9. The discharge relationship is a function of area, slope and surface discharge. In this case the drainage pattern of the catchment is adapted to represent the gully catchment as a series of nodal entry points at the top of the initial batter surface, with the slope of the gully catchment neglected, due to the nature of the constructed reservoir above the head of the gully and the assumption from this that the surface is almost completely flat (slope is 1 to 2% on site).

$$Q = \beta_3 . A^{m_3} \qquad (4.1.10)$$

where

Q = average discharge for 1 hour of each of the storm events,
A = area of the gully catchment,
m_3 = exponent on the area in discharge used in sediment transport,
β_3 = coefficient between discharge and area used in sediment transport.

The discharge per unit width term, **q** was evaluated to be the discharge entering the head of the gully network averaged over the duration of the storm. The average discharge over a 1 hour period, for each of the storm events was used to determine the parameter β_3, with exponent m_3 representing a non-linear relationship with area, disabled ($m_3 = 1$).

$\beta_3 =$ discharge average in 1 hour / area of gully catchment (4.1.11)

The runoff module within SIBERIA does not directly model runoff, with no continuity of water or runoff routing routine within the model. For this case, a user-specified runoff module was adopted with this representing a series of feed points located at the head of the gully network, at the outlet of the gully catchment. This constituted the discharge-area relationship discussed in equation 4.1.10 above, being applied initially at the 2 or 4 inlet points of the constructed initial landscape.

The parameter β_3 is equivalent to 'mm' of rainfall, and was calibrated for each storm event, whilst it is also noted that β_3 only appears in the discharge-area relationship used in SIBERIA and is representative of the average storm duration of 1 hour.

The coefficient β_1 of the sediment transport equation, represents the erodibility of the waste rock material, and was determined using site specific data and is considered the final component of the calibration process.

The bulk density, ρ_s (1-n) from equation 4.1, for the waste rock material was determined from soil analysis conducted at three locations on the batter slope. The β_1 value, derived from erosion studies and the devised bulk density estimate are combined in the β_1 coefficient used for SIBERIA in equation 4.1.12, with derivation appearing in Appendix D.

From equation 4.1.1, the sediment transport equation was calibrated as follows:

$$\beta_1(siberia) = \frac{\beta_1}{\rho_s(1-n)} \cdot \frac{60s}{\min} \qquad (4.1.12)$$

where

$\rho_s(1\text{-}n)$ = bulk density,
$beta_1$ = sediment transport coefficient from equation 4.1.9,
time = conversion factor for timestep from 1 hour to 1 minute.

The value of bulk density was used to derive the erodibility coefficient in SIBERIA, with time step reduced from 1 hour duration (derived from the 1 hour duration β_3 discharge relationship) to 1 minute.

It was also noted numerical stability requirements dictated iteration timestep length, within the SIBERIA program, was set to be 0.05 for model simulations presented.

Modelling Methodology

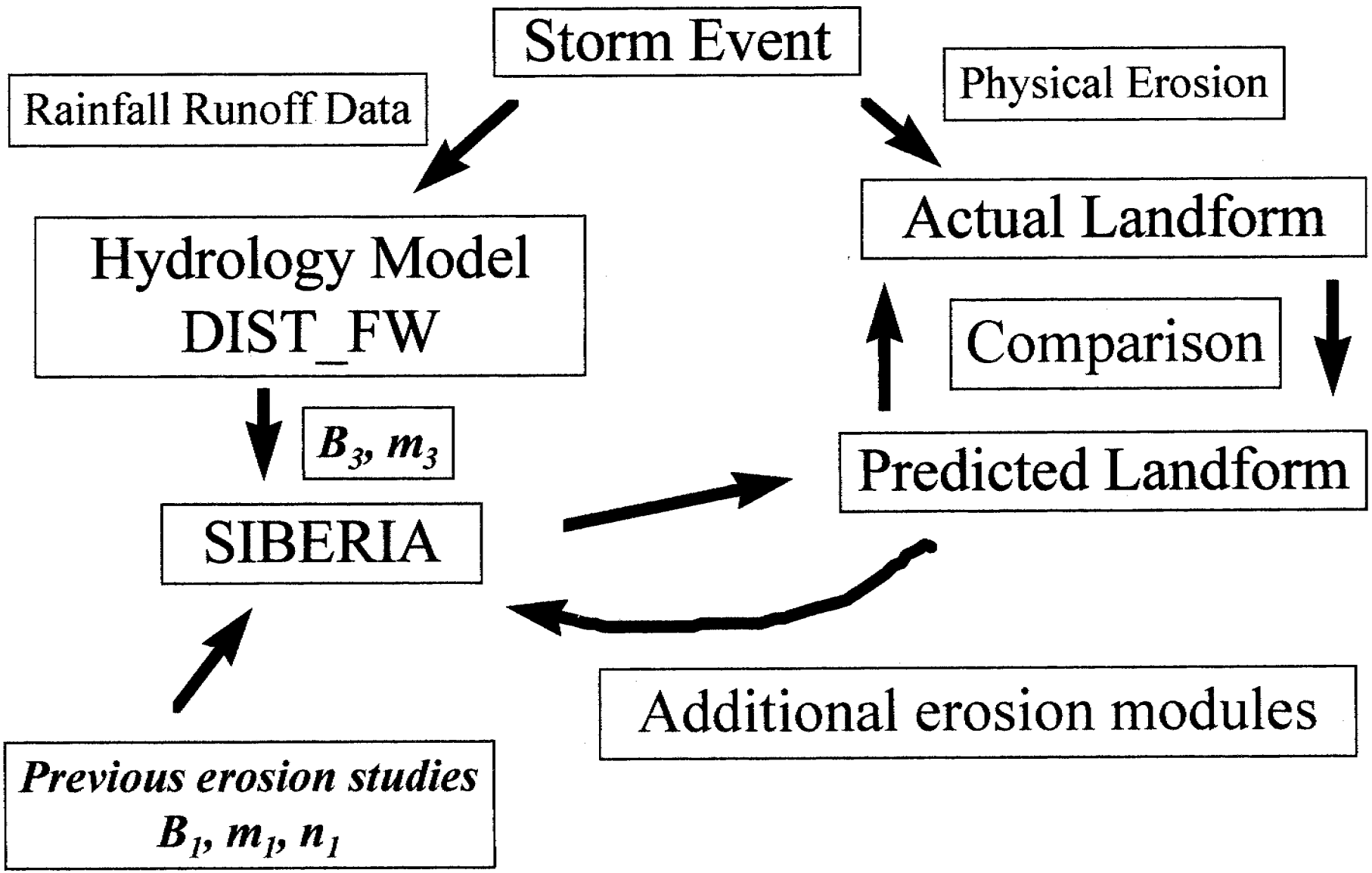


Figure 4.1: The combination of the two major model components, from hydrology and sediment erosion models, allowed the calibration of the landform model SIBERIA to be representative of the batter slope study site. The runoff model was instigated using a series of inlet points across the top of the batter slope, with erosional characteristic (β_1, m1, and n1) of the site adapted from previous studies.

4.2 Initial Surface and Determination of Parameters

The evolution of the batter slope over the 96-97 Wet Season was intensively monitored. Hydrological data was adapted to represent the three storm events that initiated and altered the gully significantly.

The initial surface was created to approximate the geometry of the batter slope, and gully catchment with runoff from the catchment entering the head of the batter slope from an outlet cut into the bund wall (Section 2.2).

The profile of the batter slope has been described as complex, with 2 approximations being made. The first surface incorporates a small section of the gully catchment, with the top of the surface extending back about 10m into the catchment.

The other alternative did not include the upper section of the catchment, and effectively represented only the study site area. Both of these alternatives are illustrated in Figure 4.2.1 and 4.2.2 respectively.

From Figure 4.2.1, the study area was approximated to a 20m by 60m rectangular grid, closely resembling the transect measurement sections described in Section 2.0. Grid spacing of 1m simplified the calibration of the initial parameters for SIBERIA with each grid representing an area of $1m^2$.

The inlet points were located at points (9,60) and (10,60) for the initial discretisation, with a wide inlet point scenario also considered, with inlet points across points (8,60) to (11,60). The outlet point, as described in Figure 4.2.1, was located at the base of the slope and was assumed to be fixed elevation at points (8,2) to (11,2). The elevations at the entry points to the batter slope were assumed not to be fixed.

Both surfaces were evaluated during the modelling process with theoretical behaviour approaching equilibrium profile of the slope with these surfaces constructed using from results devised from survey conducted during monitoring period. The elevation profile is represented in Figure 4.2.1, and Figure 4.2.2, with nature of slope, rising to elevation of 13m.

The initial profiles were created with another small fortran program named CREATERST2.f and detailed listings of the derivation and implementation are contained in Appendix E.

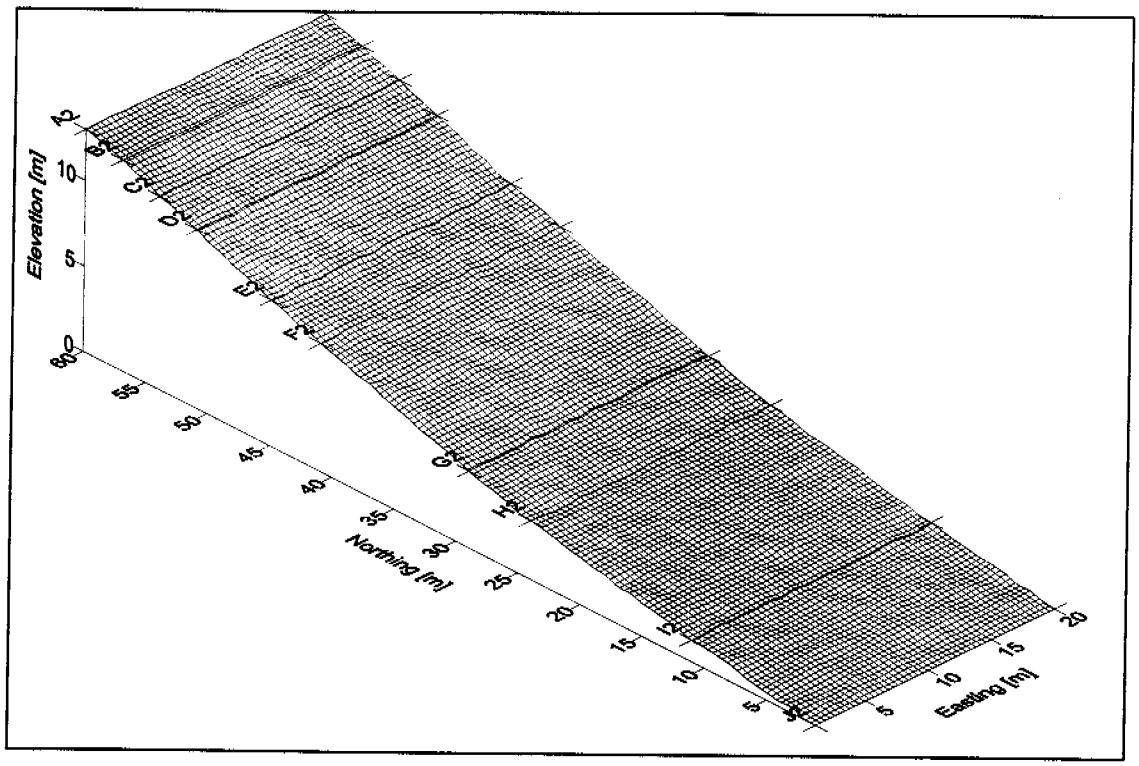


Figure 4.2.1: Initial surface incorporating flat sloping upper section, representative of the catchment outlet point . Feed points for runoff module were set at the extreme left end at the approximate location of the outlet point.

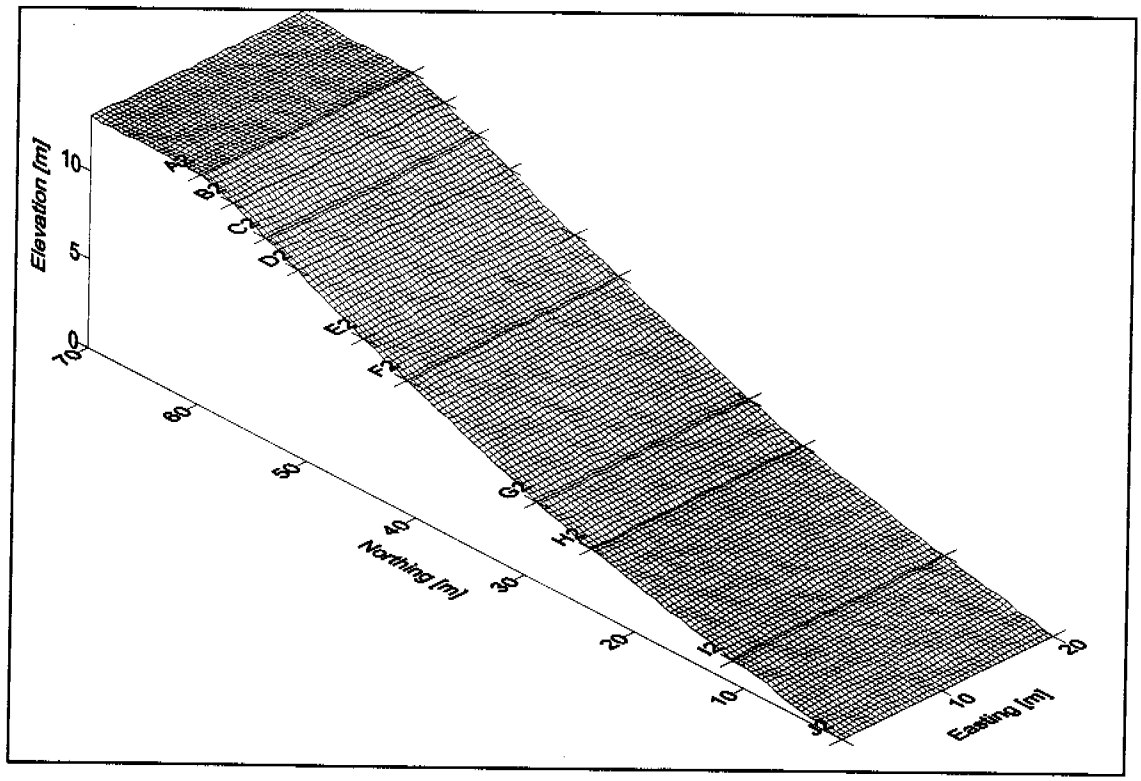


Figure 4.2.2: The other alternative for the initial landform profile did not represent the upper section of the catchment outlet. The inlet feed points of the batter slope appear along the top of the study area.

There are a large number of parameters in SIBERIA, and these control the modes of operation of the model, actual physical parameters, and numerical behaviour of the model. Willgoose, 1992 notes that there are 20 integer parameters and 50 real parameters, with many not presently used but present to allow continuing development of the model. Other input requirements are user defined modules representing the runoff module, and armouring module. Figure 4.2.4 below illustrates the typical format used to present the parameters values adopted for each of the modelling scenarios detailed in Section 4.3.

Many parameters were not altered during the modelling process. Parameters such as β_3, and the initial surface profiles were altered after each storm event, and other user defined modules were incorporated into investigation of different modelling scenarios. The definition of each of these parameters, illustrating default values if they are not

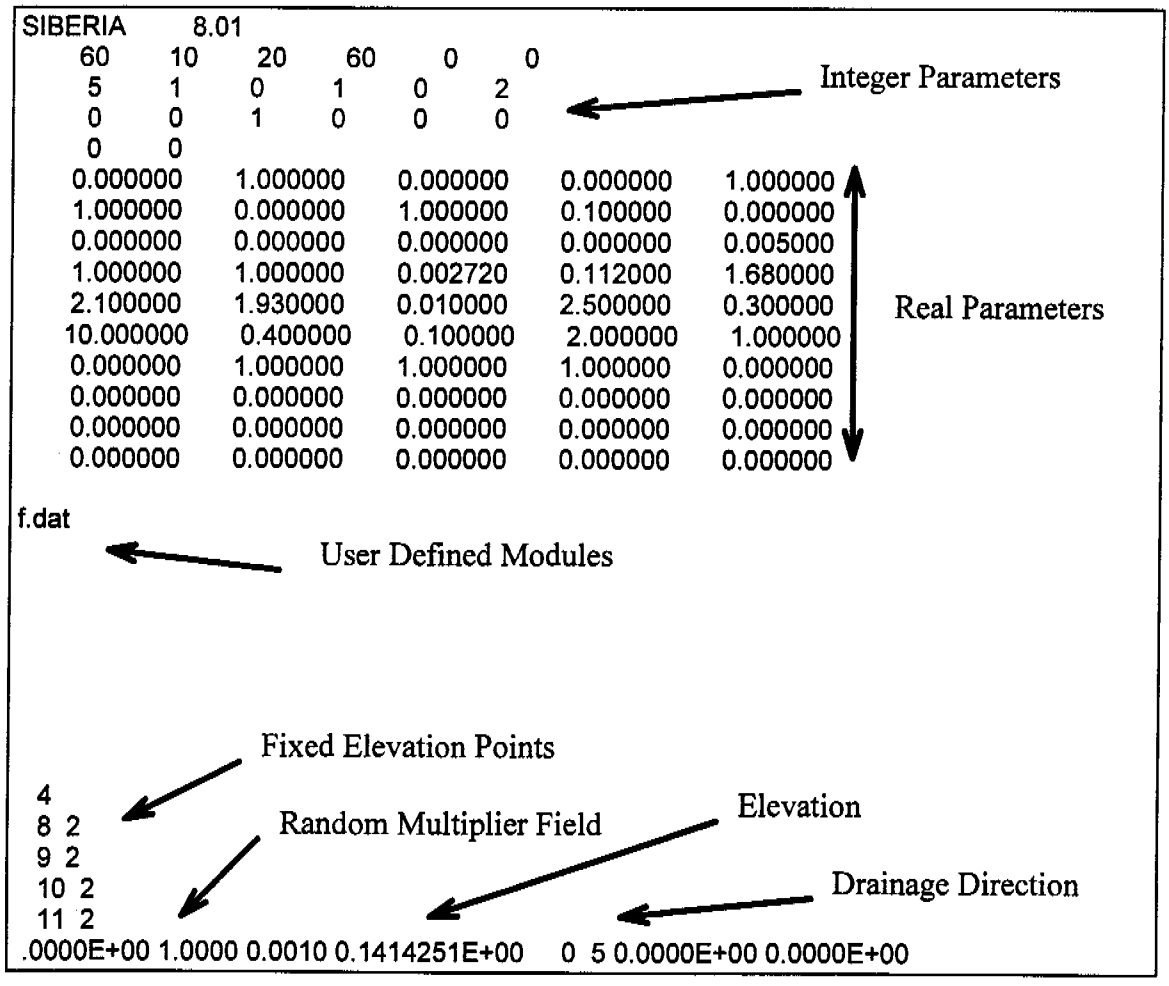


Figure 4.2.4: Parameters allocated for each of the modelling scenarios are illustrated below using this format. It is noted that parameter value used during each of these scenarios did not alter significantly during the modelling process.

presented below, appears in Willgoose, 1992.

RunT: (#1)

Total time length for duration, set to be 60 minutes, as timestep calibrated to 1 minute periods.

OutT: (#2)
Statistics output duration, set to be 10. This produces a statistical summary of the iteration process, at every 10 timesteps, in this case 10 minutes.

Kx, Ky : (#3 and #4)
Grid coordinates are 20m by 60m, with grid size effectively $1m^2$.

ModeS: (#7)
The mode of solution of the sediment transport equation using explicit or analytic solids. For all cases this was set to be 5.

ModeRn: (#10)
Enabled random perturbations instigated in the initial surface landforms *.rst2 files to be read. For all cases this was enabled, as different surface profiles were used. The multiplier factor is illustrated in Figure 4.2.4 above, with default value of 1.

UserRO: (#12)
This module is activated by UserRO, where the integer parameter refers to either 'f.dat' or 'fwide.dat' representing the two alternative water source entry points. This routine is illustrated in Figure 4.2.5 below, and involves coordinates of the inlet points and amount of area (number of nodes) contributing to each of the points. It was highlighted that the total area was $7200m^2$, with each node equivalent to 3600 nodes for the narrow feed point, and 1800 nodes for wide inlet point. Inlet points incorporating the upper section of the gully catchment into the initial surface were between (8,70) and (11,70) respectively.

UserFT: (#11)
This module is similar to UserRO, with user defined sediment transport rate incorporating the rudimentary armouring component into the model, Figure 4.2.6.

```
SIBERIA RUNOFF
1ST LINE
2ND LINE
3RD LINE
2
9 60 3600 1
10 60 3600 1

SIBERIA RUNOFF
1ST LINE
2ND LINE
3RD LINE
4
8 70 1800 1
9 70 1800 1
10 70 1800 1
11 70 1800 1
```

Narrow Inlet Standard Profile: 20 by 60.

Wide Inlet with Extended Profile: 20 by 70.

Figure 4.2.5: The used defined runoff module replicates the gully catchment behind the 2 or 4 inlet points at the top of the batter slope. Filename 'f.dat' or 'fwide.dat', appears in Figure 4.2.4, with total contributing area of 7200 m^2 (equivalent to nodes) representing an inflow of 7200/4 or 7200/2 for each inlet point.

The spatially constant mode was adopted for all cases except when considering armouring component. Inclusion of the depth erodibility relationship involved setting this mode to 1 from default value of 0 (Section 4.4).

The exponential relationship between erodibility (measured as function of mean grain size) and depth used to derive these coefficients, are used to multiply the calculated depth of erosion within the SIBERIA model before evaluating new elevations.

This relationship effectively reduces erosion with depth, however cannot distinguish at this stage between previously eroded material, or unsullied hillslope.

```
1ST LINE
2ND LINE
3RD LINE
15.0 1.0
```

Depth Coefficient, C ~ 15, and exponent, m ~ 1.

Figure 4.2.6: The user defined erosion module involved setting the integer parameter, UserFT from 0 to 1. The implementation of this module involves two coefficients used in an exponential relationship between erodibility and depth.

The remainder of the modules (integer parameters) were not considered or altered during the modelling process, and were set at default values.

The next group of parameters were the real parameters, which allocated numerical values to each of the coefficients, and exponents used in the sediment transport model, discharge-area relationship.

1/a_t: (#27)
The channel initiation threshold was set to be 0, such that a channel would not be formed, and the channelisation (different sediment transport equation) not implemented.

The differential erosion rate of the hillslope and channel was not considered in this study, with channelisation module disabled for all model simulations.

m_3: (#37)
The discharge-area relationship is assumed to be linear, with m_3 taken to be unity.

β_3: (#38)
The coefficient in the discharge-area relationship, equation 4.1.10, was determined from the gully catchment outlet points at the top of the batter slope. For each of the storm events the following values were adopted, with consequent storm events run in series.

Table 4.2.1: The coefficient in the discharge-area relationship was adapted to represent the outlet of the gully catchment. Duration of each storm event were averaged over 1 hour, whilst the event on 230197 was considered to maintain intensity for entire hour, although event only lasted 25 minutes.

Event	Average Discharge (m^3/hr)	β_3
261296	19.59	2.72×10^{-3}
010197	14.33	1.99×10^{-3}
230197	22.75	3.16×10^{-3}

β_1: (#39)
The coefficient in the sediment transport equation, equation 4.1.9, was adapted using the bulk density determined on-site to be 1.93gcm^{-3} in equation 4.1.12 above. The value adopted was 0.112 and represented the erodibility of the surface material within the SIBERIA program.

m_1: (#40)
The exponent on discharge in sediment transport equation was evaluated using equation 4.1.9 from fitted erosion studies at value of 1.68.

n_1: (#41)
The exponent on slope in sediment transport equation is discussed in Section 4.1 above, where a value of 0.69 from equation 4.1.9, or the default value of 2.1 being adopted during the initial modelling period. Sensitivity analysis of the effect of this parameter will be conducted initially, and using the final simulation scenario comparing all of the implemented modules.

time: (#43)
Iteration time step was set at 0.05 for the majority of simulations conducted, for numerical stability, resulting in computational time lengths of about 25 minutes per storm event.

The modelling process involved the approximation of an initial surface, with the addition of random noise to elevations used to simulate the relatively uniform topography, whilst representing the nature of the waste rock material. This is illustrated in Figure 4.2.1, and Figure 4.2.2 above.

4.3 Simulations

The implementation of parameters into the SIBERIA model was varied to test the capability of the model to predict size and shape, as well as characteristic of the behaviour of gullies formed. By comparison between predictions from SIBERIA to the actual formation, the impact of different mechanisms, and the determination of important parameters could be conducted.

A number of simulation scenarios were investigated to assess the various aspects of erosional mechanisms. These simulations include firstly a standard case, by which the remained of simulations are compared, incorporation of the gully catchment, increase in the width of the inlet points, introduction of random erodibility in the waste rock material, as well as the assessment of the rudimentary armouring model and determination of sensitive parameters such as the slope exponent n_1.

Standard

The initial surface created to represent the batter slope marks the first stage in assessing model behaviour and predictions. The relationships outlined above, are used to derive the parameters required for the SIBERIA model, with this case specifically representing a standard by which all the other simulation scenarios are compared.

This surface effectively represents a uniform, homogenous material, with fixed outlet point, and the armouring module disabled.

The gully catchment was represented by the user defined runoff module described in Figure 4.2.5 above, with 'f.dat' being adopted for the study site (Figure 4.2.2), and 'fup.dat' being adopted for the extended study site incorporating the gully catchment (Figure 4.2.1).

Increased Width

The impact of increasing the at the top of batter slope was investigated. The total contributing area, representative of the gully catchment was 7200m^2 (equation 4.1.10), with standard runoff module 'f.dat' in Figure 4.2.5 replaced with 'fwide.dat'.

The 'fwide.dat' runoff module distributed the surface flow from the catchment across 4 nodes, instead of 2 nodes for the narrow feed case. Although the total flow is not altered and the erodibility of the surface material remains unchanged, the wide entry point may reduce the extensive erosion observed in preliminary modelling results, with the head of the gully eroding to depths in the order of 2 to 3m. The discretisation of the batter slope into a 20 by 60, $1m^2$ grid, may not be conducive for the development of more than one gully, as the flow-path from the 4 inlet points may concentrate to one within only a few nodal steps.

From Table 4.2.1, the discharge-area coefficient β_3 attempts to characterise the nature of the three storm events. This involved replacing the initial surface for the second storm event with the last generated surface from the first event. i.e. gully-0000060.rst2 is used as the initial surface file for the 010197 storm.

Upper Section

The extension of the batter slope study area to incorporate the 10m of the gully catchment is described in detail above. The expected equilibrium profile for the overall landscape (Figure 1.1.4) tends to indicate that incision of the high wall will extend back into the cap. By extending the profile of the slope to include this additional 10m, with a slope of 2%, this aspect will be investigated.

Alteration of input parameters was restricted to a revised initial surface profile only. However, due to the extensive erosion expected at the head of the gully (at the inlet points), it is possible that a similar landscape to the standard case will be generated, except that erosion will extend a further 10m.

This may indicate the runoff, drainage density being the dominant erosion factor, rather than the slope transition between the catchment and the batter site. Considerable amounts of water are applied to these upper sections, with the development of a gully on these slopes more closely resembling theoretical behaviour.

Random Erodibility

The erodibility of the rock material of the NWRD was approximated from calibration of the sediment transport equation parameter β_1 from previous studies and modified

using the bulk density (Section 4.1) to represent the erosional characteristic of the batter slope.

The entire landform represents a diverse range of erodibility, a function of mean particle diameter, d_{50} and geophysical weathering characteristics of the material, by introducing a random multiplier to the β_1 parameter, a more dynamic and realistic behaviour may be achieved.

As described above, the operational parameter 'ModeRn' has been already implemented, with the coefficient multiplier involving the alteration of the initial surface profile file from a default value of 1.0. By generating a random distribution between 0 and 5, with a mean of 1.0, the overall characteristics of the site is unchanged, but variation in the erodibility of the material has been introduced.

This aspect incorporates a more realistic impression of the gully development observed on site, with pathway dictated primarily by the variability of the material, or the dominant runoff drainage density relationship.

The sediment transport relationship has 2 major components, one of which depends on discharge (relative directly to the amount of water feeding each node) and the other is dependent on slope.

As outlined above, it is expected that for the standard homogenous case the pathway of the gully adopted will not be significantly affected by the random perturbations given to the initial surface elevations. The pathway will more than likely be straight down the slope, depositing material at the change of curvature point between Row G to Row I, before the dominant erosional process changes to be a function of material erodibility. This will be reflected in the comparison between this simulation scenario in the standard batter profile and extended profile cases.

By incorporating random erodibility into this relationship, the pathway adopted will vary, and move across the slope for the standard profile, however once the gully is instigated it is considered unlikely that a new path could be commenced as the drainage density of each node within the gully increases dramatically once it has formed (Figure 4.3.1).

Another interesting consideration may be the effect of deposition on the gully pathway adopted. Although the batter slope was relatively uniform, and the development observed on site was dominated by the initial erodibility of material in the upper sections, deposited sections tended to influence the pathway adopted below the point of curvature change. By changing the behaviour of the simulated gully from a straight line (standard case) to a more realistic random motion, less material was concentrated at these points.

The drainage direction of the nodes surrounding each node point is illustrated in Figure 4.3.1 below, with this indicating which of the 8 adjacent nodes the current node drains into. Once the gully is established, this pathway seems to be determined by dominant drainage direction until the slope component driving the sediment transport equation is reduced in the lower sections.

Once the gully was initiated, the drainage density relationship remains dominant until slope component becomes considerable, observed in transition in lower sections with accumulated material.

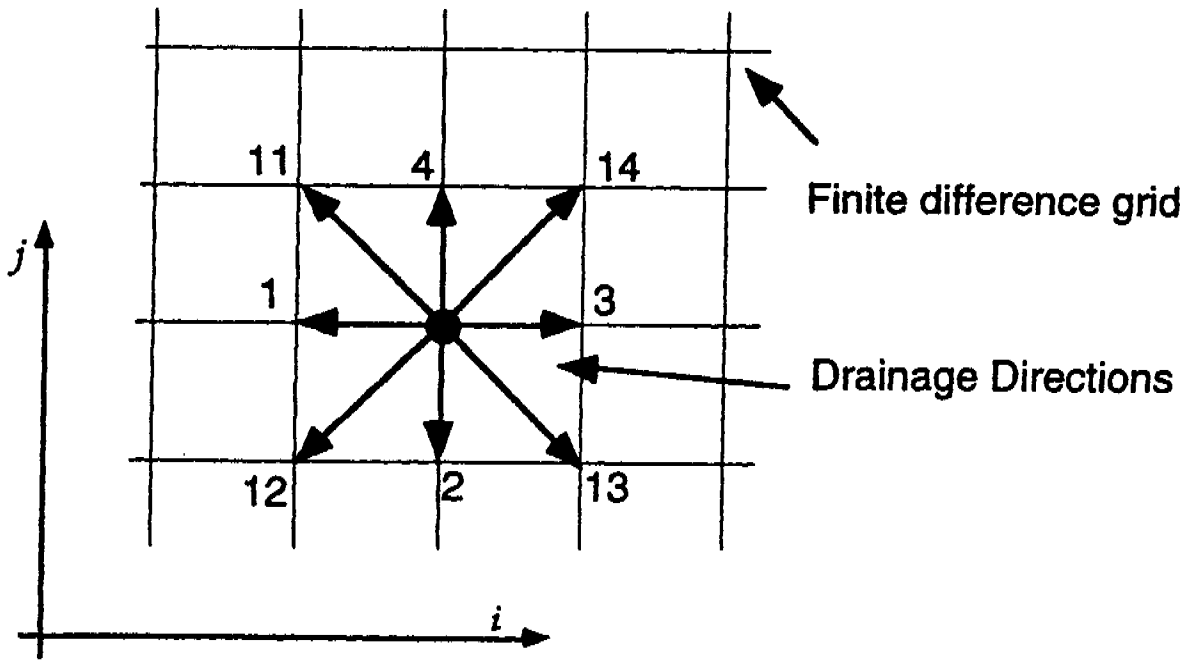


Figure 4.3.2: Drainage direction of the finite difference grid indicates which of the 8 adjacent nodes each node drains into (Willgoose, 1992 Figure 1). The drainage density of the gully once it has been initiated will tend to dictate only one pathway to be adopted. This may be overcome by increasing the grid discretisation of the profile, as well as widening the inlet point or introducing erodibility with depth relationship as described below.

Differential Erodibility with Depth

Armouring was considered to represent the decrease in erodibility with depth of erosion. Conceptually this model is an exponential relationship, a function of mean particle diameter, and represents the risk of erosion of the material at various depths into the batter slope.

The mean particle diameter, d_{50} was used as the measure of the change in the surface characteristic and was incorporated into the following relationship (Figure 4.3.2):

$$\text{erodibility} = \text{initial erodibility} * \frac{1}{C * \text{depth}^{\text{exponent}} + 1} \qquad (4.3.1)$$

where

depth = depth of erosion from commencement
exponent = exponent on the depth of erosion (set initially to 1)
C = coefficient reflects the initial and final mean grain size over a given depth eroded.

The implementation of this erosion module involved considerations such as the crude measure of the change in erodibility, no distinction between previous eroded material, and unsullied hillslopes, and conservative estimates of relationship parameters.

Conservative estimate of the erodibility of surface material is based on relationship: $1/d^{3/2}$, with d_{50} initial at 2mm = $1/2^{3/2}$ leading to erodibility ~ 1/3, whilst d_{50} final at 20mm at a depth of 2m = $1/20^{3/2}$ ~ 1/90 represents a reduction in erodibility by a factor of 1/30.

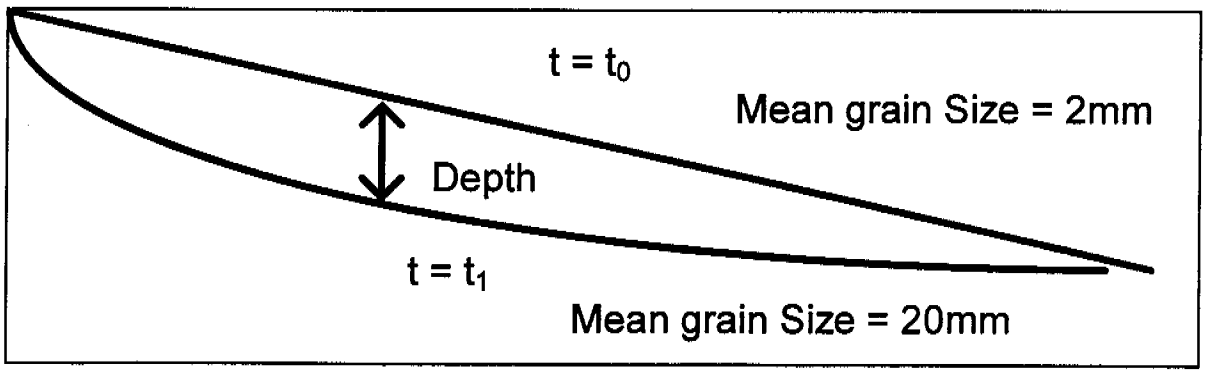


Figure 4.3.2: The effect of the change in d_{50} of surface material with depth represents the next component of the investigation. Although initial and final grain sizes were set to 2mm and 20mm respectively, they represent a conservative approximation.

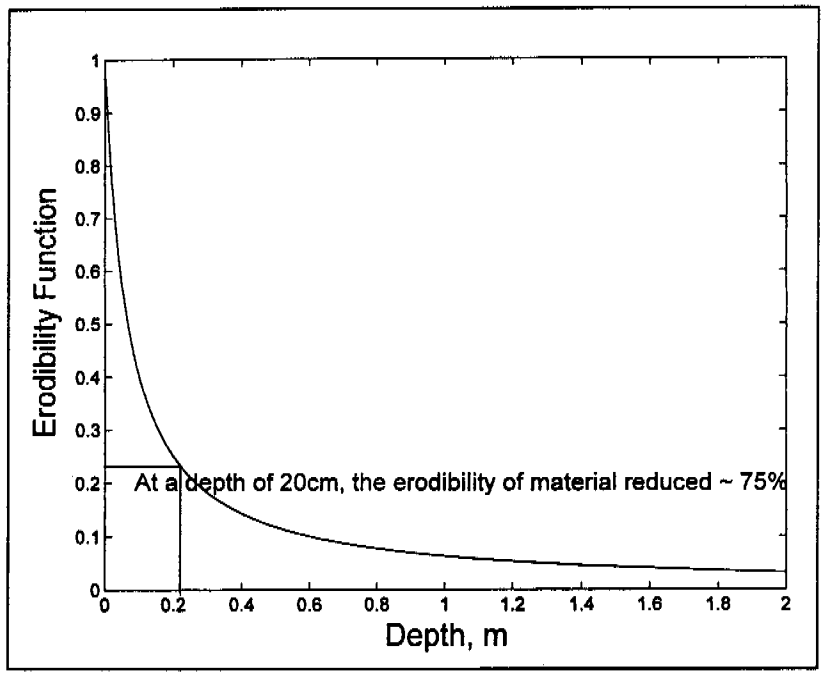


Figure 4.3.3: The change in erodibility function term (1/coefficent*depth^{exponent}+1) represents an exponential relationship between the depth and erodibility of the surface, determined from the coefficient (relating mean grain size, d_{50}) allocated (C ~ 2). i.e. at a depth of 20cm, the erodibility function is ~ 0.25 equating a reduction in erosion of 75%.

The erodibility of the surface, as the gully forms rapidly decreases with parameter values of C ~15, and C ~2 being considered. Although this is a relatively crude relationship applied to an extremely complex process, it represents a reasonable estimate or summary of the interaction observed on site, with a dramatic decrease in erodibility of the 'channel bed' once the fine material (d_{50} small) was removed leaving larger boulders exposed, Figure 4.3.4.

Incision in the upper section of the batter slope ranged between 40 and 80cm, with armouring maximised on the very upper sections where water velocity was minimal. Once this characteristic was in place, little further movement or activity occurred.

Further approximations in the erodibility-depth function included the evaluation of sections where deposition had occurred. These sections composed of the fine material from the upper sections represented a highly erodible surface (observed) and implementation of differential erosion between original hillslope and these components represent future research (pers. com. Willgoose, 97).

Numerous modelling scenarios were investigated during the experimental stage, with the impact of various components of the model assessed by progressive inclusion to

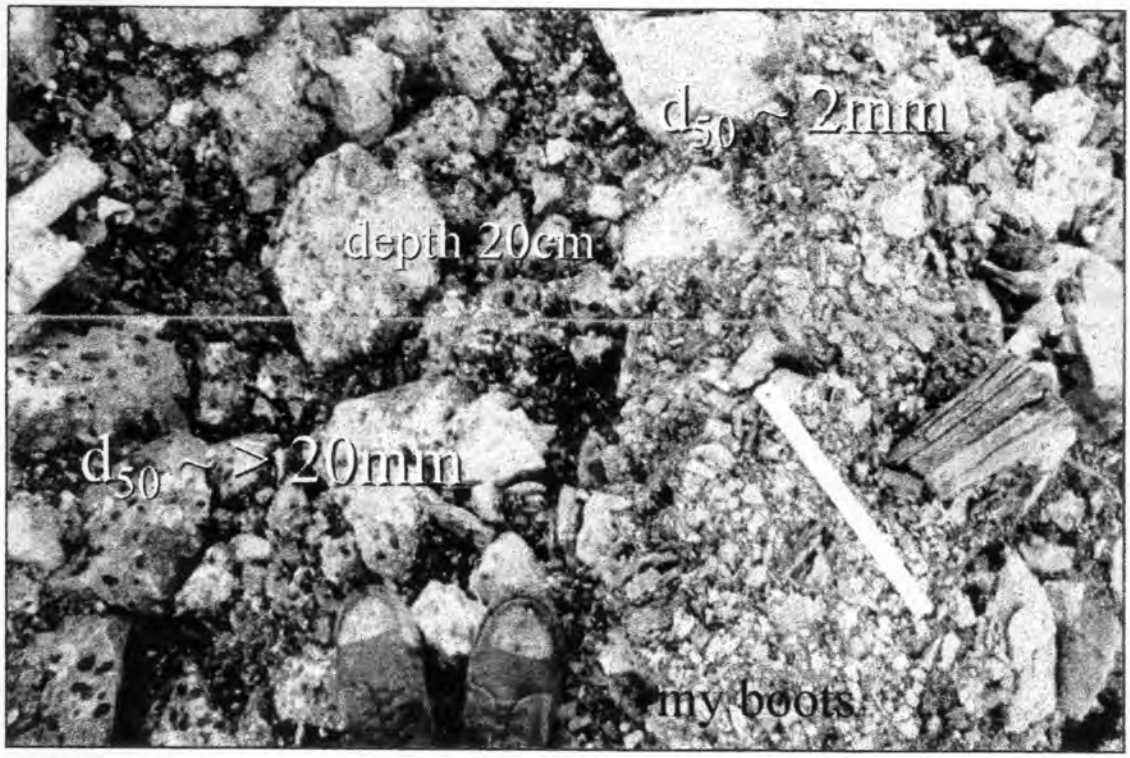


Figure 4.3.4: The difference observed in mean particle diameter, d_{50} between the active (gully) and inactive (hillslope) components of the surface was significant. The fine material observed was quickly eroded leaving large rock fragments exposed which significantly resisted further movement.

an eventual best possible representation. By comparison between the nature of the gully and predictions from the SIBERIA model, an understanding of the soil erosion mechanisms in operation on site can be developed.

Determination of impact of additional components such as heterogeneity, and armouring evolves the prediction to resemble the nature of the actual landform, as closely as possible. Feed back indicated areas of sensitivity, such as the exponent on the slope component in the sediment transport equation, and allowed the evaluation of gullies likely to be formed on the steep batter slopes.

From these regimes, the impact of each component can be assessed, with the final scenario representing the combination of all the erosional mechanisms.

A series of scenarios were considered in this methodology:

- assessment of the behaviour of the exponent on the slope component n_1 with both the standard and extended profile batter sites.

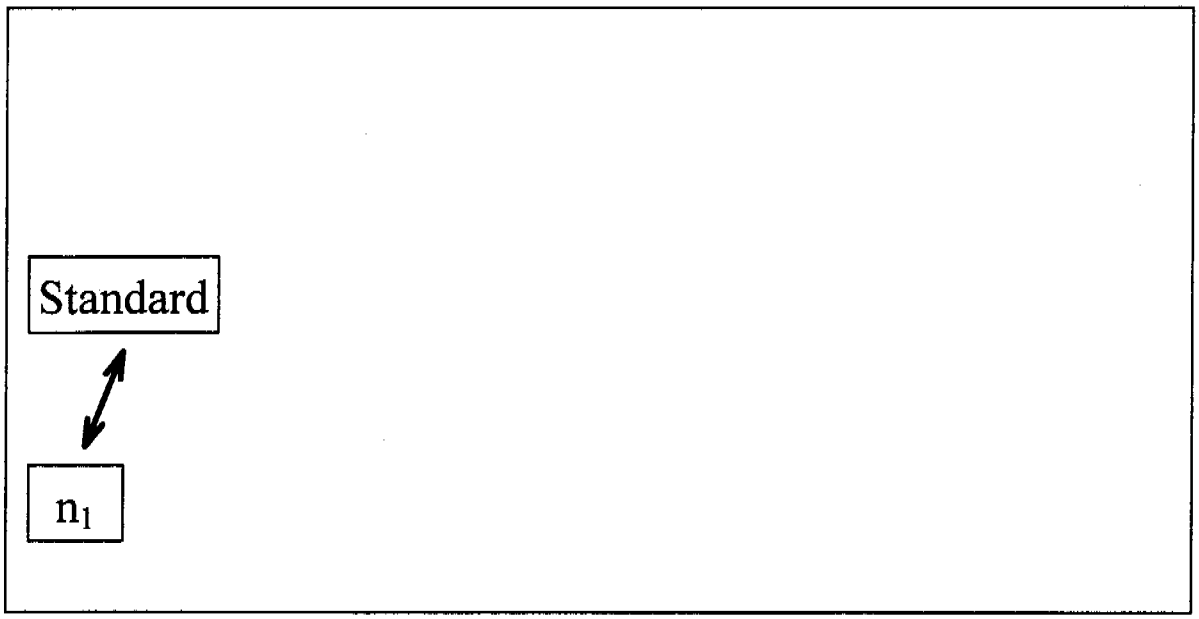


Figure 4.3.5: Two case scenarios were run; standard refers to the assumption of homogenous material, with armouring module disable, and the inclusion of extended profile in the second file.

```
SIBERIA      8.01
    60     10     20     70      0      0
     5      1      0      1      0      2
     0      0      1      0      0      0
     0      0
  0.000000    1.000000    0.000000    0.000000    1.000000
  1.000000    0.000000    1.000000    0.100000    0.000000
  0.000000    0.000000    0.000000    0.000000    0.005000
  1.000000    1.000000    0.002720    0.112000    1.680000
  0.690000    1.930000    0.100000    2.500000    0.300000
 10.000000    0.400000    0.100000    2.000000    1.000000
  0.000000    1.000000    1.000000    1.000000    0.000000
  0.000000    0.000000    0.000000    0.000000    0.000000
  0.000000    0.000000    0.000000    0.000000    0.000000
  0.000000    0.000000    0.000000    0.000000    0.000000
```

Upper Surface with n_1 at 0.69, non-armouring, homogenous.

fup.dat

n_1 at 0.69, and upper inlet runoff module

```
 4
 8 2
 9 2
 10 2
 11 2
.0000E+00 1.0000 0.0010 0.1771374E+00    0  5 0.0000E+00 0.0000E+00
```

Figure 4.3.6: These are the parameter files used to generate the standard and extended profile batters, with exponent on the slope component n_1 changed from 2.1 to 0.69, equation 4.1.9.

- assessment of increasing the inlet width from 2 node points for narrow case, to 4 inlet points for the wide case.

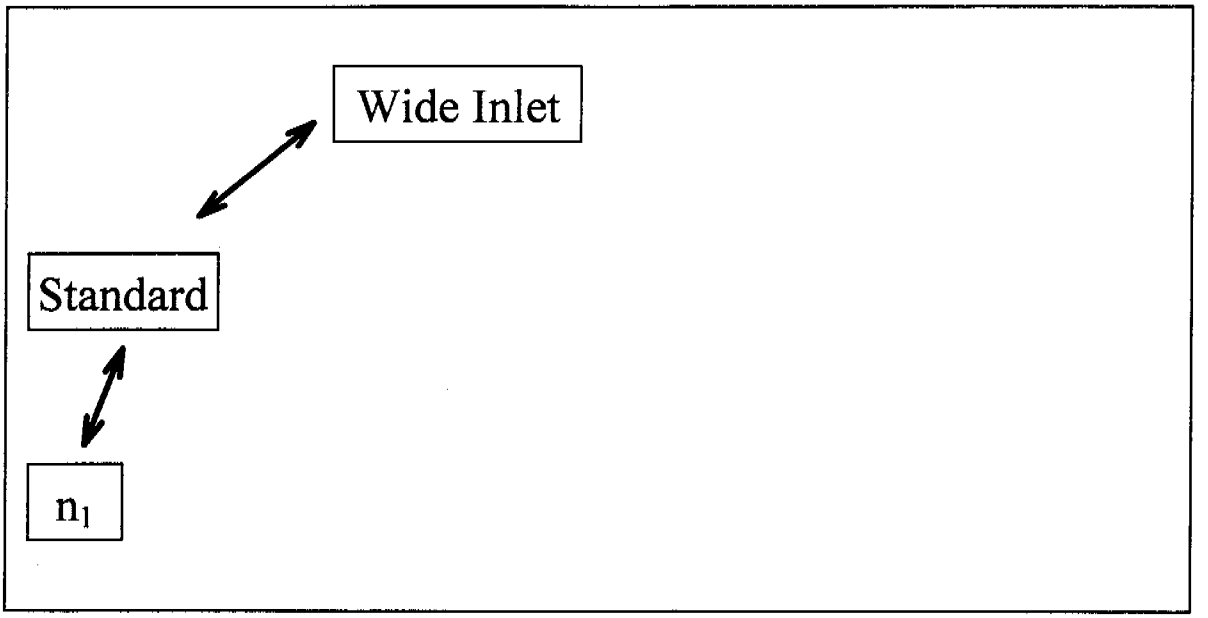


Figure 4.3.7: Parameter files incorporating wide inlet points, and alteration of the user defined runoff module file to describe either the narrow or the wide case.

The parameter files used in these scenario are as follows:

```
SIBERIA      8.01
    60     10     20     60      0      0
     5      1      0      1      0      2
     0      0      1      0      0      0
     0      0
  0.000000    1.000000    0.000000    0.000000    1.000000
  1.000000    0.000000    1.000000    0.100000    0.000000
  0.000000    0.000000    0.000000    0.000000    0.005000
  1.000000    1.000000    0.002720    0.112000    1.680000
  2.100000    1.930000    0.010000    2.500000    0.300000
 10.000000    0.400000    0.100000    2.000000    1.000000
  0.000000    1.000000    1.000000    1.000000    0.000000
  0.000000    0.000000    0.000000    0.000000    0.000000
  0.000000    0.000000    0.000000    0.000000    0.000000
  0.000000    0.000000    0.000000    0.000000    0.000000

fwide.dat
```

wide inlet runoff module

```
 4
 8 2
 9 2
 10 2
 11 2
.0000E+00 1.0000 0.0010 0.1150964E+00    0  5 0.0000E+00 0.0000E+00
```

Figure 4.3.8: The implementation of this simulation involved altering the user defined runoff module to represent a more evenly distributed inlet flow. This file standard profile, with wide inlet point.

- assessment of the alteration of the random field multiplier parameter was used to introduce heterogeneity. Another two scenarios were also used to compare the combined of both the wide inlet feed along with randomised erodibility.

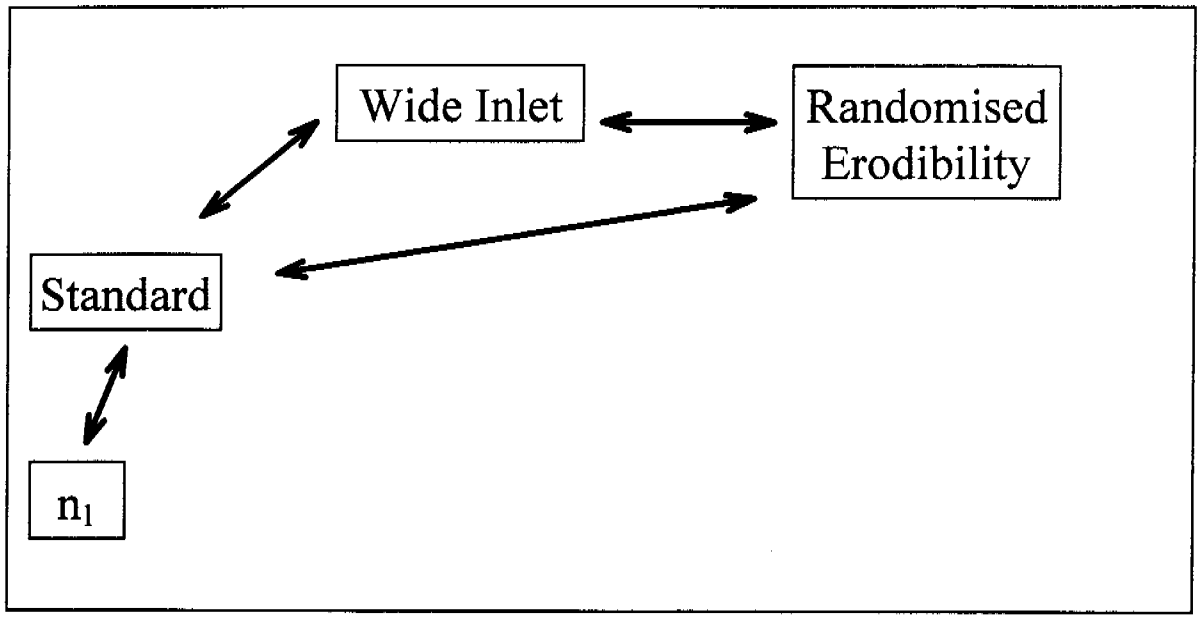


Figure 4.3.9: Methodology flow-paths for the inclusion of wide inlet point, and introduction of randomised erodibility to the batter slope material.

The parameter files used in these scenario are as follows:

```
SIBERIA      8.01
    60     10     20     60      0      0
     5      1      0      1      0      2
     0      0      1      0      0      0
     0      0
  0.000000    1.000000    0.000000    0.000000    1.000000
  1.000000    0.000000    1.000000    0.100000    0.000000
  0.000000    0.000000    0.000000    0.000000    0.005000
  1.000000    1.000000    0.001990    0.112000    1.680000
  2.100000    1.930000    0.010000    2.500000    0.300000
 10.000000    0.400000    0.100000    2.000000    1.000000
  0.000000    1.000000    1.000000    1.000000    0.000000
  0.000000    0.000000    0.000000    0.000000    0.000000
  0.000000    0.000000    0.000000    0.000000    0.000000
  0.000000    0.000000    0.000000    0.000000    0.000000
```

f.dat

Second storm event, $\beta_3 = 0.00199$

Change in random field multiplier

```
 4
 8 2
 9 2
 10 2
 11 2
.0000E+00 0.1119 0.0010 0.5261294E-01    0  5 0.0000E+00 0.0000E+00
```

Figure 4.3.10: The implementation of this simulation involved altering integer parameter ModeRn, and adjusting the multiplier coefficients in the initial landscape file, along with increasing inlet width.

- assessment of depth-erodibility relationship, equation 4.3.1 was used to determine the reduction factor that was multiplied by the erosion depth evaluated by SIBERIA before the new elevations for the batter slope catchment were calculated.

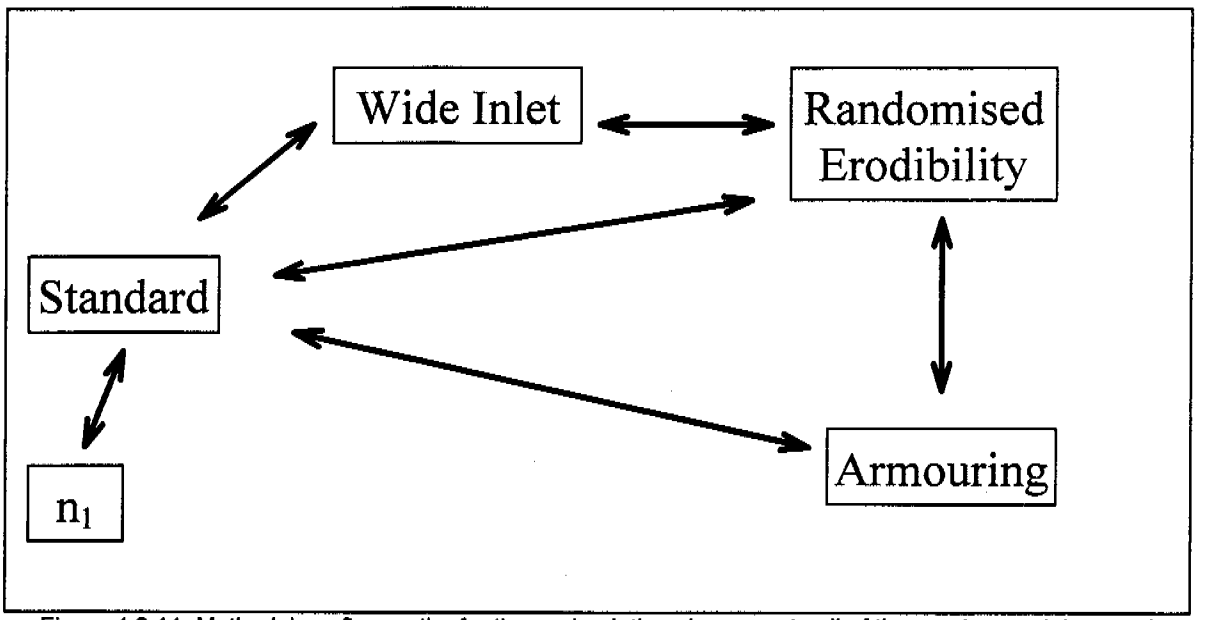


Figure 4.3.11: Methodology flow-paths for these simulations incorporate all of the erosion modules used in this study.

The parameter files used in these scenario are as follows:

```
SIBERIA      8.01
    60     10     20     70      0      0
     5      1      0      1      1      2
     0      0      1      0      0      0
     0      0
    0.000000     1.000000     0.000000     0.000000     1.000000
    1.000000     0.000000     1.000000     0.100000     0.000000
    0.000000     0.000000     0.000000     0.000000     0.005000
    1.000000     1.000000     0.002720     0.112000     1.680000
    2.100000     1.930000     0.100000     2.500000     0.300000
   10.000000     0.400000     0.100000     2.000000     1.000000
    0.000000     1.000000     1.000000     1.000000     0.000000
    0.000000     0.000000     0.000000     0.000000     0.000000
    0.000000     0.000000     0.000000     0.000000     0.000000
    0.000000     0.000000     0.000000     0.000000     0.000000
armour.dat
fup.dat
```

Armouring module

Random multiplier factor not altered between simulations.

```
 4
 8 2
 9 2
 10 2
 11 2
.0000E+00 0.0379 0.0010 0.5501554E-01    0  5 0.0000E+00 0.0000E+00
```

Figure 4.3.12: The implementation of this simulation incorporated the user defined sediment transport rate 'armour.dat'. Incorporates extended profile, randomised erodibility, and differential erode with depth

- investigation into the sensitivity of the exponent on the slope component of the sediment transport equation, n_1 constituted the final step in the modelling analysis.

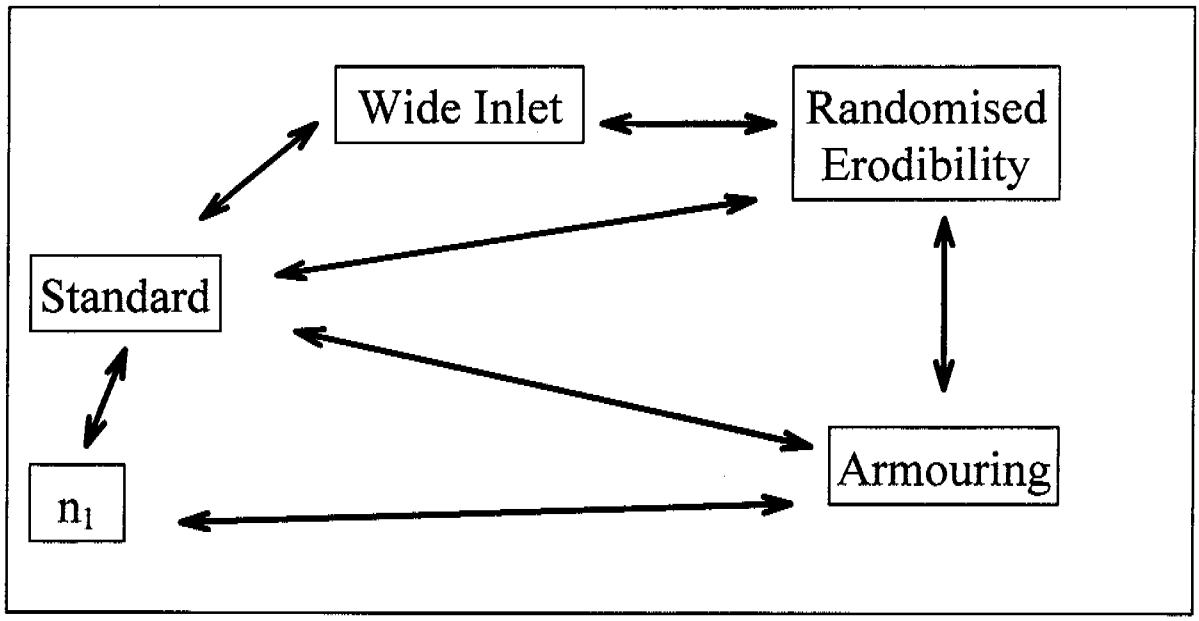


Figure 4.3.12: Methodology flowpaths for these simulations incorporate all of the erosion modules used in this study, combined with a exponent on the slope parameter, n_1 = 0.69 in place of 2.1.

The parameter files used in these scenario are as follows:

```
SIBERIA      8.01
     60     10     20     70      0      0
      5      1      0      1      1      2
      0      0      1      0      0      0
      0      0
     0.000000      1.000000      0.000000      0.000000      1.000000
     1.000000      0.000000      1.000000      0.100000      0.000000
     0.000000      0.000000      0.000000      0.000000      0.005000
     1.000000      1.000000      0.002720      0.112000      1.680000
     2.100000      1.930000      0.100000      2.500000      0.300000
    10.000000      0.400000      0.100000      2.000000      1.000000
     0.000000      1.000000      1.000000      1.000000      0.000000
     0.000000      0.000000      0.000000      0.000000      0.000000
     0.000000      0.000000      0.000000      0.000000      0.000000
     0.000000      0.000000      0.000000      0.000000      0.000000
armour.dat
fwideup.dat









  4
  8  2
  9  2
  10  2
  11  2
.0000E+00 0.0379 0.0010 0.5501554E-01    0  5 0.0000E+00 0.0000E+00
```

Figure 4.3.13: This simulation investigates the sensitivity of the slope exponent n_1 with all of the erosion modules enabled. This file incorporates all of the modelling components of randomised erodibility, armouring, and extended profile with wide inlet field, and n_1 = 0.69.

5.0 Assessment of Batter Slope Landforms

The relationships developed in the preceding sections were used to determined the parameters implemented by SIBERIA and to approximate the nature of the batter slope. Initial surface profiles are described, with the effect of each additional component assessed individually, and cumulatively against the standard homogenous scenario.

Evaluation of the impact of these soil mechanisms involves 2 methods: visualisation of areas of erosion and deposition, together with difference between simulation time periods using contour maps. Surface landforms are illustrated below and can be considered representative of predictions from the model produced at a grid size of 0.4m with a numerical mapping package. Interpolation between computational grid points has also lead to appearance of erosion 'holes', which were purely an artifact of the modelling simulation process. Contour plots illustrated below are changes that have taken place since the previous time period, and are considered an optimal method for presentation of erosion depths using colour schemes attached to each simulation result.

Initially activity will be concentrated at the top of the batter slope, and over time as the gully develops, the relative sections of erosion and deposition will alter, as the gully extends to the base of the slope.

Erosion is represented as negative numbers on the colour scale, whilst deposition is represented on the positive scale. Areas of deposition can be visualised in the surface landform plots as smoothed areas.

The estimates of differences will highlight aspects observed on site, such as the stabilisation of the gully formation once the gully had initiated, with relatively little activity in the upper sections of the study site.

5.1 Standard

The standard case was run with all of the external erosion modules disabled. This surface is representative of a homogenous material (calibrated to represent the batter slope) and these scenarios were run for equivalent of three hours duration.

At the end of each hour, the average length of storm event, the β_3 parameter was changed to represent the next storm event and the model run again using the last generated surface as the new starting point. Figure 5.1.1 and Figure 5.1.2 give the perspective development of the gully over the monitoring period at 10, 20, 30 and 60 minutes, 1.5, 2, 2.5 and 3 hours respectively. The maximum depth of the gully after 3 hours, at the head of the fully was 5.7m, with deposition between Row G and Row H reaching 0.35m after 1 hour. It is noted that these estimates were obtained using Figure 5.1.3, the contour map of difference between consequent surface profiles.

Significant erosion occurs at the head of the gully, with eroded material from this area deposited at the change of curvature during first hour, whilst deposition between Row H and Row I occurs after 2 and 3 hours. The homogenous nature of the batter slope, combined with the relatively uniform initial surface determine the straight path adopted.

The fixed outlet point is the flume located at the base of the slope, and this can be seen as a boundary condition for the finite difference grid, with transported material surrounding it, at the end of the time period. The material deposited or eroded at each node element within the batter slope catchment influences the drainage direction of nodes, based on altered surface topography. This is apparent as governing equation is directly reliant on the drainage density, as well as the drainage direction and the gully direction changes between 1 and 1.5 hours, as the curvature change is reached, the area of significant deposition.

From Figure 5.1.3 it is apparent that initial activity of the gully on the upper sections of the slope transports considerable amounts of material with the gully developing to between Row F to Row H, within the first storm event. By the end of the first event, the change in direction of the gully is noted in Figure $5.1.3_e$ and Figure $5.1.4_f$. Although maximum erosion occurs at the head of the gully, the section below Row H at 3 hours duration is observed to establish the same nature of erosion as initially observed, with material eroded, deposited in a straight line through Row H and Row I in Figure $5.1.2_d$. This is a reflection of the homogenous nature of the material, and indicates that the investigation into the contribution of the slope component in the sediment transport equation is warranted.

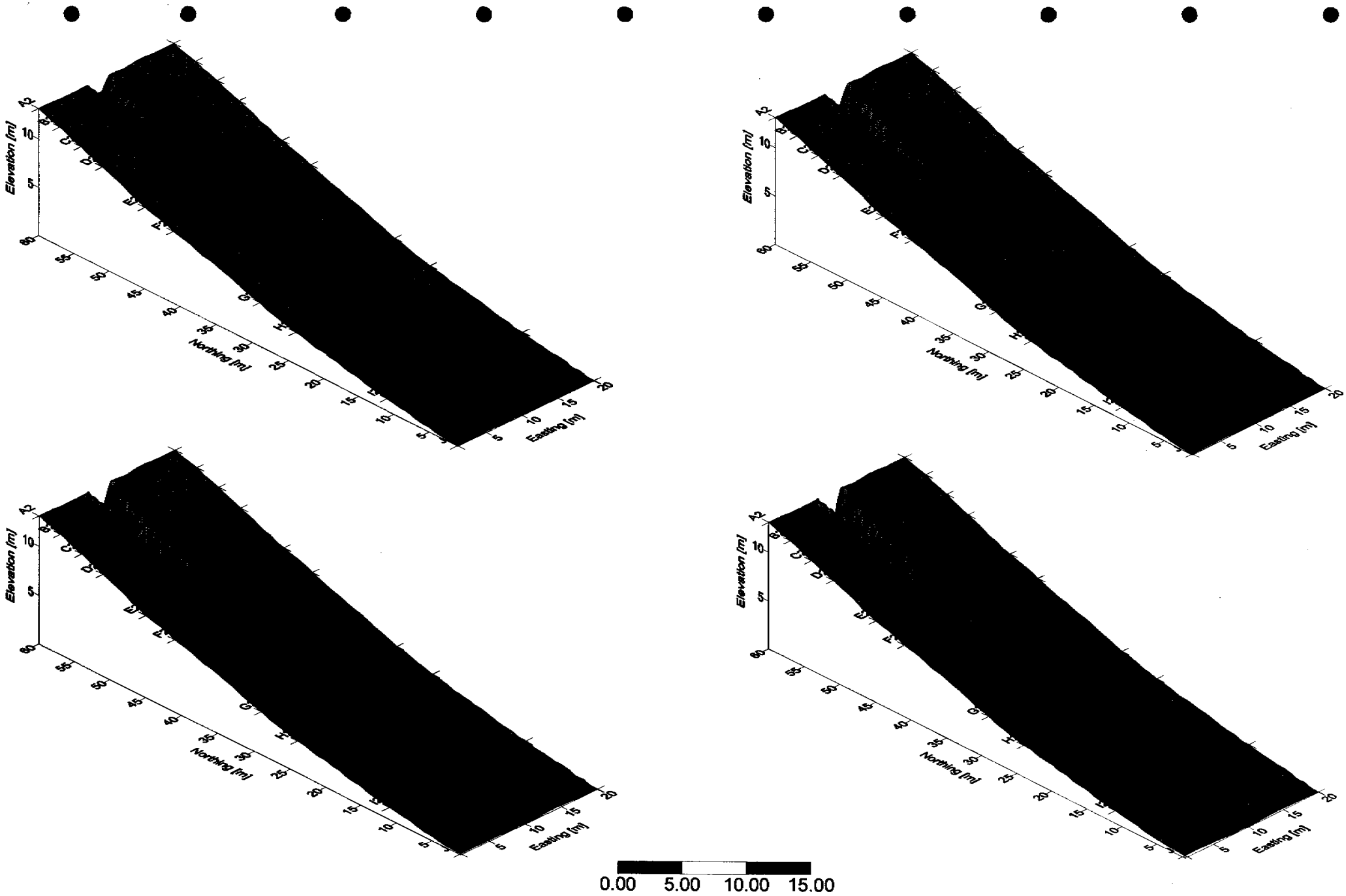


Figure 5.1.1: Simulations for STANDARD scenario at a)10 minutes, b) 20 minutes, c) 30 minutes, and d) 1 hour.

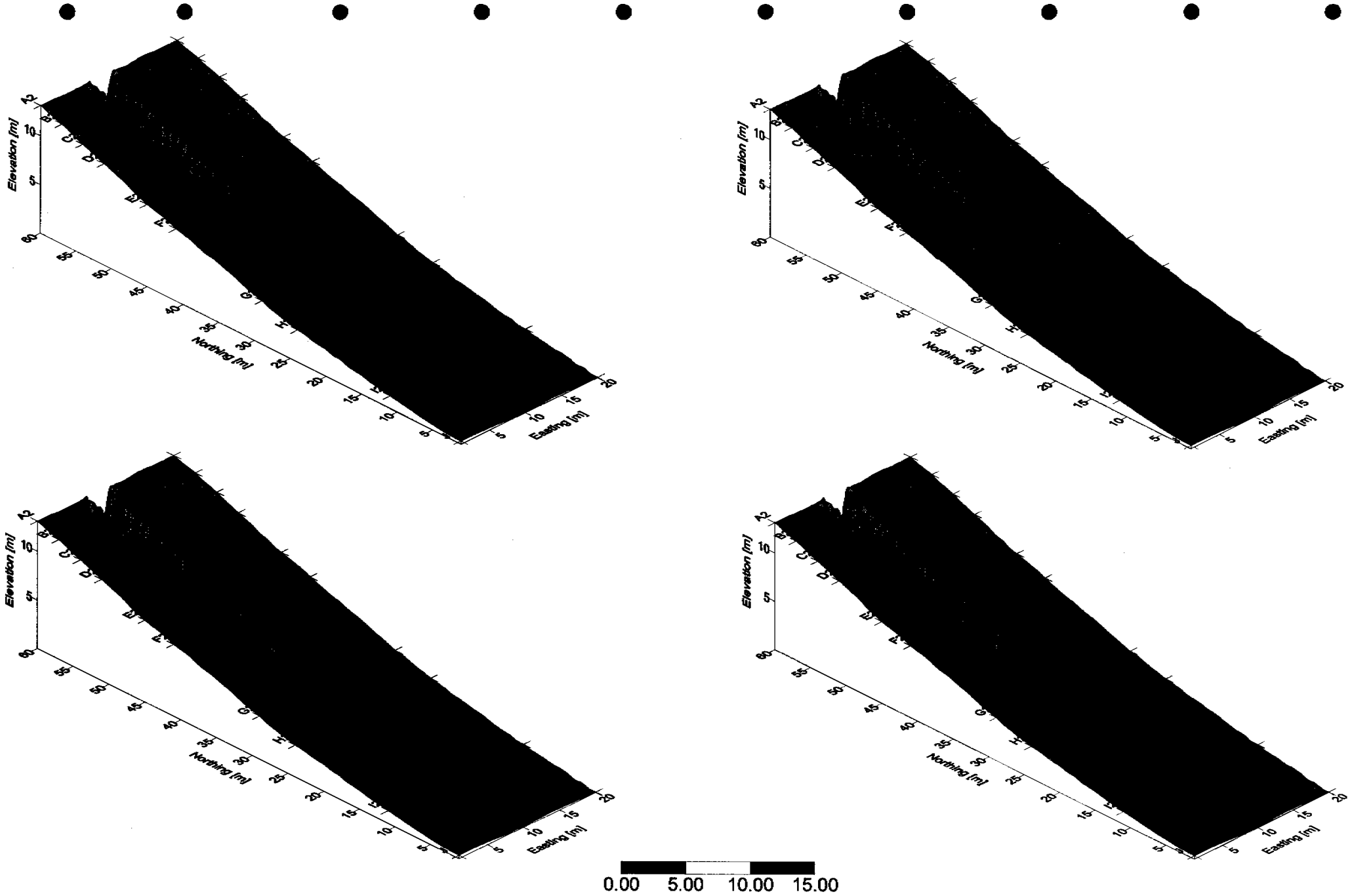


Figure 5.1.2: Simulations for STANDARD scenario at a)1.5 hours, b) 2 hours this represents the second storm event, and c) 2.5 hours and d) 3 hours representing the final storm event.

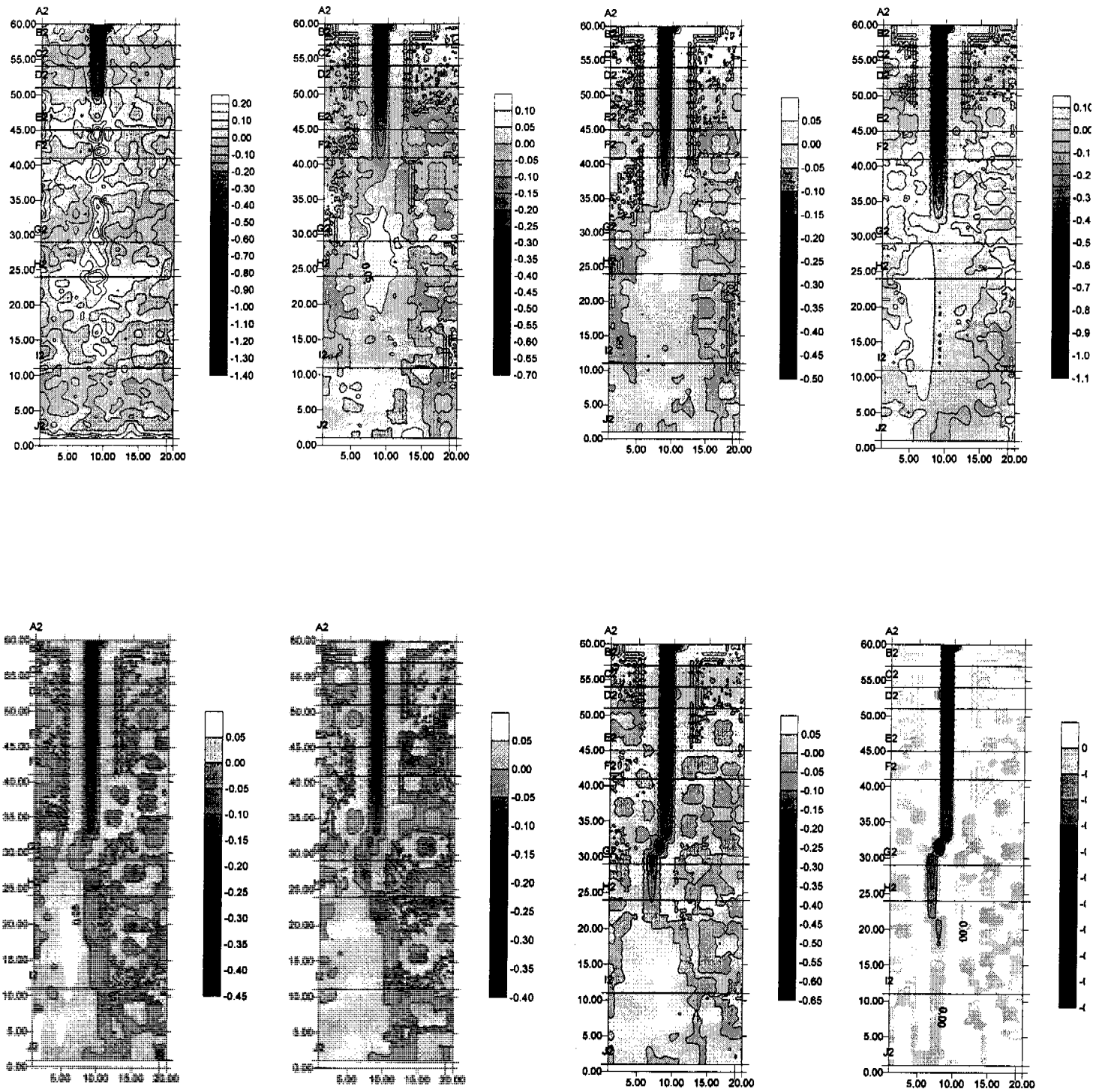


Figure 5.1.3: The initial elevations subtracted from appropriate time period (where erosion is negative, and deposition is positive) such that a) difference between initial surface and prediction at 10 minutes, b) 10 minutes and 20 minutes, c) 20 minutes and 30 minutes, d) 30 minutes and 1 hour. The difference in elevations are also calculated from the remainder of the simulations with e) difference between 1 hours and 1.5 hours, f) 1.5 and 2 hours, g) and 2.5 hours, and h) 2.5 and 3 hours.

The impact of extending the profile of the study area to include a 10m segment of the gully catchment was also investigated. Figure 5.1.4, and Figure 5.1.5 illustrate the simulation surfaces produced by the SIBERIA model for this scenario.

The gully begins to develop after about 30 minutes, with little change occurring at the transition point between the catchment and the batter slope. This point can be identified as Row A between simulations Figure $5.1.4_b$, and Figure $5.1.4_c$. The surface erodes toward the cap site, with a gully also developing onto the batter slope. Final surfaces were expected to resemble those observed in Figure 5.1.1, and Figure 5.1.2, whereas development process was slower, overall characteristics should be similar.

Once the formation reaches the inlet point of the catchment, the depth of this section increases during the remainder of the 3 hours to a maximum depth of 3 to 4 m. Noting that the depth of the gully at the top of the study area (Row A) reaches 3.4m, approximately half the depth of the previous scenario.

At the change in curvature, the path of the gully changes due to the combination between deposited material, and the contribution of the slope component in the sediment transport equation. Also noted in Figure $5.1.4_c$ and Figure $5.1.4_d$ where the path of the gully in the upper section appears to have been dictated by the random perturbations in initial elevations, a function of drainage density due to minimal contribution by slope component.

The behaviour of the gully above this transition point was observed similarly on site, due to the relatively flat nature of the gully catchment (combination of accumulated sediments compacted over time, and the construction of a flat surface initially), and the reservoir at the head of the gully which effectively raised the head of the gully about 30cm.

The initial delay in development observed in these simulations highlights the nature of sediment transport with slope component playing a considerable role. This is highlighted by comparison with previous simulations in Figure 5.1.1 and Figure 5.1.2, where after 60 minutes duration the gully has reached Row E, compared to below Row F, and the final location of the gully was about 5m above that seen for the standard case.

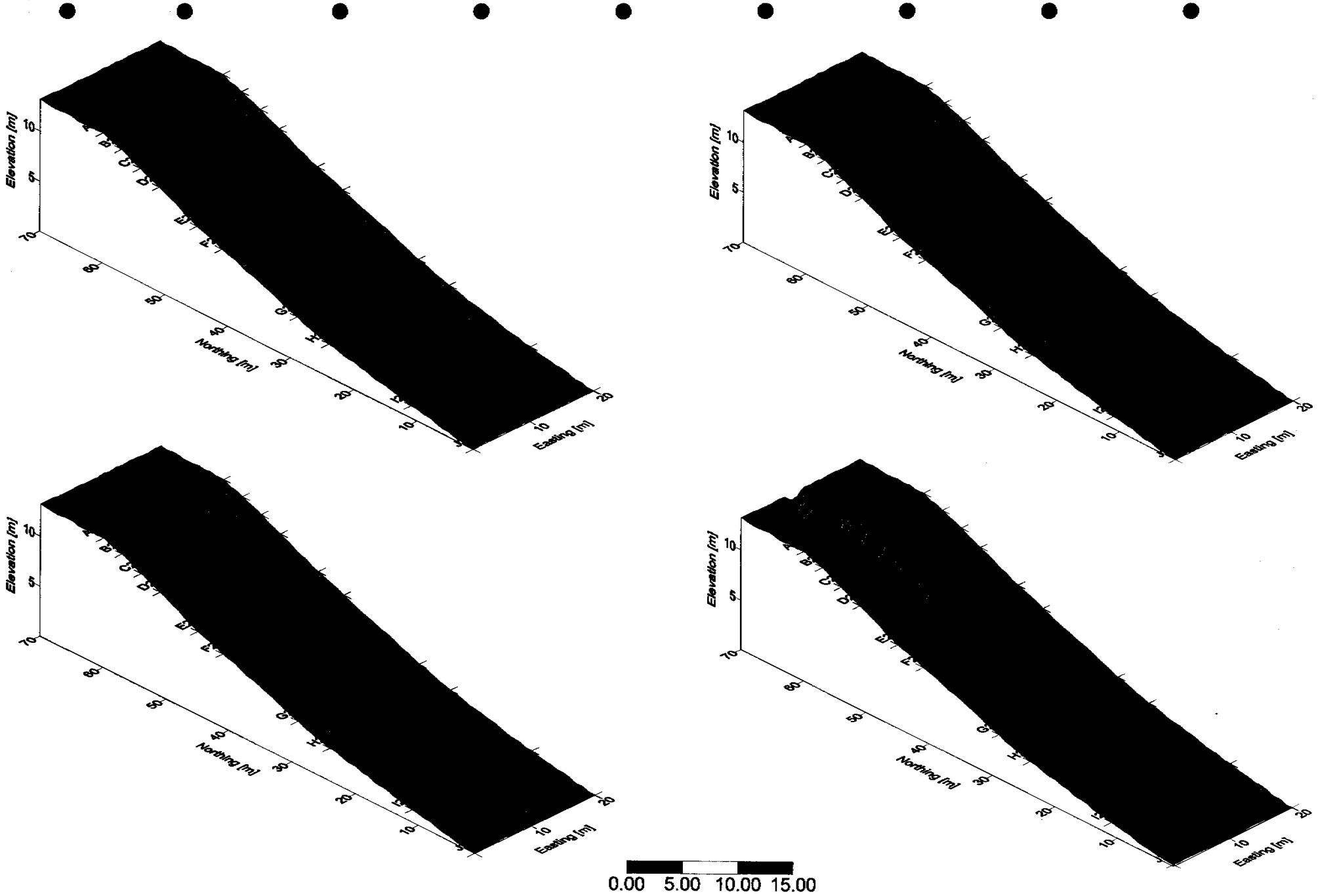


Figure 5.1.4: Simulations for extension of the batter slope to include a portion of the gully catchment, a)10 minutes, b) 20 minutes, c) 30 minutes, and d) 1 hour.

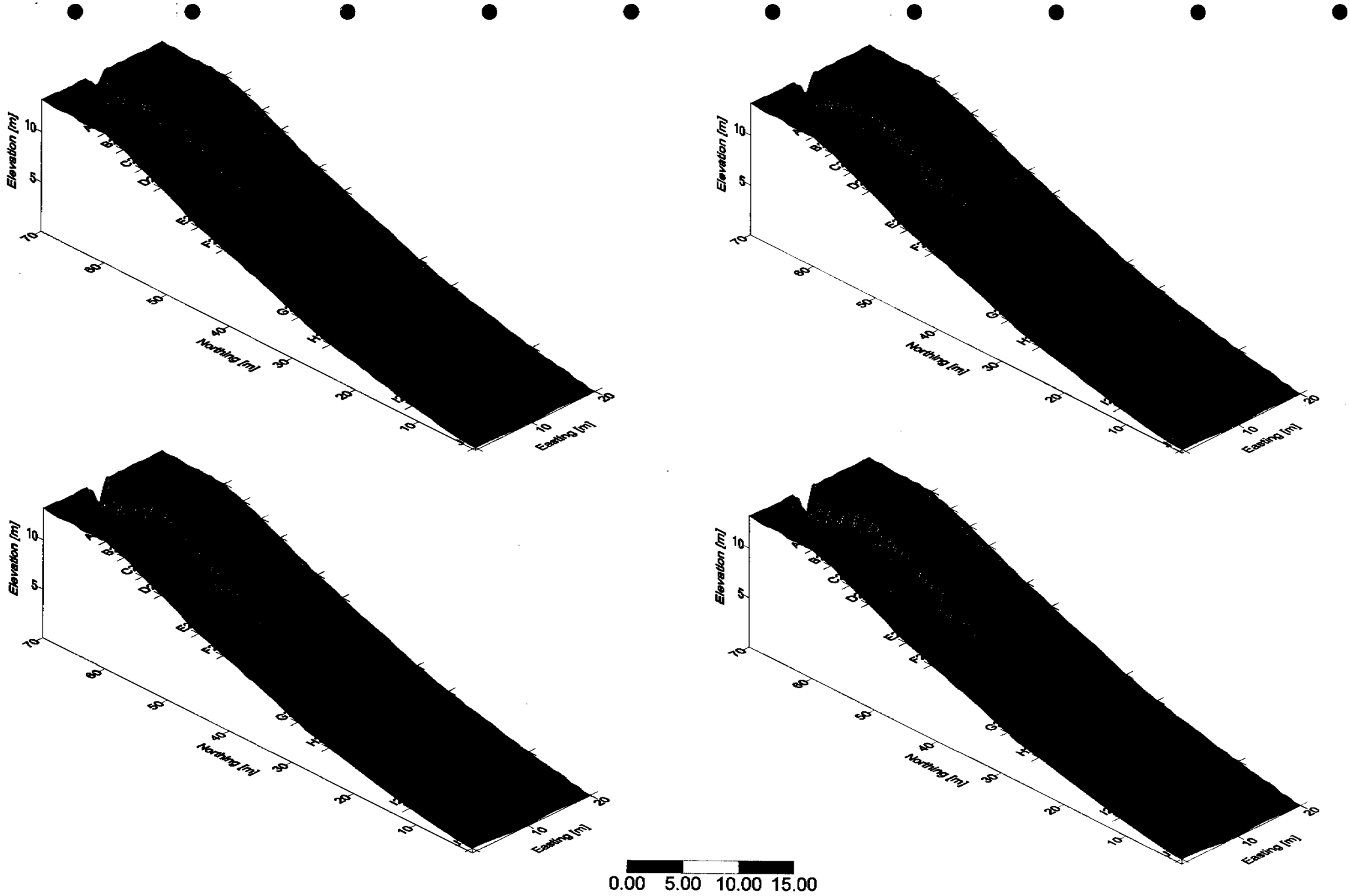


Figure 5.1.5: Simulations for extension of the batter slope to include a portion of the gully catchment at a)1.5 hours, b) 2 hours this represents the second storm event, and c) 2.5 hours and d) 3 hours representing the final storm event.

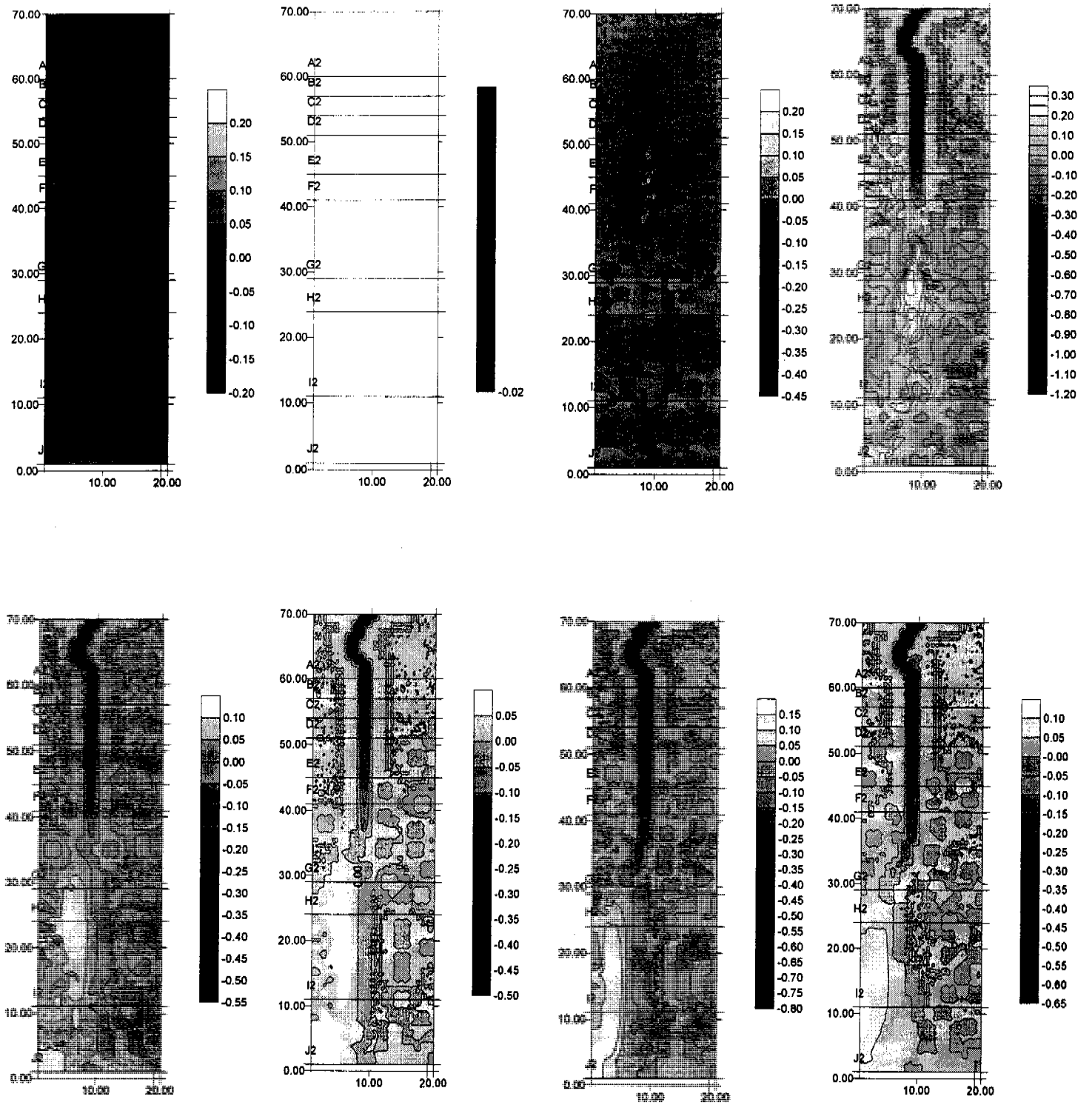


Figure 5.1.6: The initial elevations subtracted from appropriate time period (where erosion is negative, and deposition is positive) such that a) difference between initial surface and prediction at 10 minutes, b) 10 minutes and 20 minutes, c) 20 minutes and 30 minutes, d) 30 minutes and 1 hour. The difference in elevations are also calculated from the remainder of the simulations with e) difference between 1 hours and 1.5 hours, f) 1.5 and 2 hours, g) and 2.5 hours, and h) 2.5 and 3 hours.

5.2 Slope Dependence

The sediment transport equation is dependent on two major components, drainage density and slope dependent component. The exponent on the slope term n_1 has been estimated from field studies to be 0.69 (Section 4.1), however if the sediment transport equation is described according to the Einstein-Brown relationship, a value for n_1 of 2.1 is default.

The impact of the alteration of this exponent was investigated, with n_1 devised from mean particle diameter, equation 4.1.5. The standard batter slope, and the extended profile scenarios were both used to assess the implication of this alteration.

The results of this alteration were expected to be dramatic, with typical slope profiles of the batter site between 20% and 25%, compared to slope profiles of 1.5% to 2% for the gully catchment. The difference in the contribution of the slope component to total sediment transport can be seen with $0.2^{0.69} \sim 0.34$, whilst adopting the same value for the catchment yields $0.2^{2.1} \sim 0.034$, and order of magnitude difference is observed.

Figure 5.2.1, and Figure 5.2.2 illustrates the elevation profiles over the 3 hour duration, with maximum erosion depth at 3 hours reaching 11 to 12m, and erosion at 10 minutes seen to be a level of 4.5m in Figure $5.2.1_a$.

A similar scenario is observed, with the extension of the batter slope site in Figure 5.2.4, and Figure 5.2.5 respectively. The same behaviour observed in Figure 5.1.4, and Figure 5.1.5 can be seen in this case, where development of the gully is delayed with little activity initially. This can be accounted specifically by consideration of the slope of the catchment, where at 2% slope n_1 at 0.69 yields 0.067, whilst at 2.1 yields 0.00027.

When the gully reaches the inlet point, the excavation of the transition point is considerably greater. Figure 5.2.3, and Figure 5.2.6 illustrate the difference in elevations between modelling simulations using contour plots.

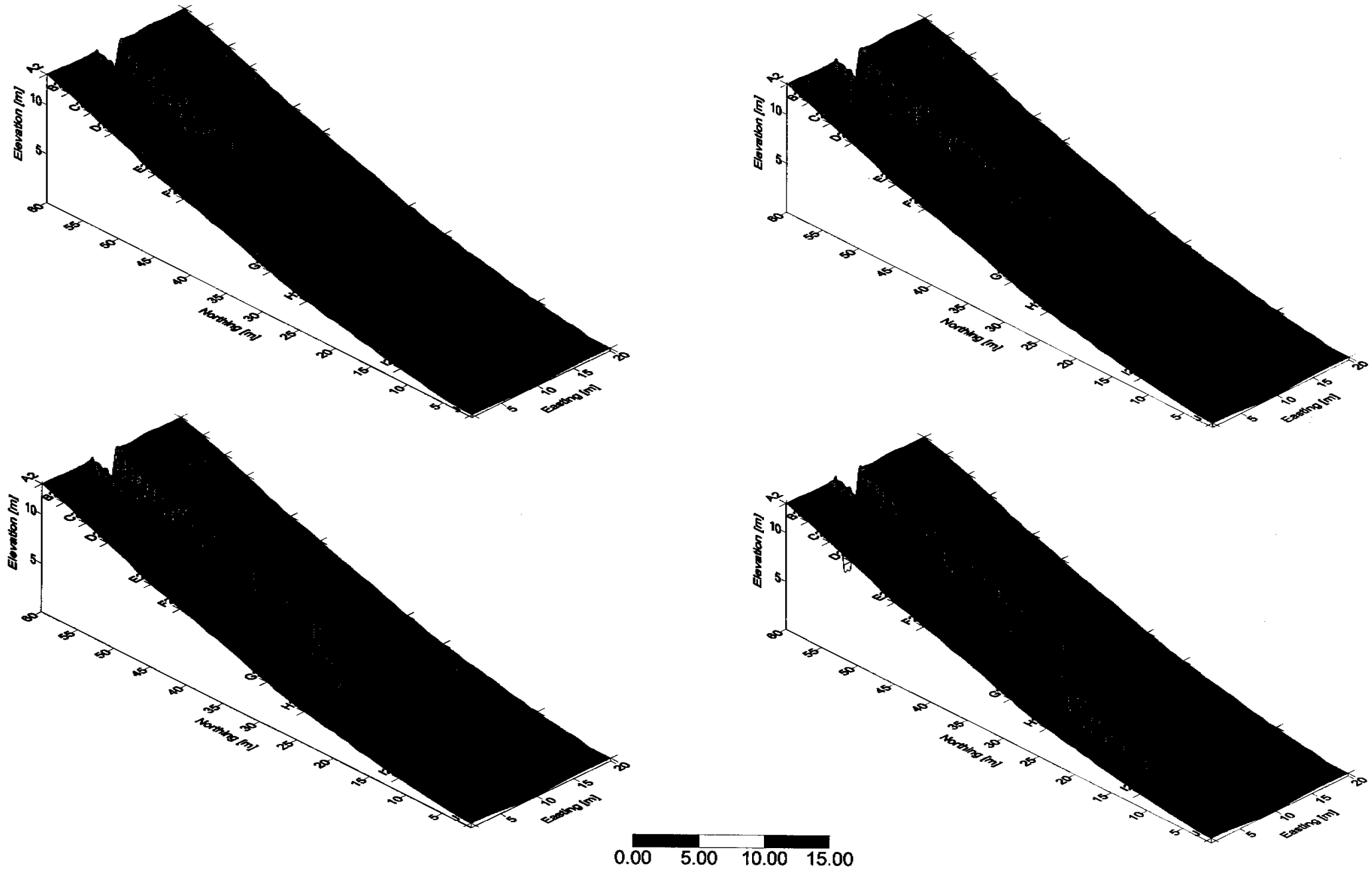


Figure 5.2.1: Simulations for standard batter slope profile with the exponent on the slope term in sediment transport equation set at 0.69, rather than 2.1, a)10 minutes, b) 20 minutes, c) 30 minutes, and) 1 hour.

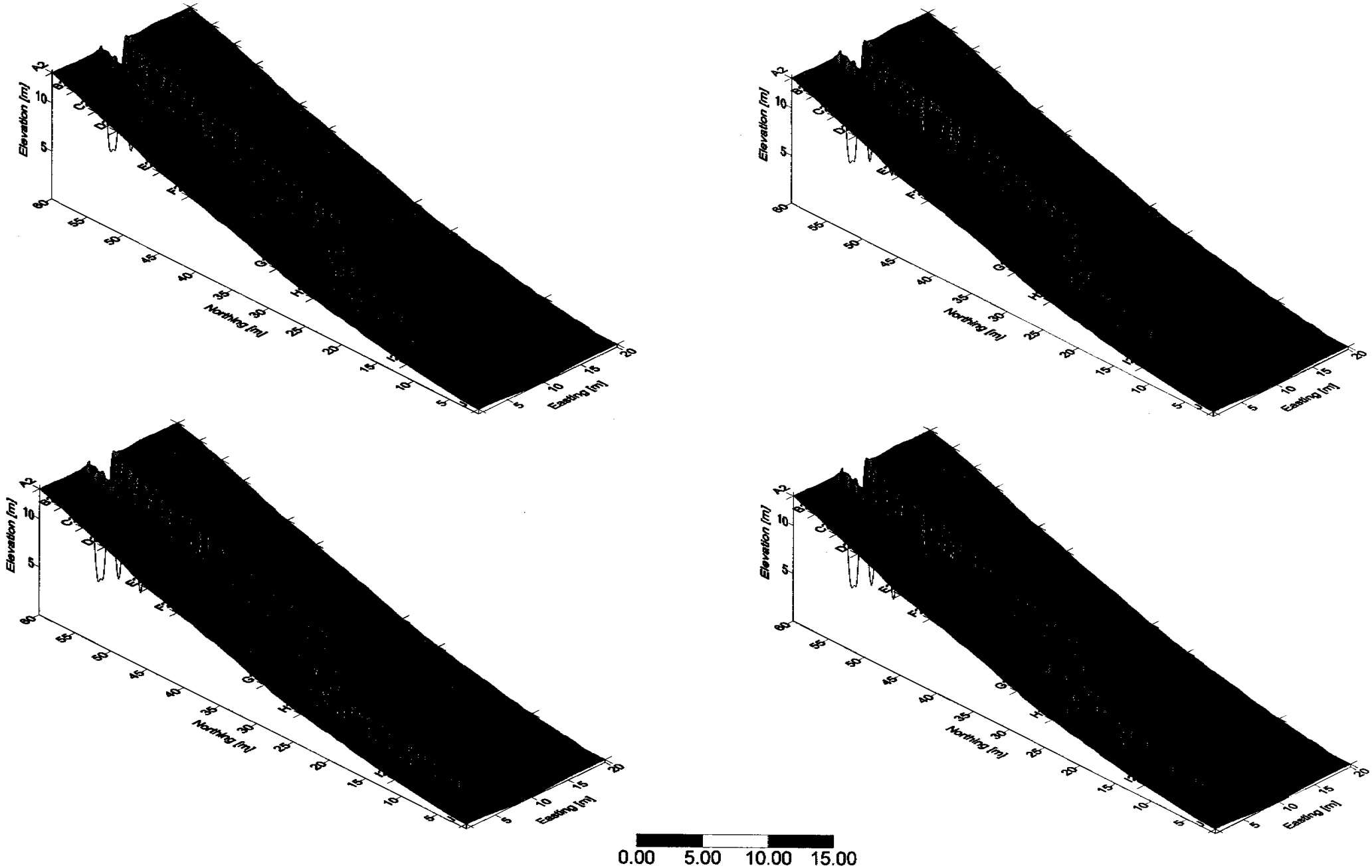


Figure 5.2.2: Simulations for standard batter slope profile with the exponent on the slope term in sediment transport equation set at 0.69, rather than 2.1, at a)1.5 hours, b) 2 hours this represents the second storm event, and c) 2.5 hours and d) 3 hours representing the final storm event.

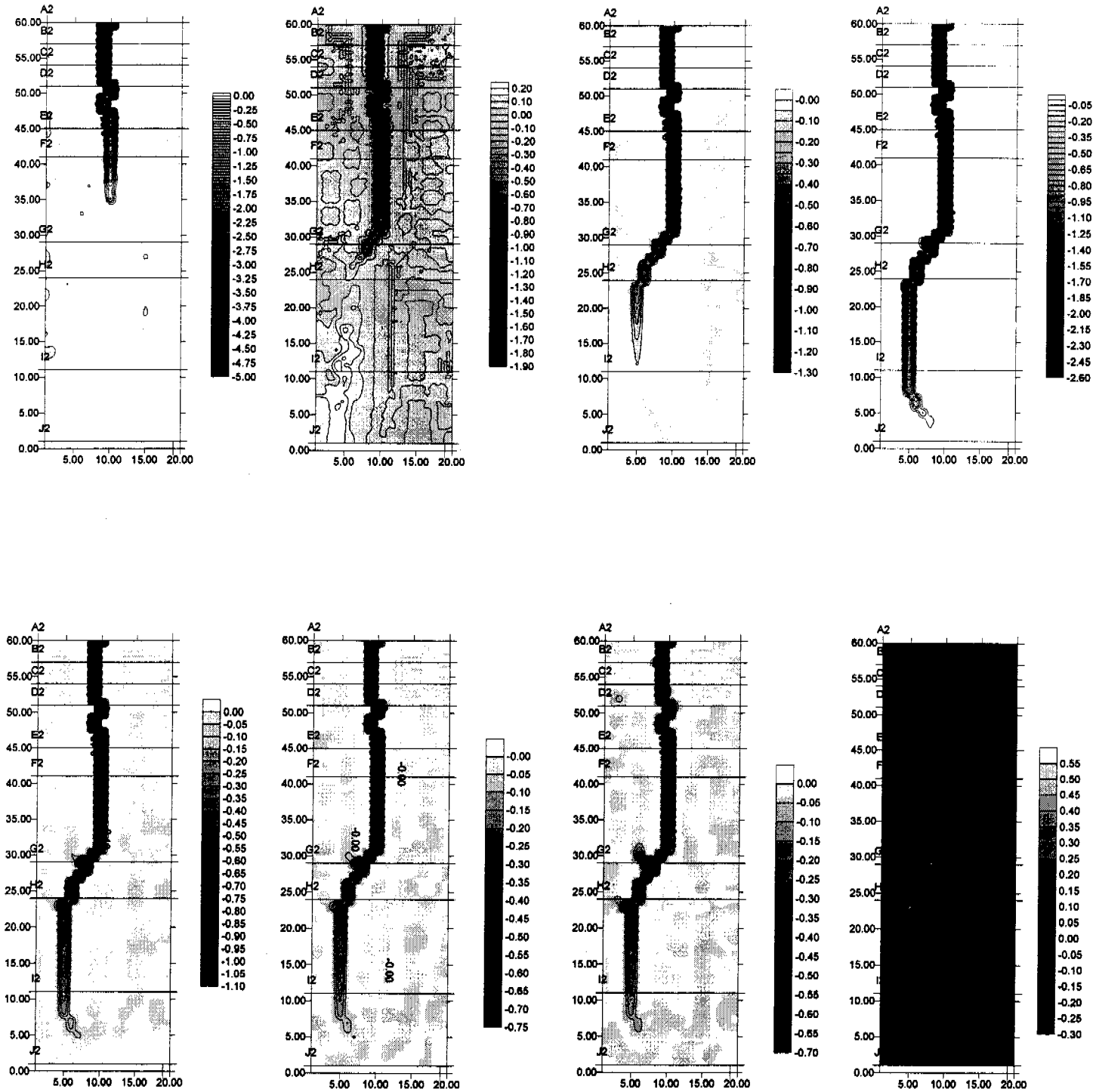


Figure 5.2.3: The initial elevations subtracted from appropriate time period (where erosion is negative, and deposition is positive) such that a) difference between initial surface and prediction at 10 minutes, b) 10 minutes and 20 minutes, c) 20 minutes and 30 minutes, d) 30 minutes and 1 hour. The difference in elevations are also calculated from the remainder of the simulations with e) difference between 1 hours and 1.5 hours, f) 1.5 and 2 hours, g) and 2.5 hours, and h) 2.5 and 3 hours.

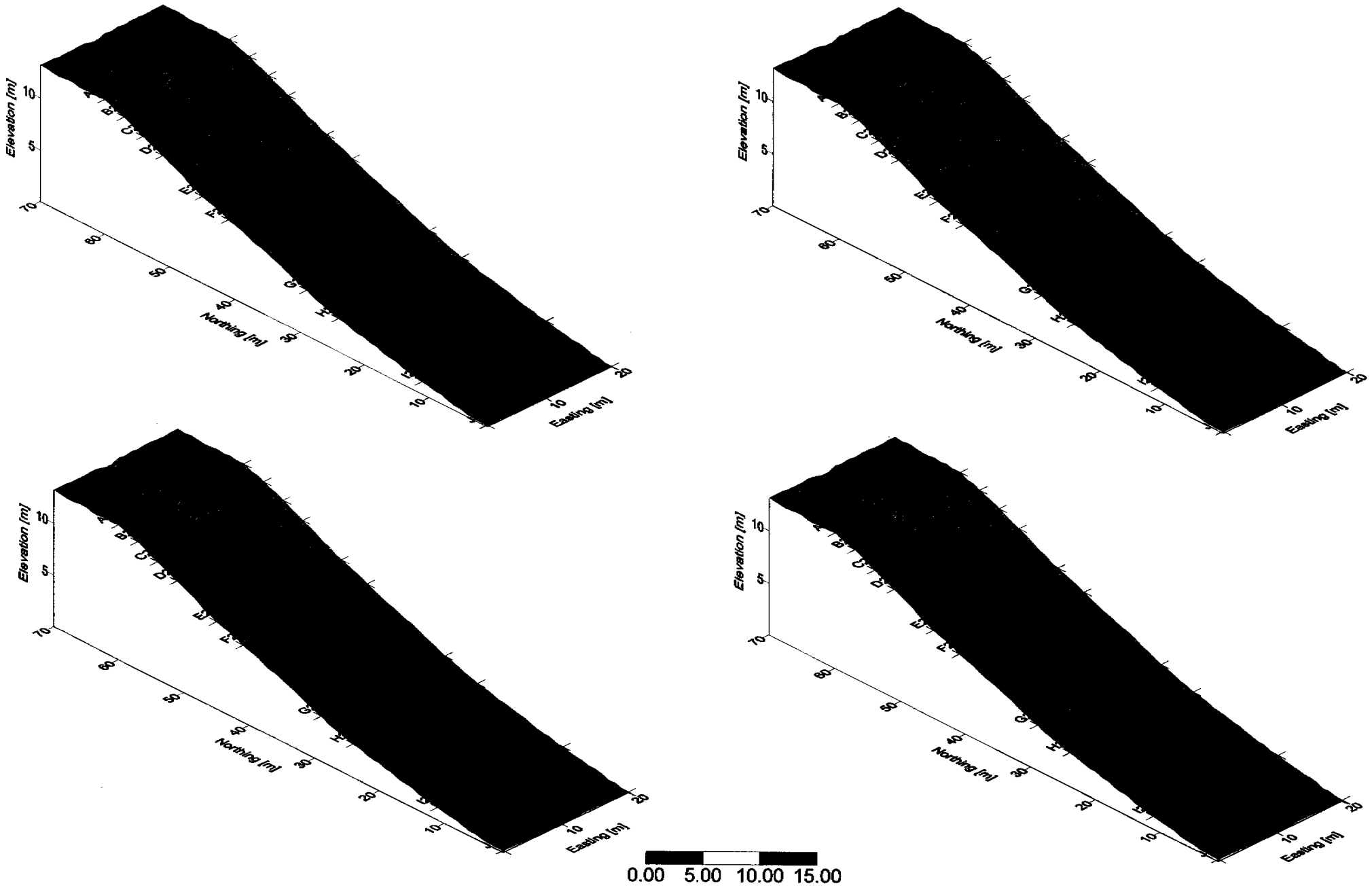


Figure 5.2.4: Simulations for extended batter slope profile with the exponent on the slope term in sediment transport equation set at 0.69, rather than 2.1, a)10 minutes, b) 20 minutes, c) 30 minutes, and d) 1 hour.

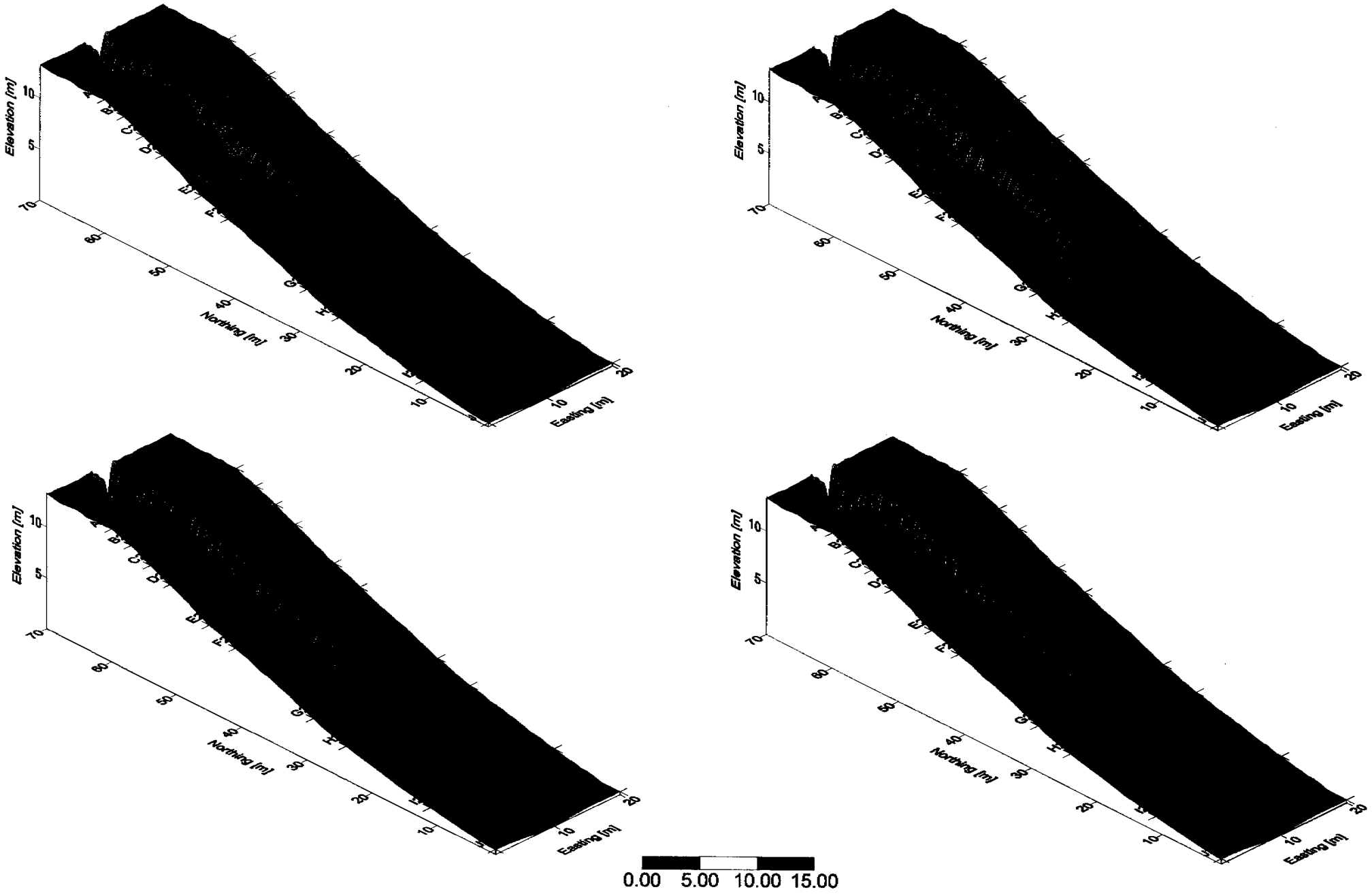


Figure 5.2.5: Simulations for extended batter slope profile with the exponent on the slope term in sediment transport equation set at 0.69, rather than 2.1, at a)1.5 hours, b) 2 hours this represents the second storm event, and c) 2.5 hours and d) 3 hours representing the final storm event.

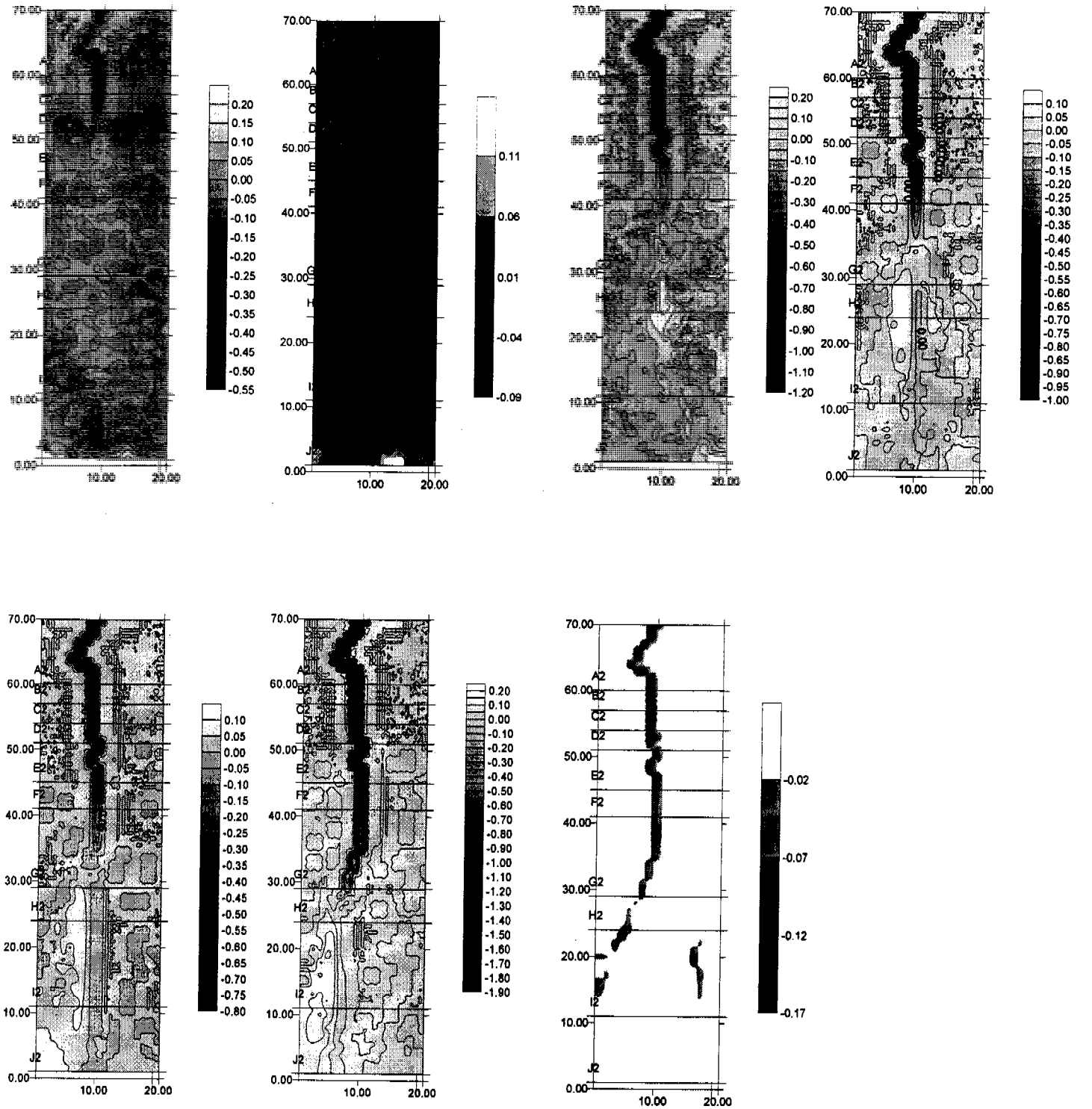


Figure 5.2.6: The morphology contour plots a) initial profile and 10 minutes, b) 10 minutes and 20 minutes, c) 20 minutes and 30 minutes, d) 30 minutes and 1 hour. The difference in elevations are also calculated from the remainder of the simulations with e) difference between 1 hours and 1.5 hours, f) 1.5 and 2 hours, g) 2 and 2.5 hours, and h) 2.5 and 3 hours.

5.3 Increased Width

The effect of increasing the number of inlet points was assessed by simulating both the standard batter slope, and also the extended batter profile. The overall discharge was maintained at the same level, with each inlet node, 1800 equivalent nodes instead of 3600 nodes for the standard narrow two feed point scenario.

Gully formation observed in Figure 5.3.1, and Figure 5.3.2, is more widespread at the top of the batter slope with maximum depth of erosion 2.5m for the standard scenario. Whilst in Figure 5.3.4, and Figure 5.3.5 similar behaviour observed in Figure 5.1.4, and Figure 5.1.5, except that the gully does not proceed onto the batter slope.

The rate of development of the gully is considerably slower for the standard profile scenario, with less pronounced regions of deposition, recognised by smoothed areas at the base of the slope (Row G to Row I), with the depth of gully ranging between 0.8 to 1.5m between Row E to Row K.

The erosion depth profiles begin to resemble those observed on site, with excavation of material in some sections to a level of 60cm. Figure 5.3.3 illustrates the spatial distribution of erosion for the wide inlet.

When the same scenario was simulated using the extended profile, considerably different results were predicted. From Figure 5.3.4, and Figure 5.3.5, the development of the gully does not reach the high wall transition point and so the large formations generated above are not predicted to occur. Further investigation including the inclusion of wide inlet point with randomised erodibility of the waste rock material yielded similar behaviour for this extended profile.

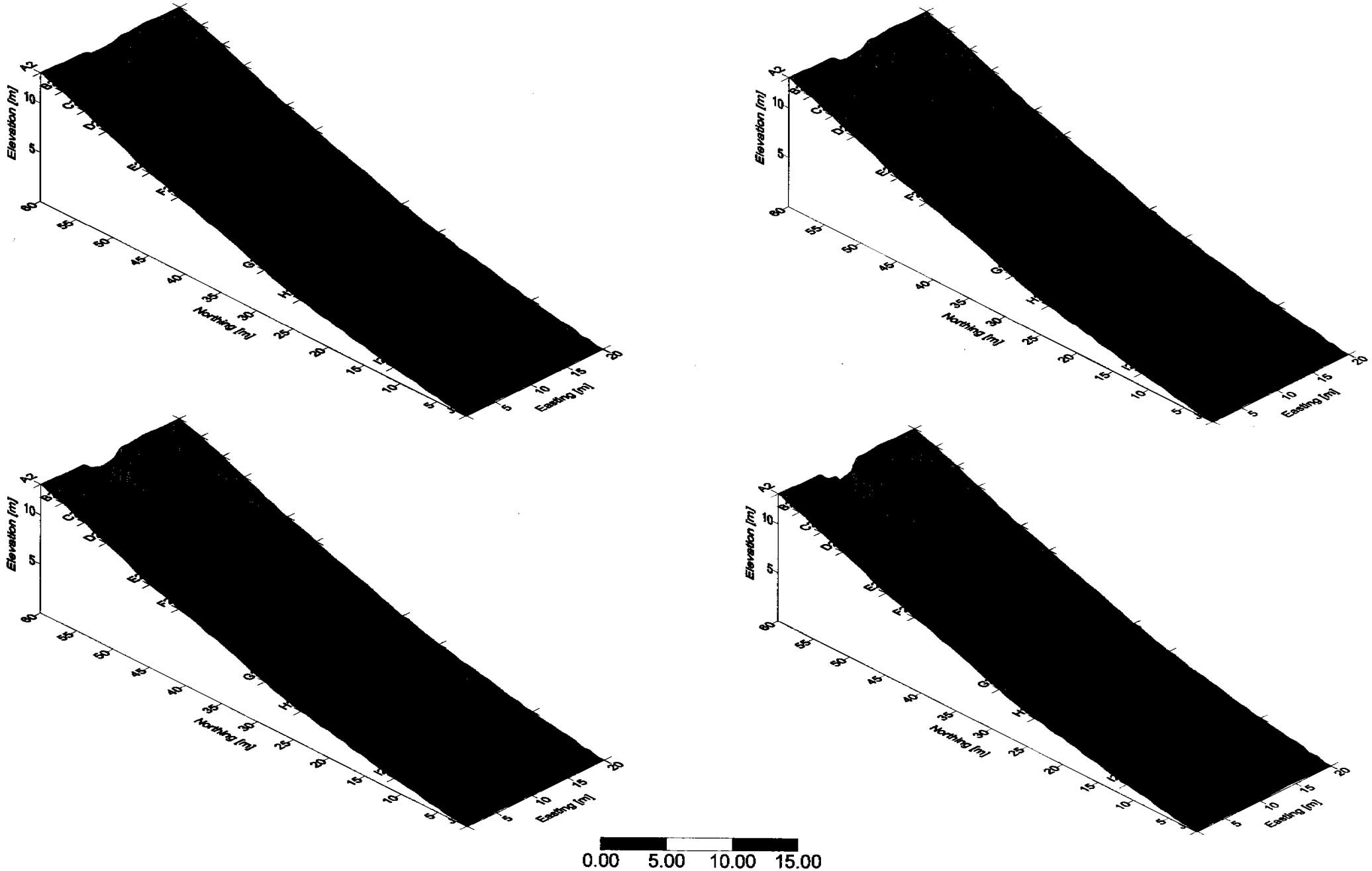
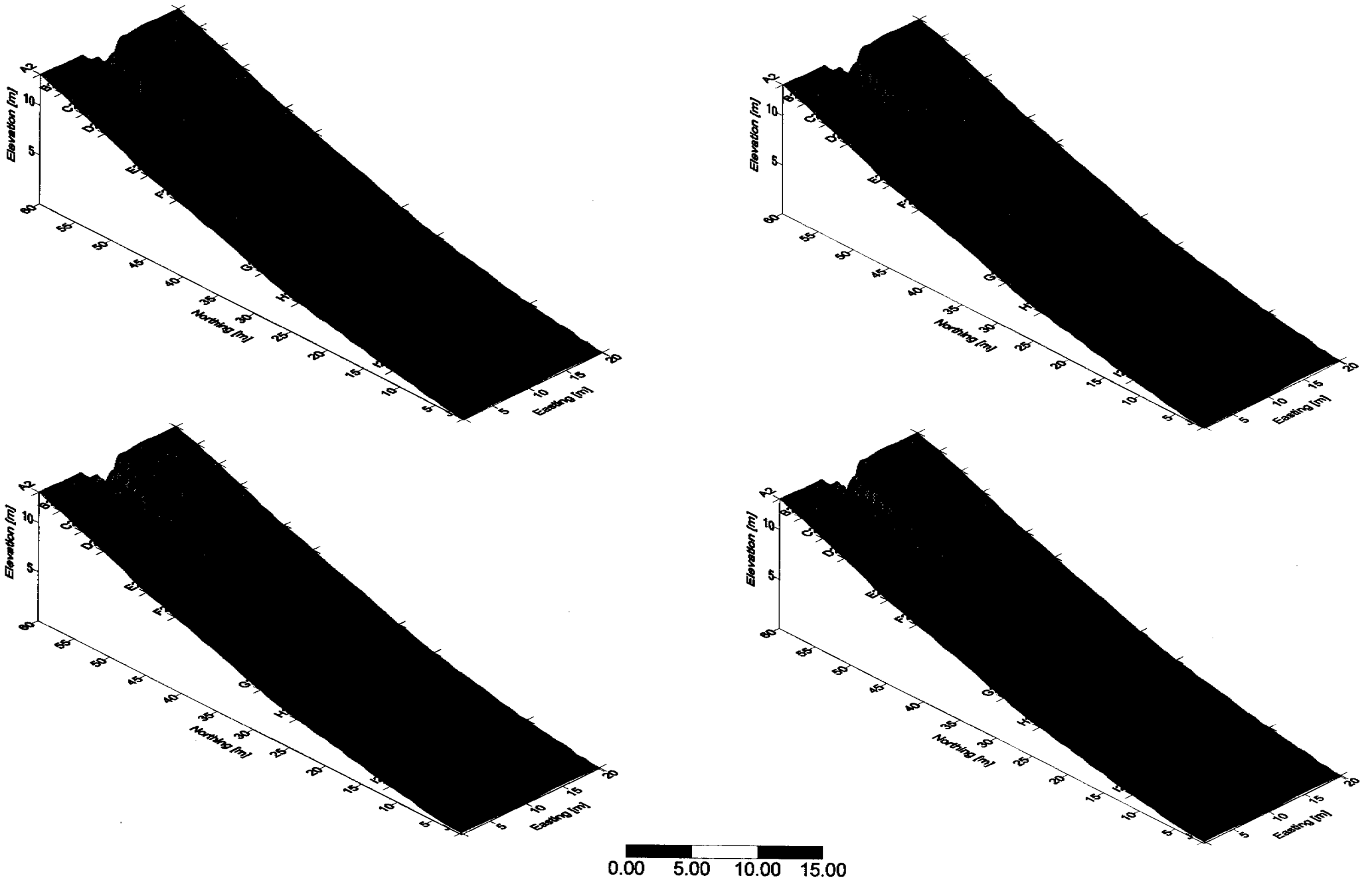
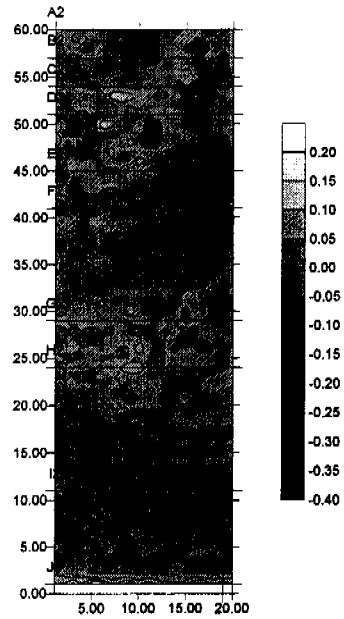
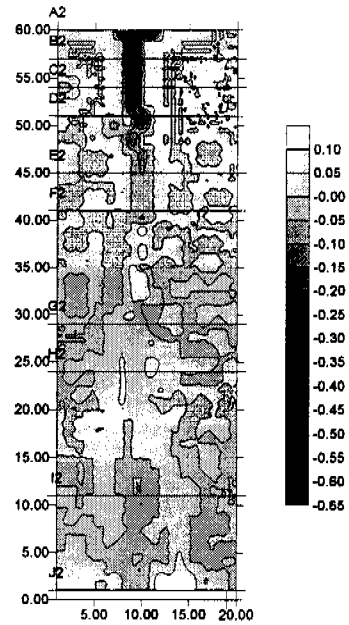


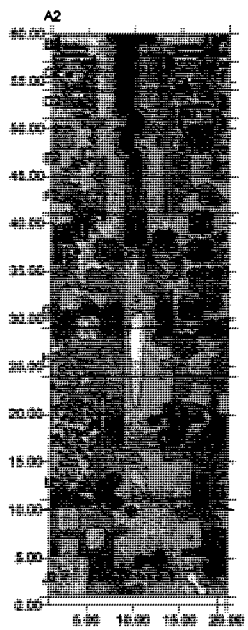
Figure 5.3.1: Simulations for standard batter slope profile with increased width inlet point to four points instead of only two, at a)10 minutes, b) 20 minutes, c) 30 minutes, and d) 1 hour.

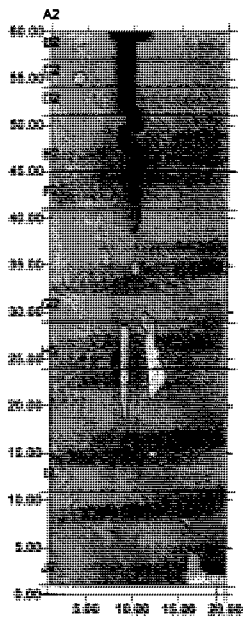


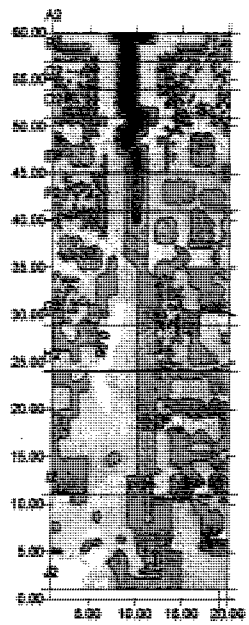
igure 5.3.2: Simulations for standard batter slope profile with increased width inlet point to four points instead of only two, at a)1.5 hours, b) 2 hours this represents the second storm event, and c) 2.5 ours and d) 3 hours representing the final storm event.











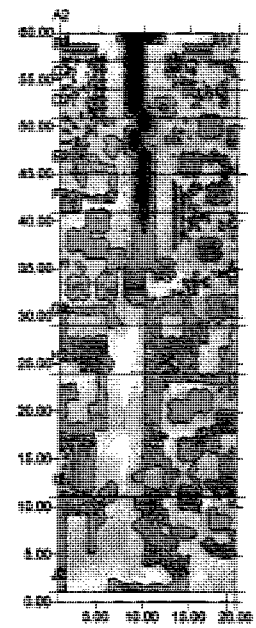


Figure 5.3.3: The morphology contour plots a) initial profile and 10 minutes, b) 10 minutes and 20 minutes, c) 20 minutes and 30 minutes, d) 30 minutes and 1 hour. The difference in elevations are also calculated from the remainder of the simulations with e) difference between 1 hours and 1.5 hours, f) 1.5 and 2 hours, g) 2 and 2.5 hours, and h) 2.5 and 3hours.

5.4 Randomised Erodibility

The erodibility factor $beta_i$ was multiplied by a randomly generated number between 0 and 5, with a mean of 1.0 to introduce a random perturbation to the surface erodibility.

By the introduction of some degree of heterogeneity, the formation of the gully was expected to follow those regions more susceptible and the straight line paths characteristic of Sections 5.1 should not be observed.

The sensitivity of the slope to erodibility will have been increased in some sections although the overall erodibility, representative of the actual site, has not been changed, leading to deeper gullies observed where they occur.

This synopsis seems somewhat reasonable, as illustrated in Figure 5.4.1, and Figure 5.4.2 with gully formation across the slope from almost in front of the inlet zone.

The pathway adopted, as discussed above, is dependent on the drainage direction, as well as the surface elevation of the nodes lying around the current node under calculation and ultimately the erodibility of this point, this influences the nature of gully formation with reduced amounts of deposition observed in Figure 5.4.3.

Although the quantity of deposition observed in each of the time periods is reduced, the dynamic nature of the pathway of erosion observed in these simulations is similar to standard scenario in Section 5.1. Inherently the overall erosional characteristic of the slope has not been altered, and predictions indicate similar maximum depths of erosion, although areas of deposition will be more widespread. The maximum depth of erosion at the head of the gully network at 5.5m, indicating that overall nature of gully development has not altered, but merely the pathway adopted. This conforms to the hypothesis that the erodibility of the material had not been significantly changed.

Figure 5.4.4 and Figure 5.4.5 illustrate the same design scenario incorporating the extended profile of the batter slope. Comparison of these simulations with Figures 5.1.4, and 5.1.5 reveal a similar behaviour with initial delay in gully development, until the 30 minute mark, where development initiates at the transition point between

the batter slope and gully catchment. Similarities in the development process also included the maximum depth of erosion at Row A at 4.5m, as can be observed in Figure 5.4.4.

The assessment of the inclusion of wide inlet point with the standard profile combined with randomised erodibility was also conducted, as illustrated in Figure 5.4.7 and Figure 5.4.8. The continuity of transported material in these cases, can be compared to Figure 5.4.4, and 5.4.5 respectively. The depth of erosion ranges between 0.5m and 1.0m for Row E to Row G, whilst more extensive excavation sections between Row B to Row D. It also noted that cross-sectional profile at Row B in Figure $5.4.7_d$ is almost identical to that observed in Figure $5.3.1_d$ Row B, with similar observations for all except just below the inlet zone in Row A.

The pathway adopted, mimics that of Figure 5.4.1, and Figure 5.4.2, whilst this is not observed when comparing standard scenario and addition of increased width component (Figure 5.1.1 and 5.1.2 against 5.3.1 and 5.3.2), with a reduction in depths of erosion observed.

A similar comparison can be drawn between the standard extended profile and randomised erodibility scenario, with depth of erosion of similar magnitude, with path dominated by developing process, rather than random perturbations in material characteristic. Once the gully extends past Row D in this figure, the dominant process changes as expected.

Another important observation from Figure 5.4.7, and Figure 5.4.8 where 2 independent erosion paths have developed. By further increasing inlet width, and increasing grid discretisation, modelling simulations can yield predictions similar to the 2 main gully pathways observed on site.

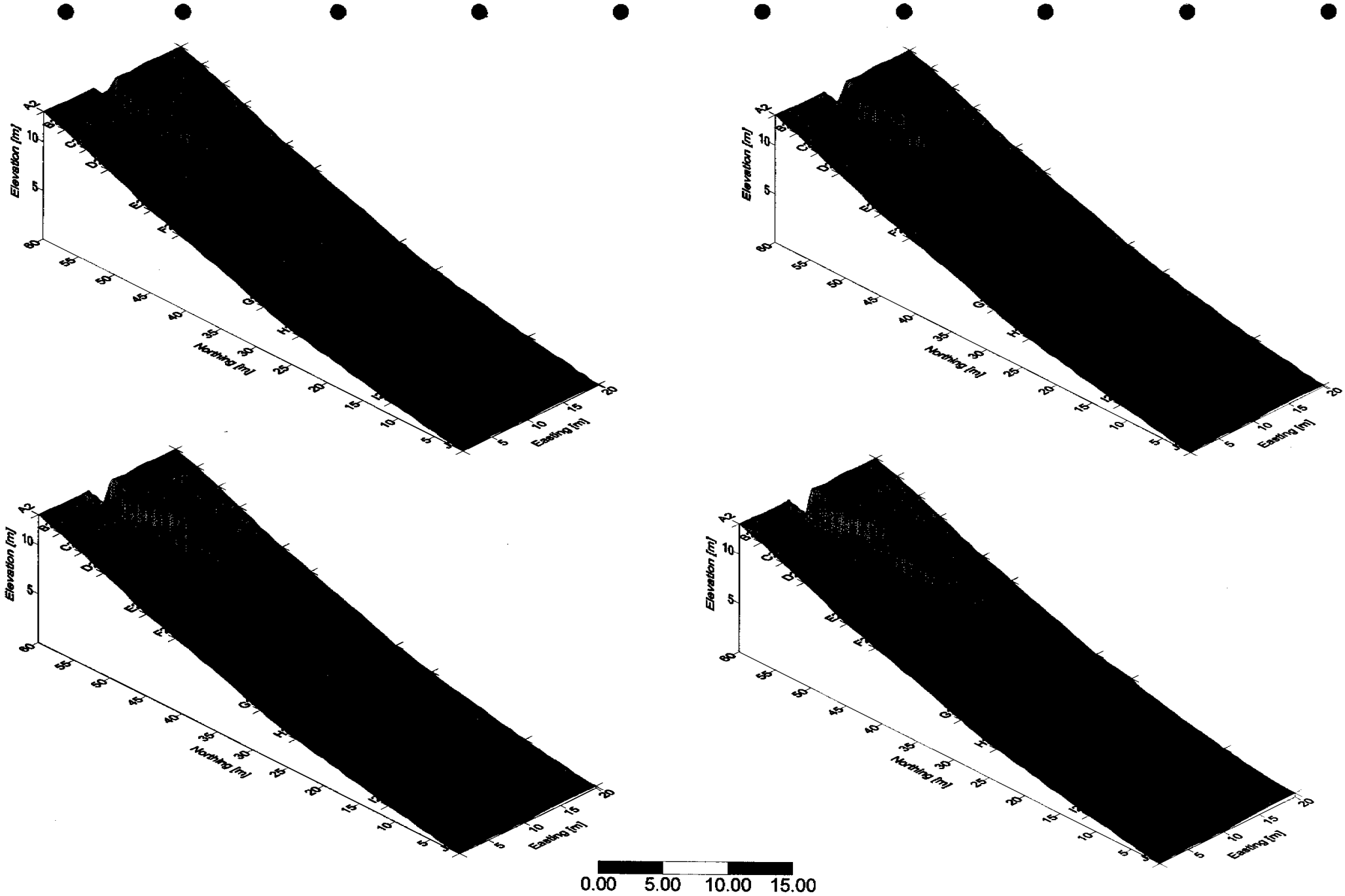


Figure 5.4.1: Simulations for standard batter slope profile with randomised erodibility at a)10 minutes, b) 20 minutes, c) 30 minutes, and d) 1 hour.

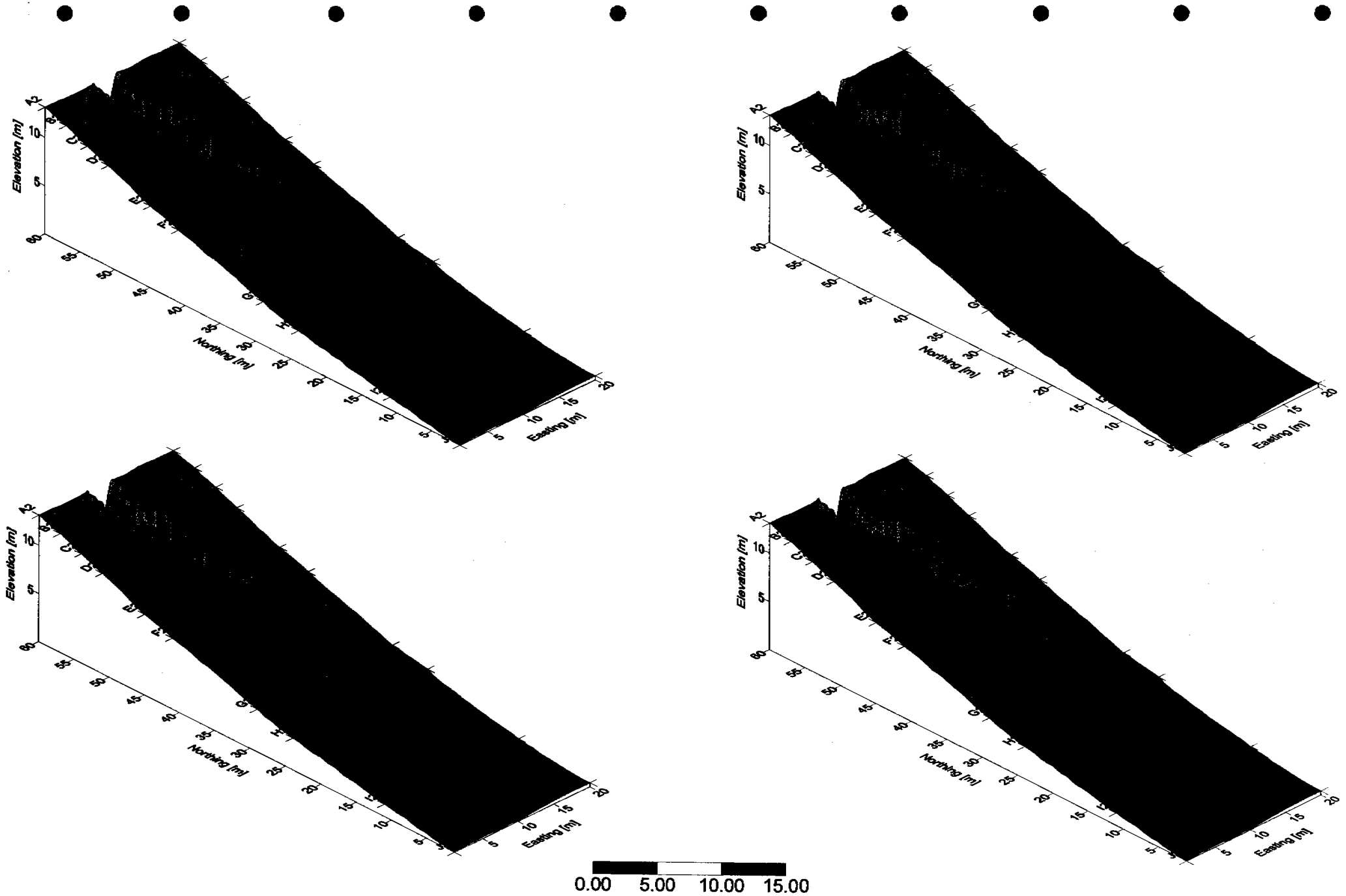


Figure 5.4.2: Simulations for standard batter slope profile with randomised erodibility, at a)1.5 hours, b) 2 hours this represents the second storm event, and c) 2.5 hours and d) 3 hours representing the final storm event.

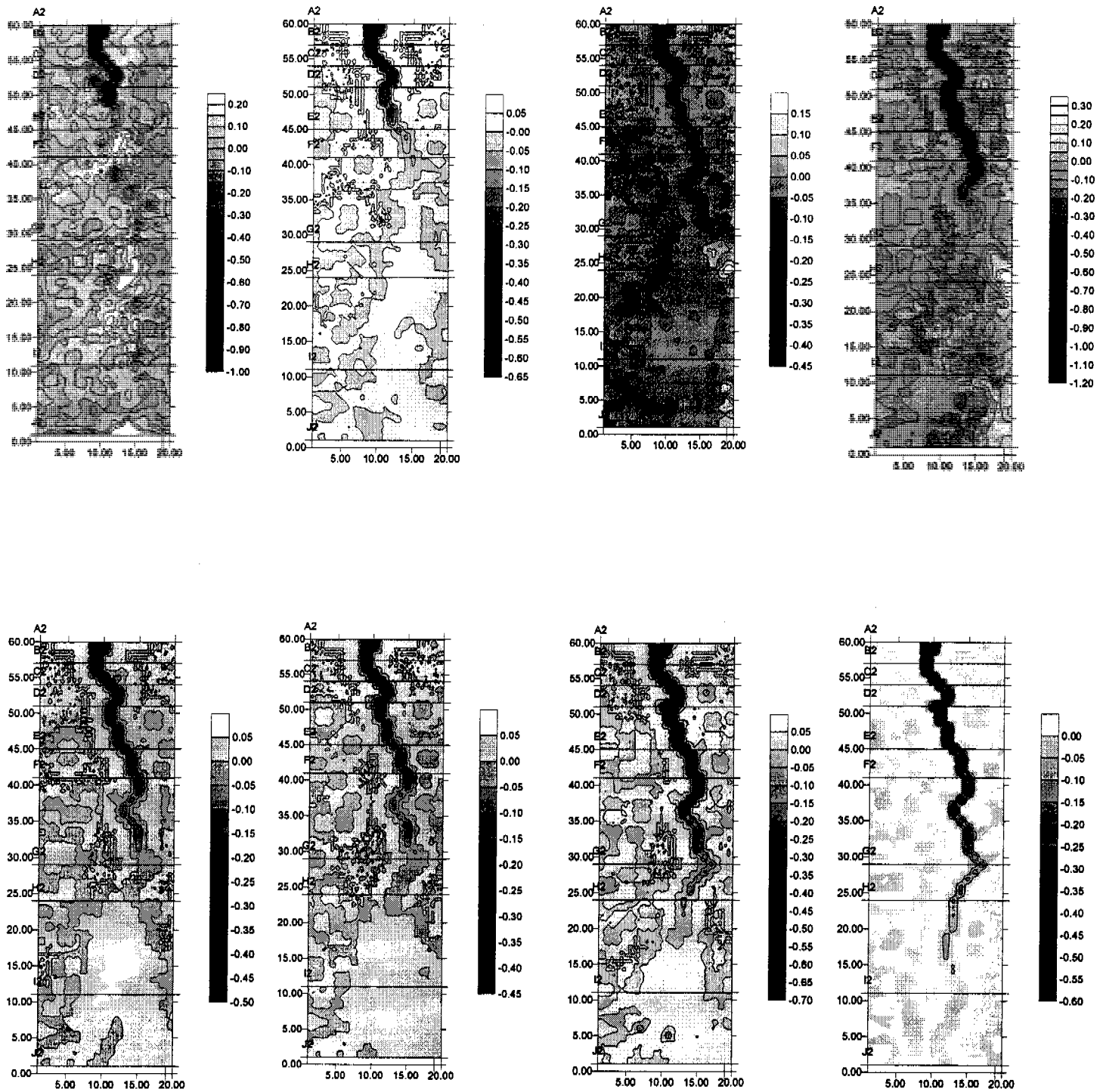


Figure 5.4.3: The morphology contour plots a) initial profile and 10 minutes, b) 10 minutes and 20 minutes, c) 20 minutes and 30 minutes, d) 30 minutes and 1 hour. The difference in elevations are also calculated from the remainder of the simulations with e) difference between 1 hours and 1.5 hours, f) 1.5 and 2 hours, g) 2 and 2.5 hours, and h) 2.5 and 3 hours.

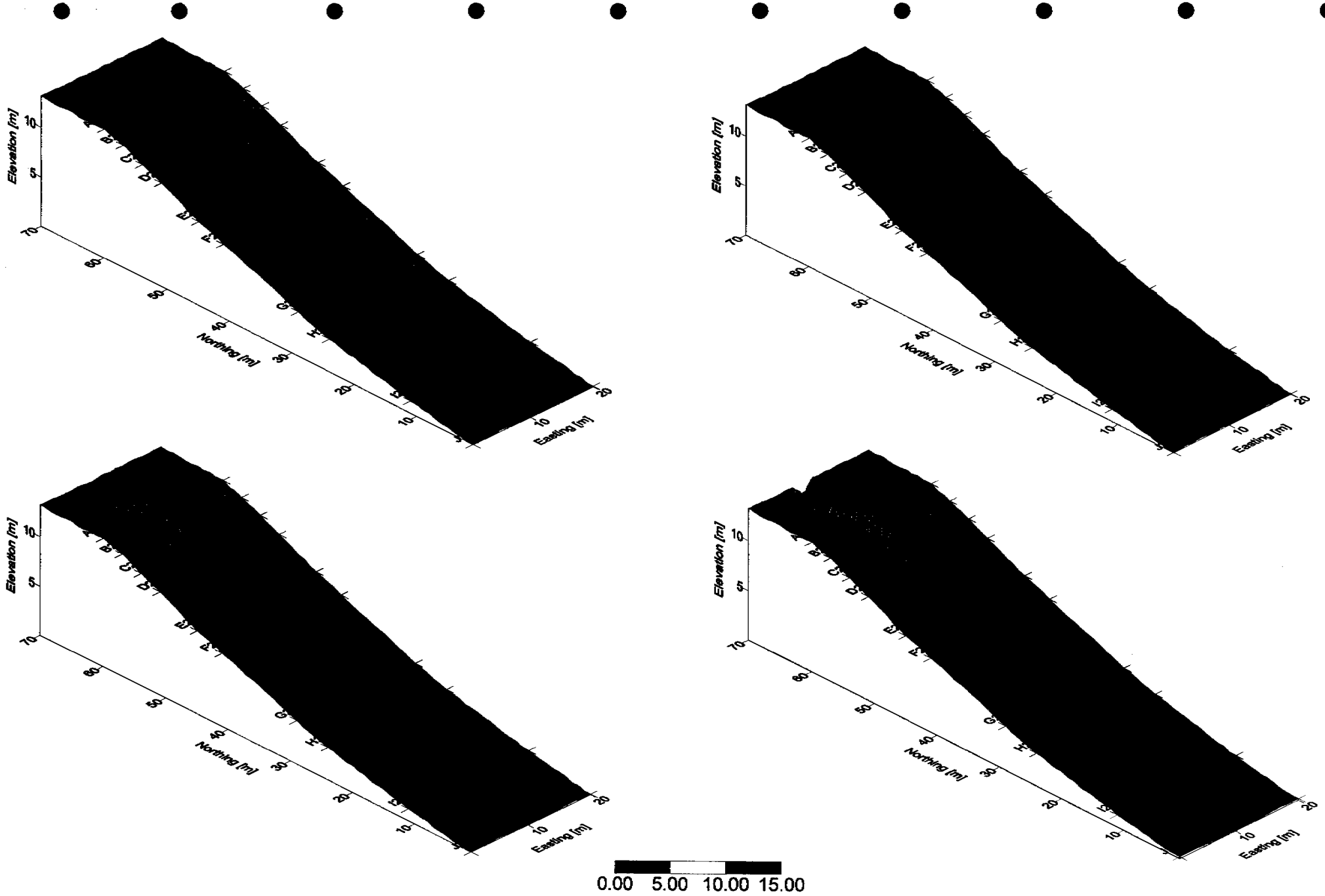


Figure 5.4 Simulations for ~~standard~~ Extended batter slope profile with randomised erodibility at a)10 minutes, b) 20 minutes, c) 30 minutes, and d) 1 hour.

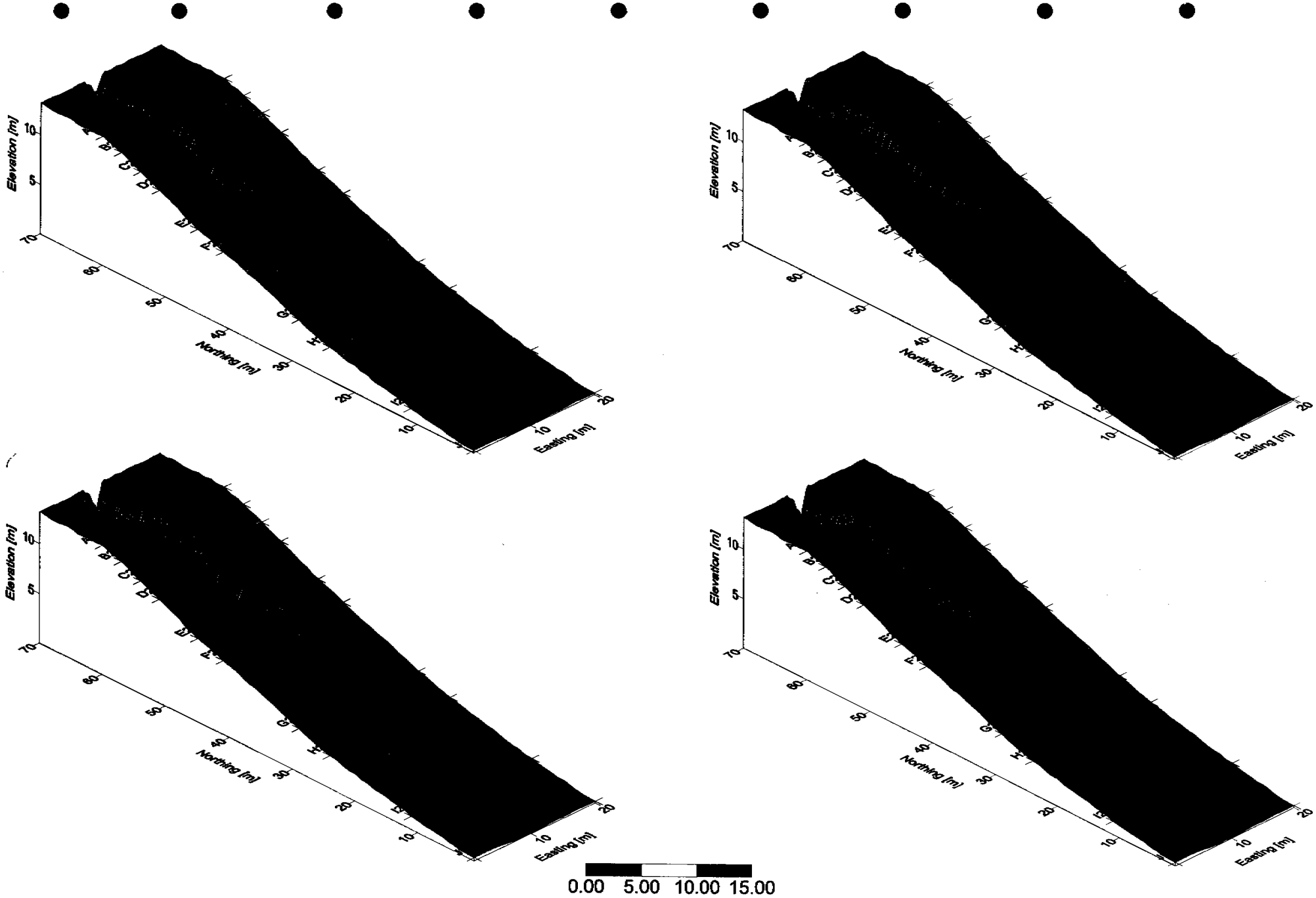


Figure 5.4.8: Simulations for standard batter slope profile with randomised erodibility, at a)1.5 hours, b) 2 hours this represents the second storm event, and c) 2.5 hours and d) 3 hours representing the final storm event.

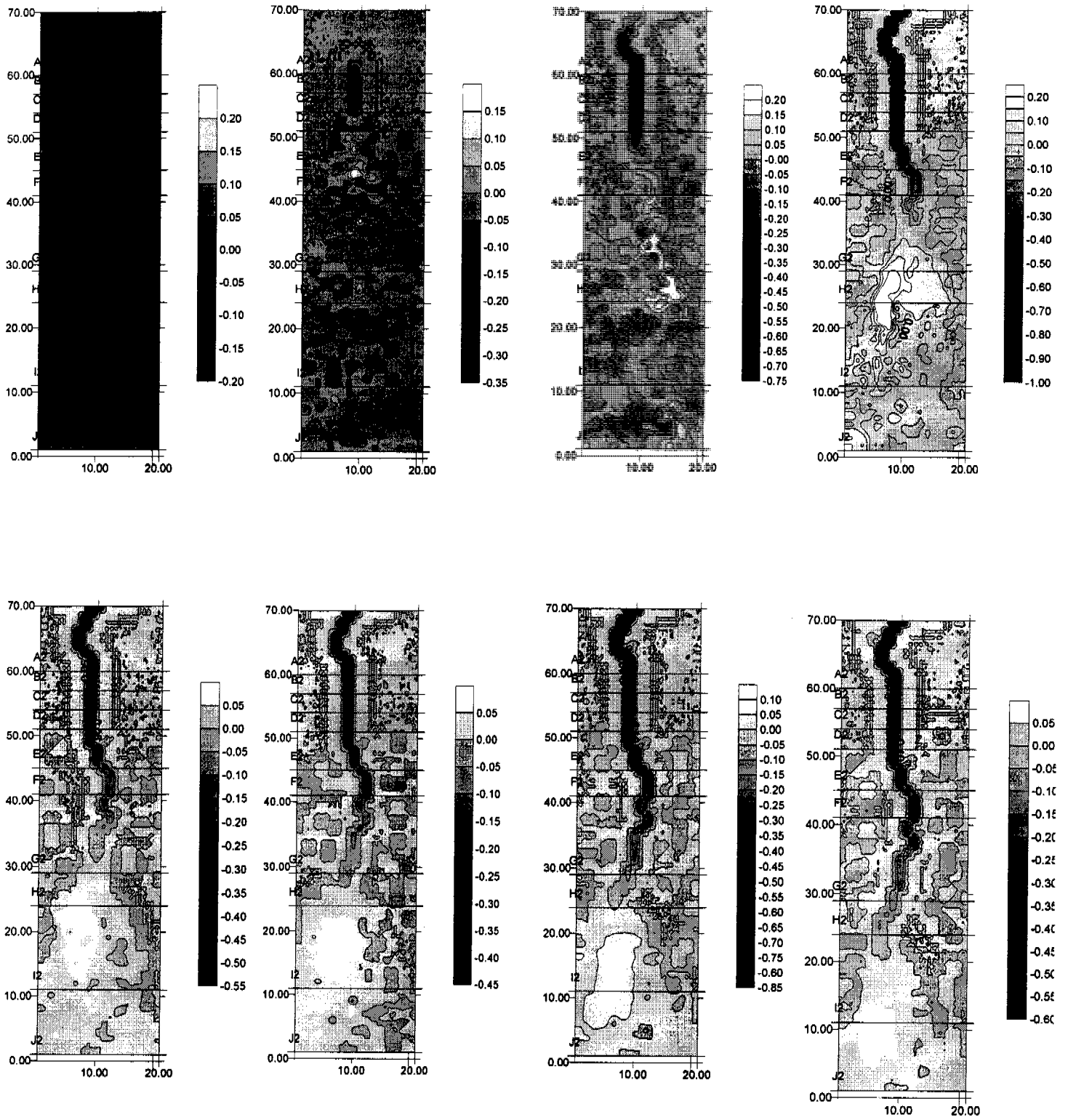


Figure 5.4.6: The morphology contour plots a) initial profile and 10 minutes, b) 10 minutes and 20 minutes, c) 20 minutes and 30 minutes, d) 30 minutes and 1 hour. The difference in elevations are also calculated from the remainder of the simulations with e) difference between 1 hours and 1.5 hours, f) 1.5 and 2 hours, g) 2 and 2.5 hours, and h) 2.5 and 3 hours.

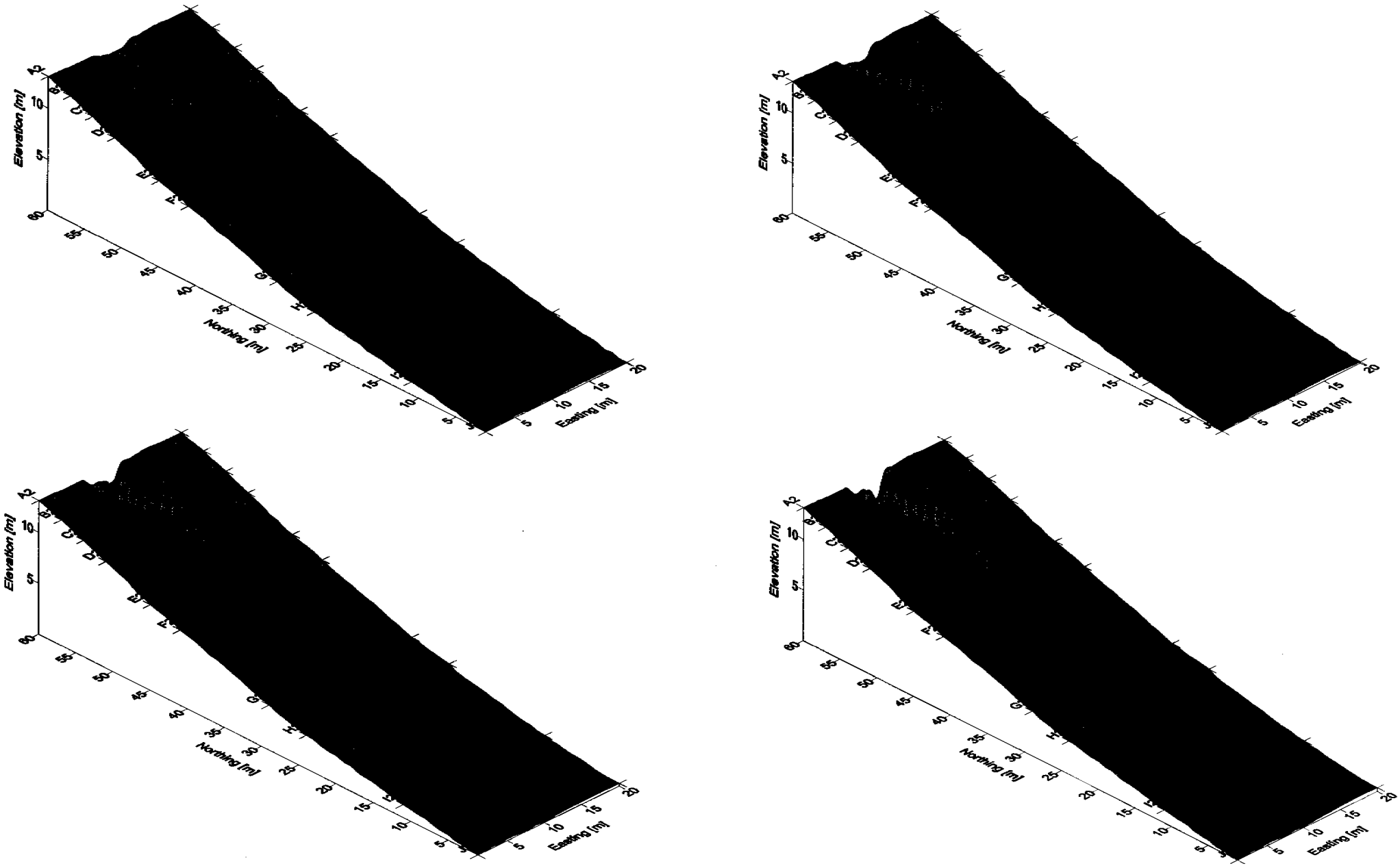


Figure 5.4.7: Simulations for standard batter slope profile with increased width inlet point to four points instead of only two, combined with randomised erodibility, a)10 minutes, b) 20 minutes, c) 30 minutes, and d) 1 hour.

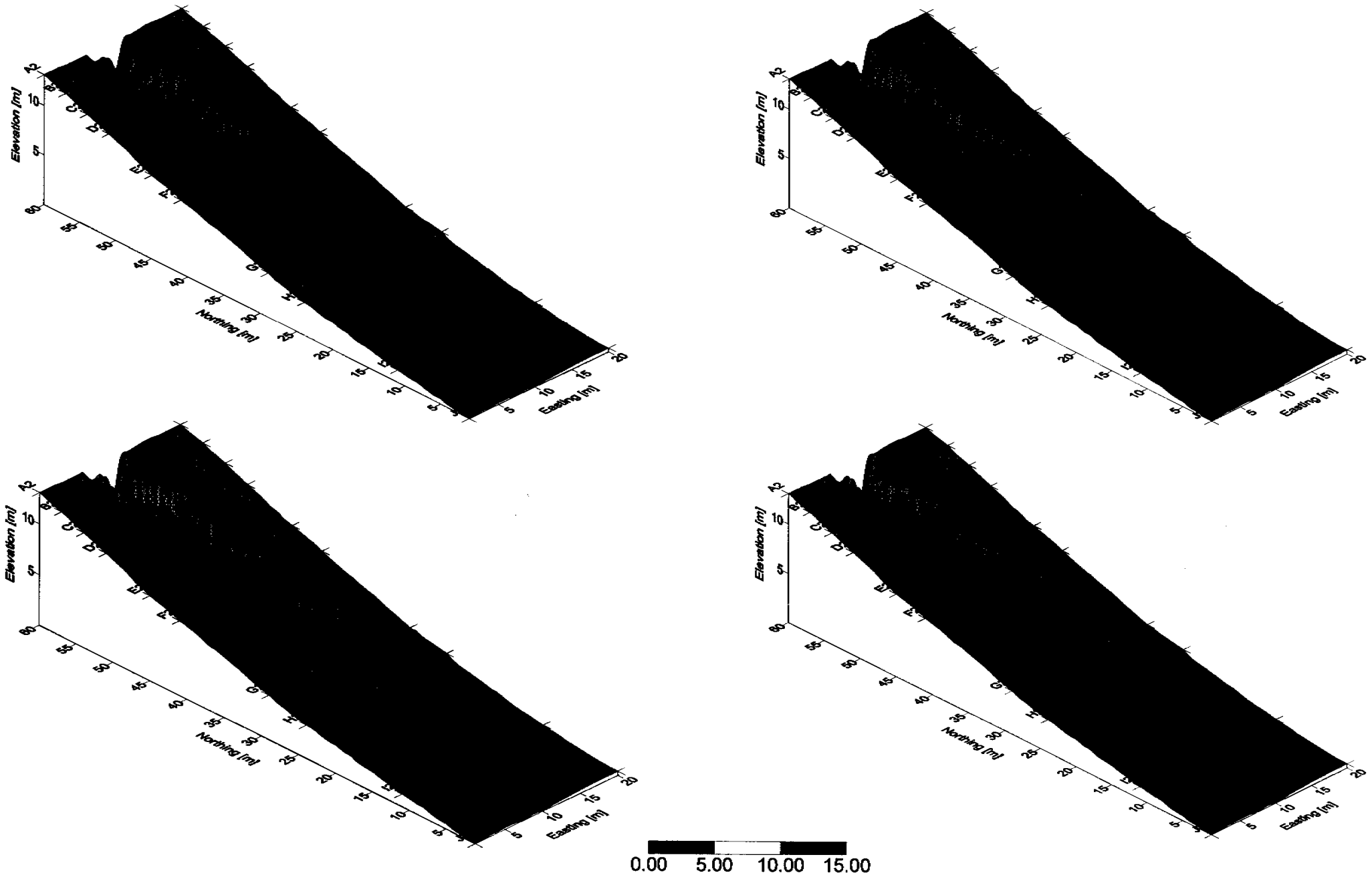


Figure 5.4.8: Simulations for standard batter slope profile with increased width inlet point to four points instead of only two, combined with randomised erodibility, at a)1.5 hours, b) 2 hours this represents the second storm event, and c) 2.5 hours and d) 3 hours representing the final storm event.

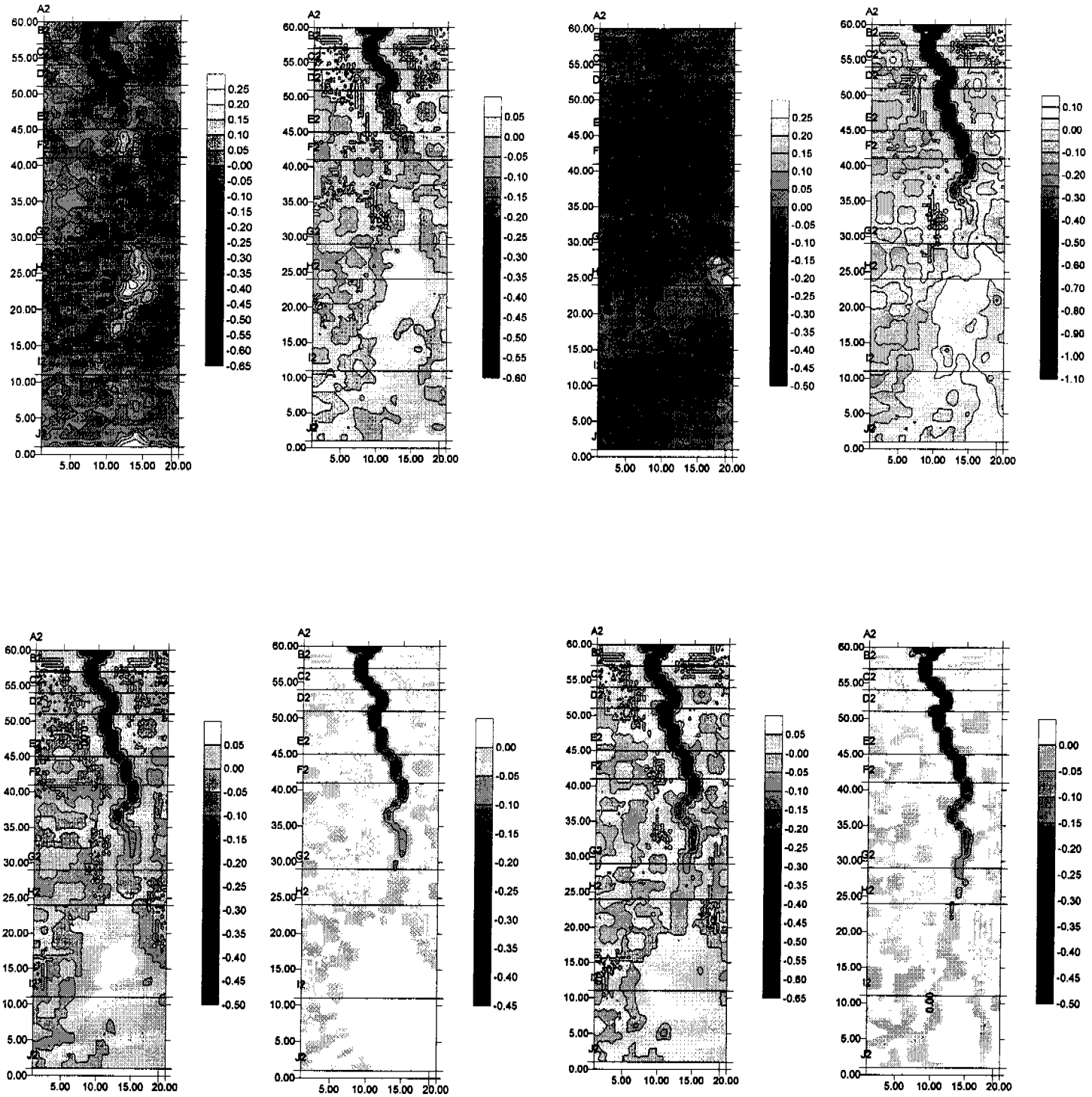


Figure 5.4.9: The morphology contour plots a) initial profile and 10 minutes, b) 10 minutes and 20 minutes, c) 20 minutes and 30 minutes, d) 30 minutes and 1 hour. The difference in elevations are also calculated from the remainder of the simulations with e) difference between 1 hours and 1.5 hours, f) 1.5 and 2 hours, g) 2 and 2.5 hours, and h) 2.5 and 3 hours.

5.5 Differential Erodibility with Depth

The next component of this investigation involved alteration of the nature of surface material from randomised erodibility (somewhat heterogeneous) to include differential erodibility with depth function.

By approximating erodibility using mean grain diameter basis, an increase in d_{50} from 2mm to 20mm over 2m depth equated to a reduction in erodibility of 30 fold. This represents a conservative estimate, as illustrated in Figure 4.3.5, with these ratios considered very conservative over a differential depth of only 20cm. However, as noted once the armouring rock layer was breached and the soft earthen material extracted from above the mined ore is exposed and this erodibility factor will change dramatically. Further work currently being conducted into dynamism in sediment size profile, with development over the dry season also considered important given the rate of geochemical weathering noted on the waste rock dumps.

The preliminary investigation would also involve an assessment of the impact of a change in the magnitude of this reduction factor, with modelling simulations used to evaluate the impact of decreasing this factor to 1/10, with depth coefficient set at C~2, instead of C~15.

Figure 5.5.1, and Figure 5.5.2 illustrate simulations using only the depth coefficient of C = 2. The comparison between Figure 5.1.1, and Figure 5.1.2 with these runs suggest that depth coefficient chosen reduces depth of erosion in all sections uniformly, with maximum erosion depth of 5 to 6m compared to about 4m for these predictions.

Equation 4.3.1 highlights the mechanism by which this armouring component functions. The change of elevation is calculated for each node point during a iteration and then this result is multiplied by the depth-erodibility relationship to reduce this depth by a factor of 1/10 for Figure $5.5.1_a$, to Figure$_d$. However for the next iteration representative of the consequent storm event, the same scenario is repeated, as equation is reapplied and depth of erosion is reduced by a factor of 1/10 again. This can be observed as a jump in erosion depth between Figure $5.5.1_d$ and $5.5.2_a$.

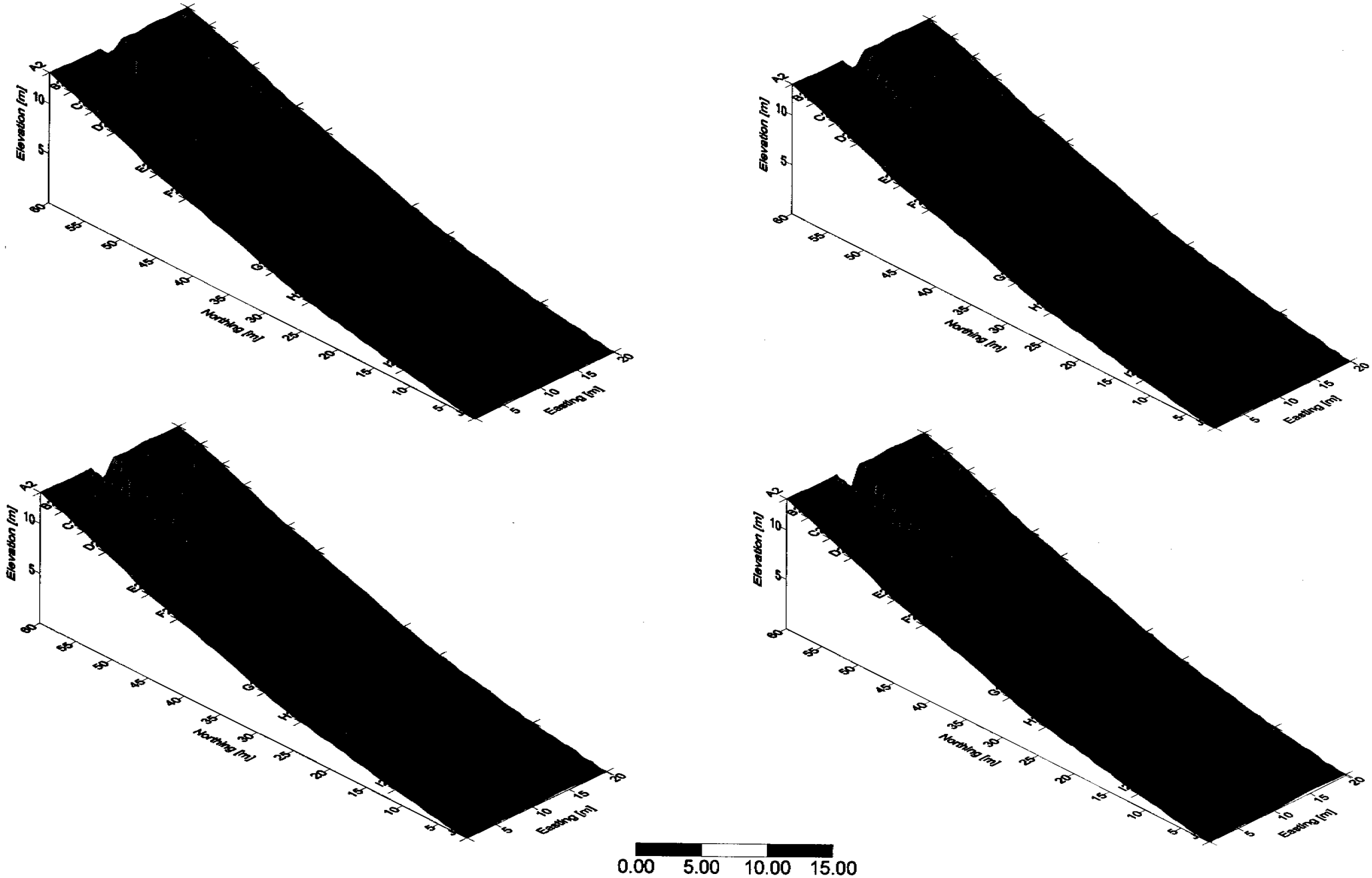


Figure 5.5.1: Simulations for standard batter slope profile with differential erodibility with depth function set at depth coefficient of 2, at a)10 minutes, b) 20 minutes, c) 30 minutes, and d) 1 hour.

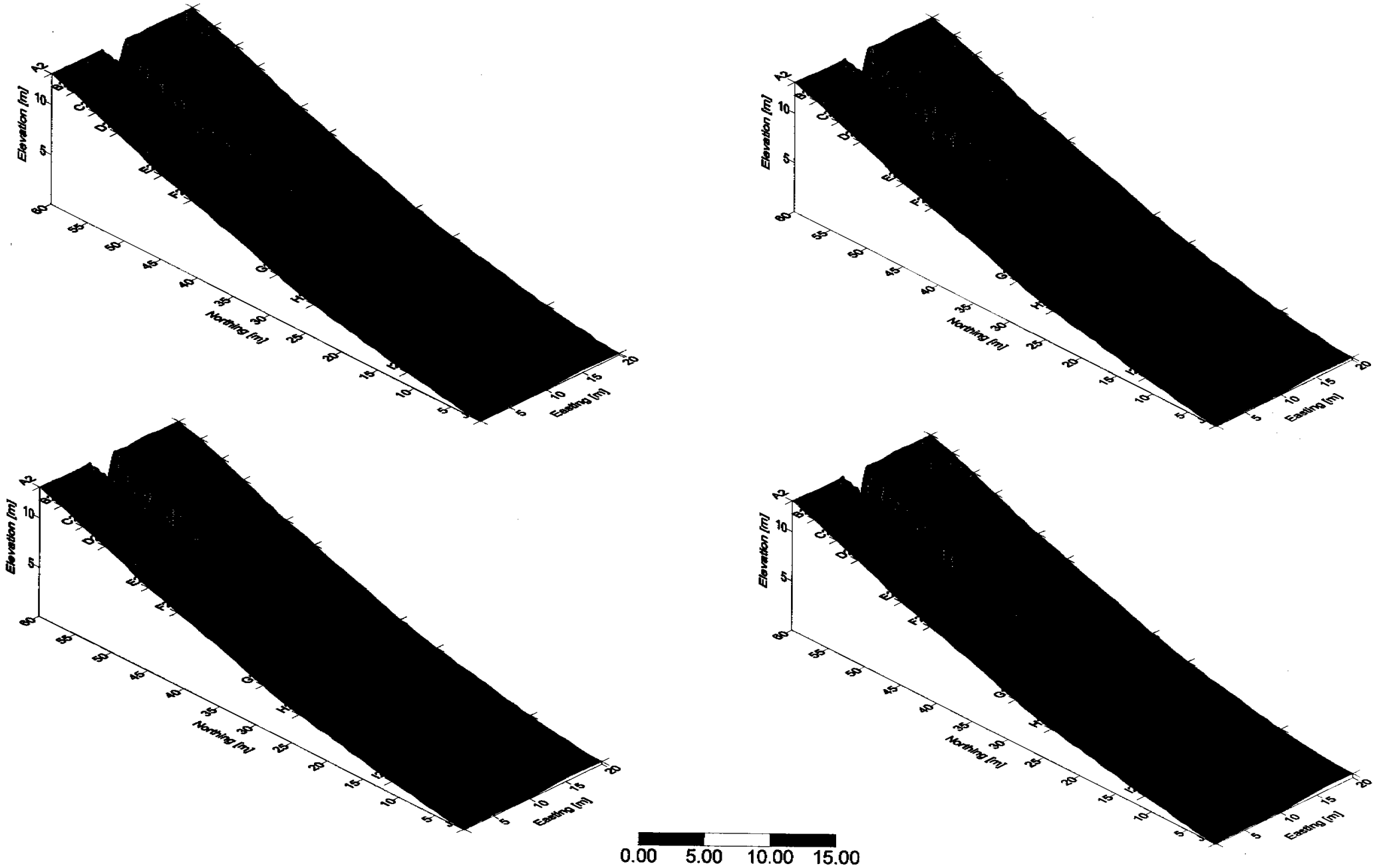


Figure 5.5.2: Simulations for standard batter slope profile with differential erodibility with depth function set at depth coefficient of 2, at a)1.5 hours, b) 2 hours this represents the second storm event, and c) 2.5 hours and d) 3 hours representing the final storm event.

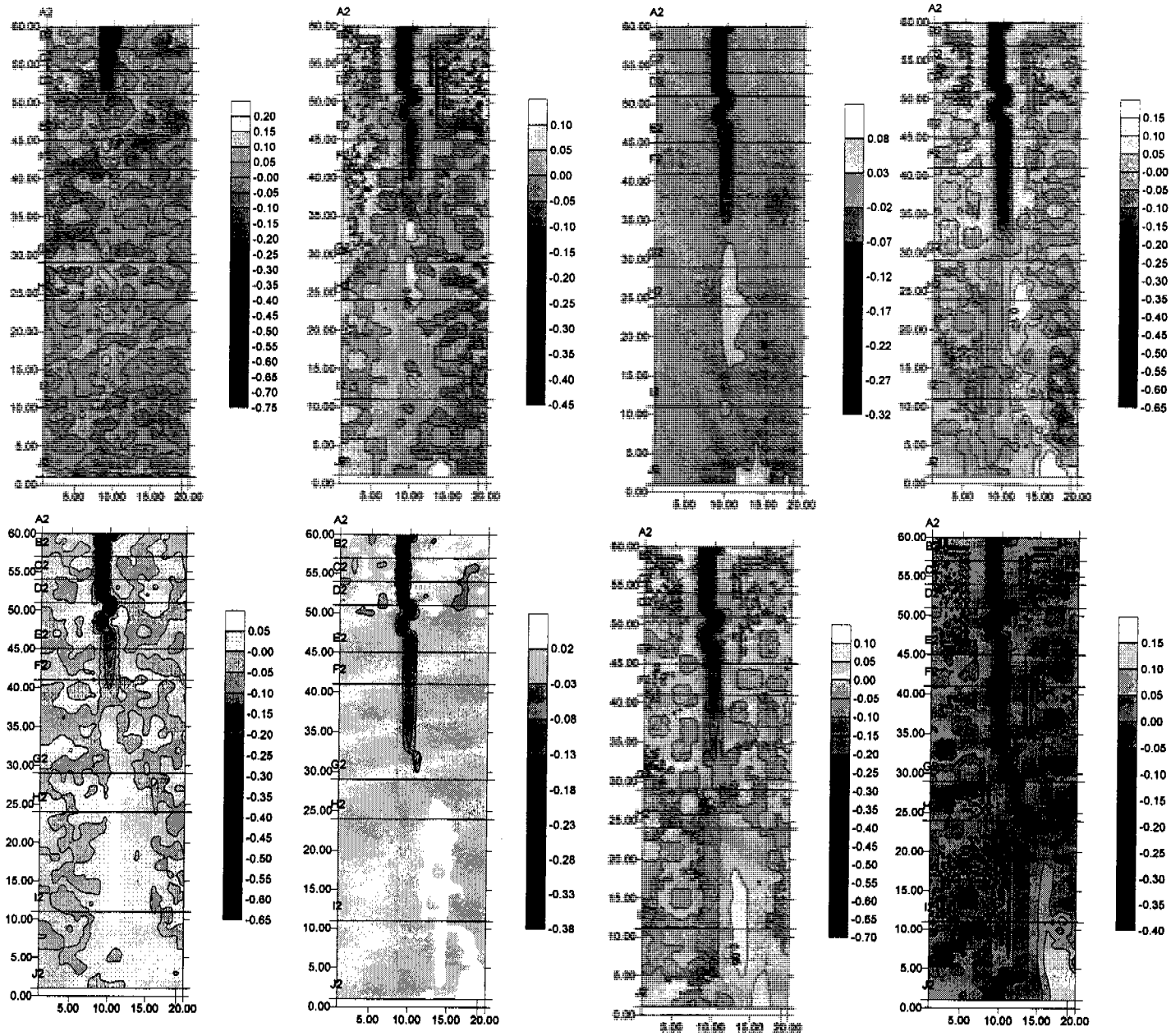


Figure 5.5.3: The morphology contour plots a) initial profile and 10 minutes, b) 10 minutes and 20 minutes, c) 20 minutes and 30 minutes, d) 30 minutes and 1 hour. The difference in elevations are also calculated from the remainder of the simulations with e) difference between 1 hours and 1.5 hours, f) 1.5 and 2 hours, g) 2 and 2.5 hours, and h) 2.5 and 3 hours.

The implementation of a series of three initial surfaces is not considered the usual adaptation for this model, and as such this application would represent an over-prediction of erosion depth for these simulations.

The implementation of the armouring component can be considered at the developmental stage, with a more realistic approximation devised when a depth coefficient of C~15, equating to a reduction factor of 1/30 when adopted. Figure 5.5.4, and Figure 5.5.5 illustrate these simulations, with Figure 5.5.6 highlighting the change in elevations between simulation time periods.

Maximum erosion depth, in this case reaches to only about 2 to 3m, approximately half of that observed in simulations observed in Section 5.1.

The development of the gully is similar between the lower erodibility coefficient and high erodibility coefficient, with more deposition of material with increased erosion associated with reduction factor of 1/10.

This is also verified when compared to the standard scenario Figure 5.1.1, and Figure 5.1.2, where the change in curvature at Row H to Row G is associated with accumulation of material and change in the path of the gully. Once again this behaviour is representative of an alteration in only one component, with the combination of these simulations with inclusion of randomised erodibility considered an even more realistic approximation.

Figure 5.5.7, and Figure 5.5.8 illustrate the effect of reduction of erodibility with depth on the extended batter site (Figure 5.1.4, and Figure 5.1.5). Similarities in development can be observed between these figures, however it is noted that from Figure $5.1.4_d$ compared to Figure $5.5.7_d$, that the gully can be seen to have developed to reach Row G, whereas it has reached only Row E in the earlier simulation. A similar comparison using Figure $5.5.4_d$ and Figure $5.1.1_d$ that although the gully depth of only about 10cm, the formation has reach almost Row I (at 60 minutes). Two explanations for this phenomenon, with reduction in transported sediment equating to a reduction in material deposited at the outlet of the gully resulting in drainage direction at these outlet points not being altered.

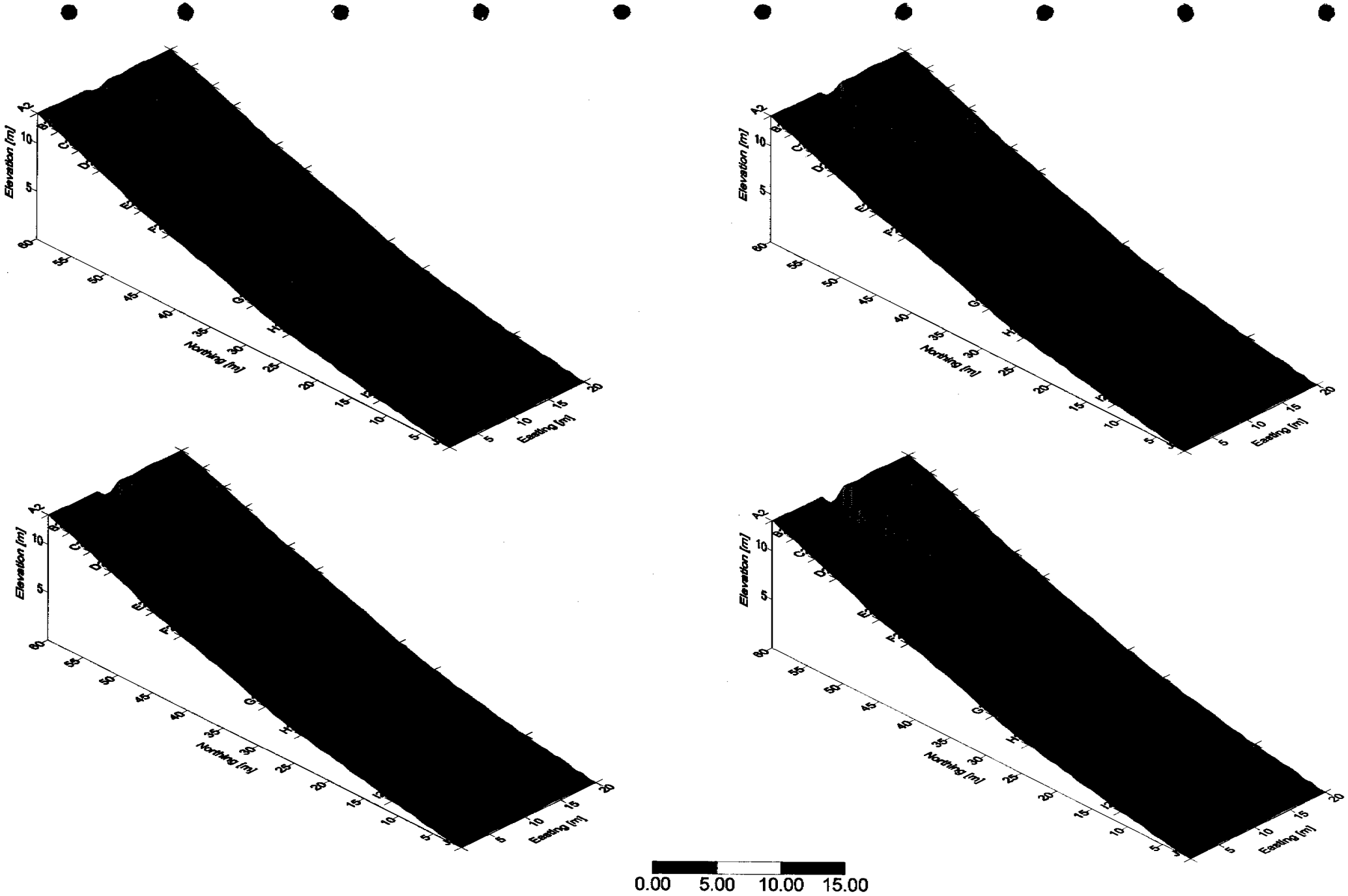


Figure 5.5.4: Simulations for standard batter slope profile with differential erodibility with depth function set at depth coefficient of 15, at a)10 minutes, b) 20 minutes, c) 30 minutes, and d) 1 hour.

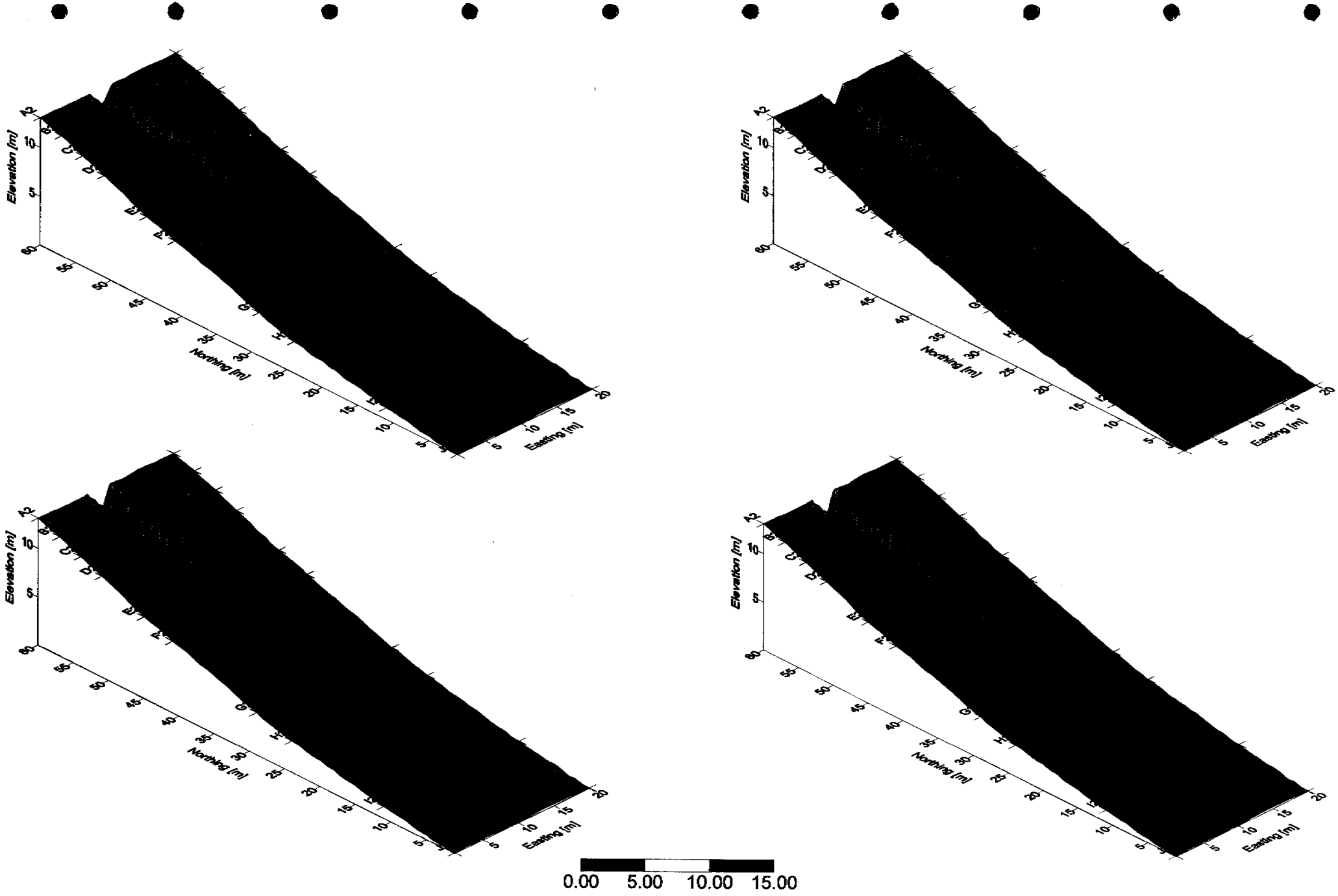


Figure 5.5.5: Simulations for standard batter slope profile with differential erodibility with depth function set at depth coefficient of 15, at a)1.5 hours, b) 2 hours this represents the second storm event, and c) 2.5 hours and d) 3 hours representing the final storm event.

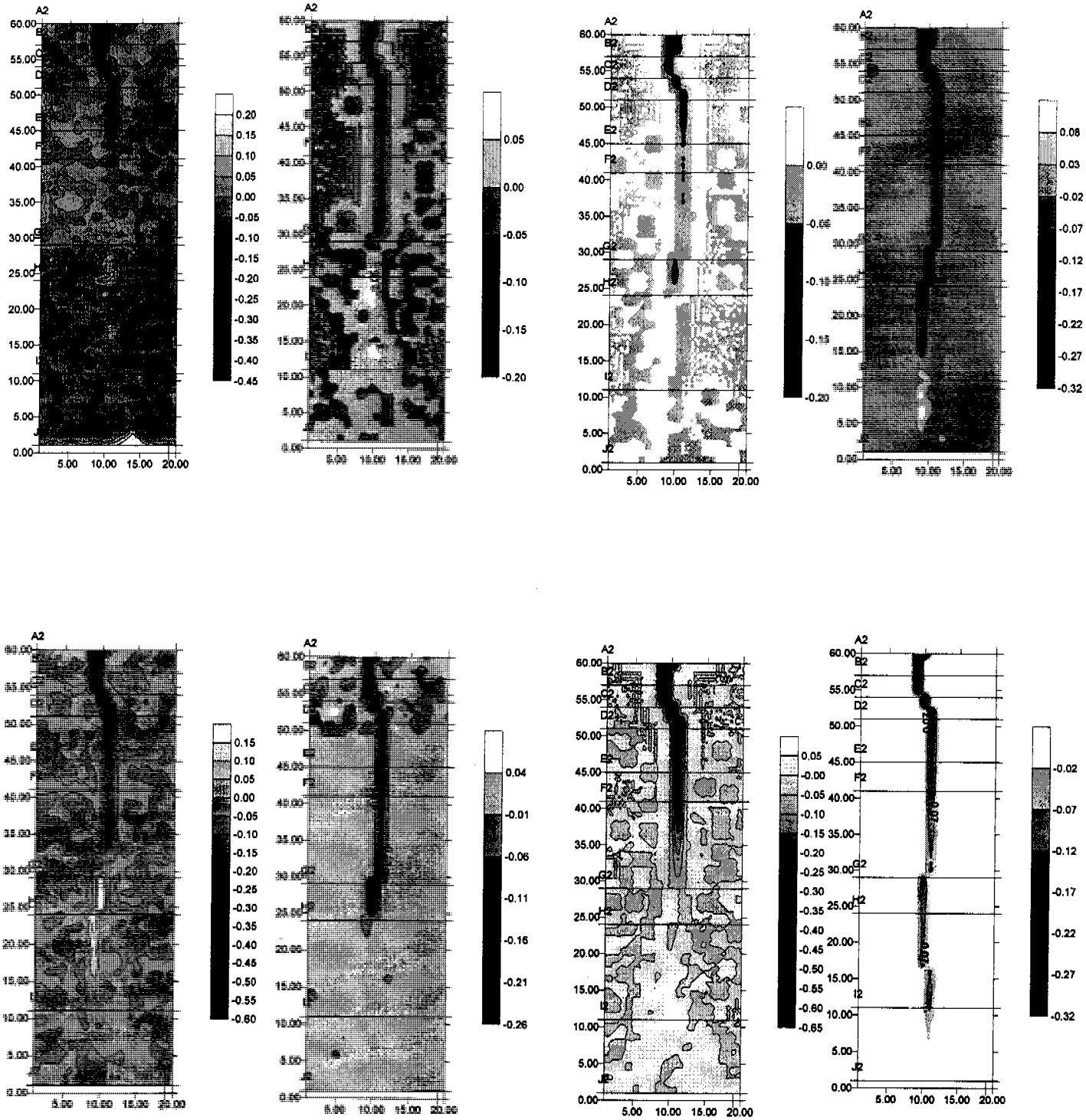


Figure 5.5.6: The morphology contour plots a) initial profile and 10 minutes, b) 10 minutes and 20 minutes, c) 20 minutes and 30 minutes, d) 30 minutes and 1 hour. The difference in elevations are also calculated from the remainder of the simulations with e) difference between 1 hours and 1.5 hours, f) 1.5 and 2 hours, g) 2 and 2.5 hours, and h) 2.5 and 3 hours.

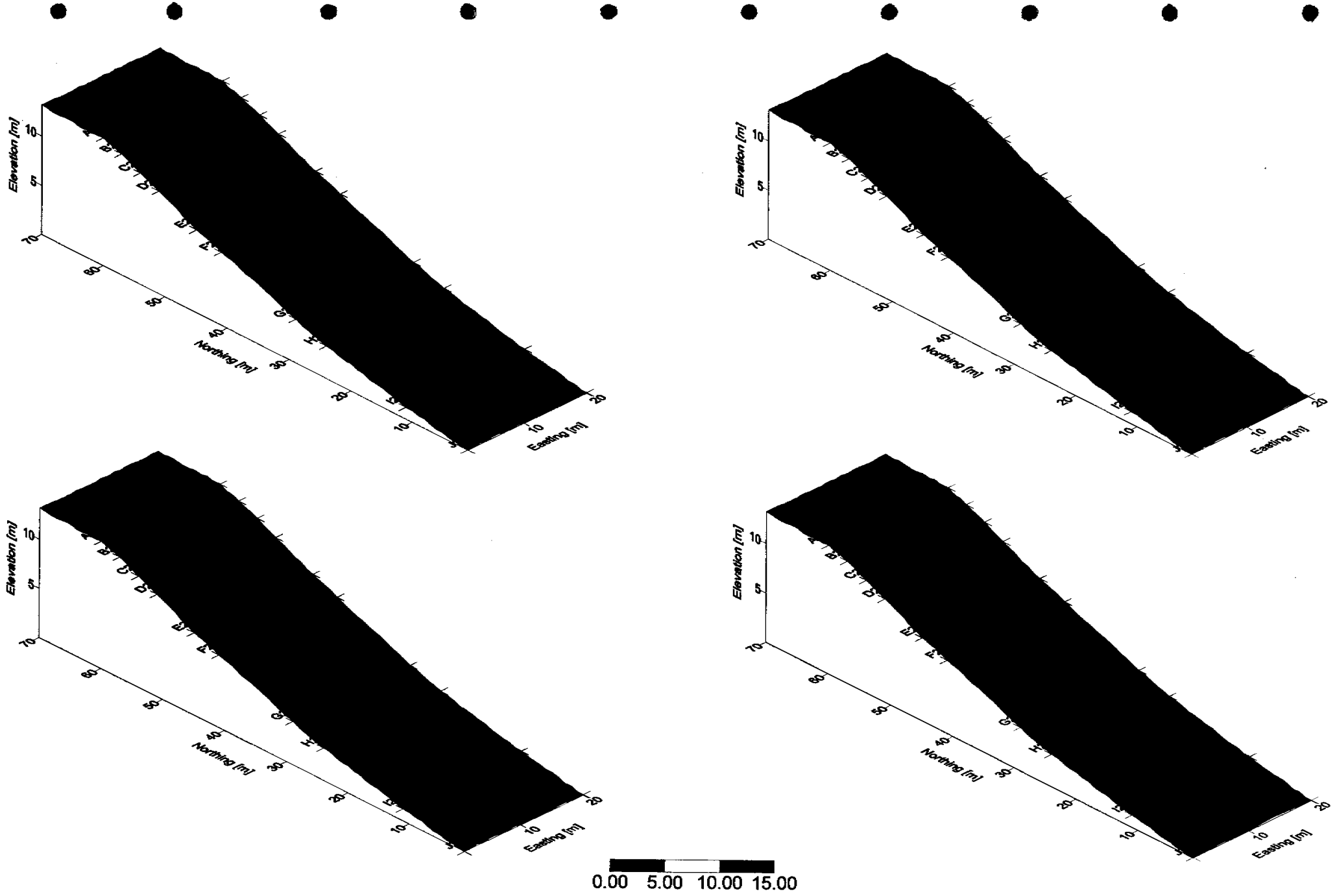


Figure 5.5.7: Simulations for extended batter slope profile with differential erodibility with depth, at a)10 minutes, b) 20 minutes, c) 30 minutes, and d) 1 hour.

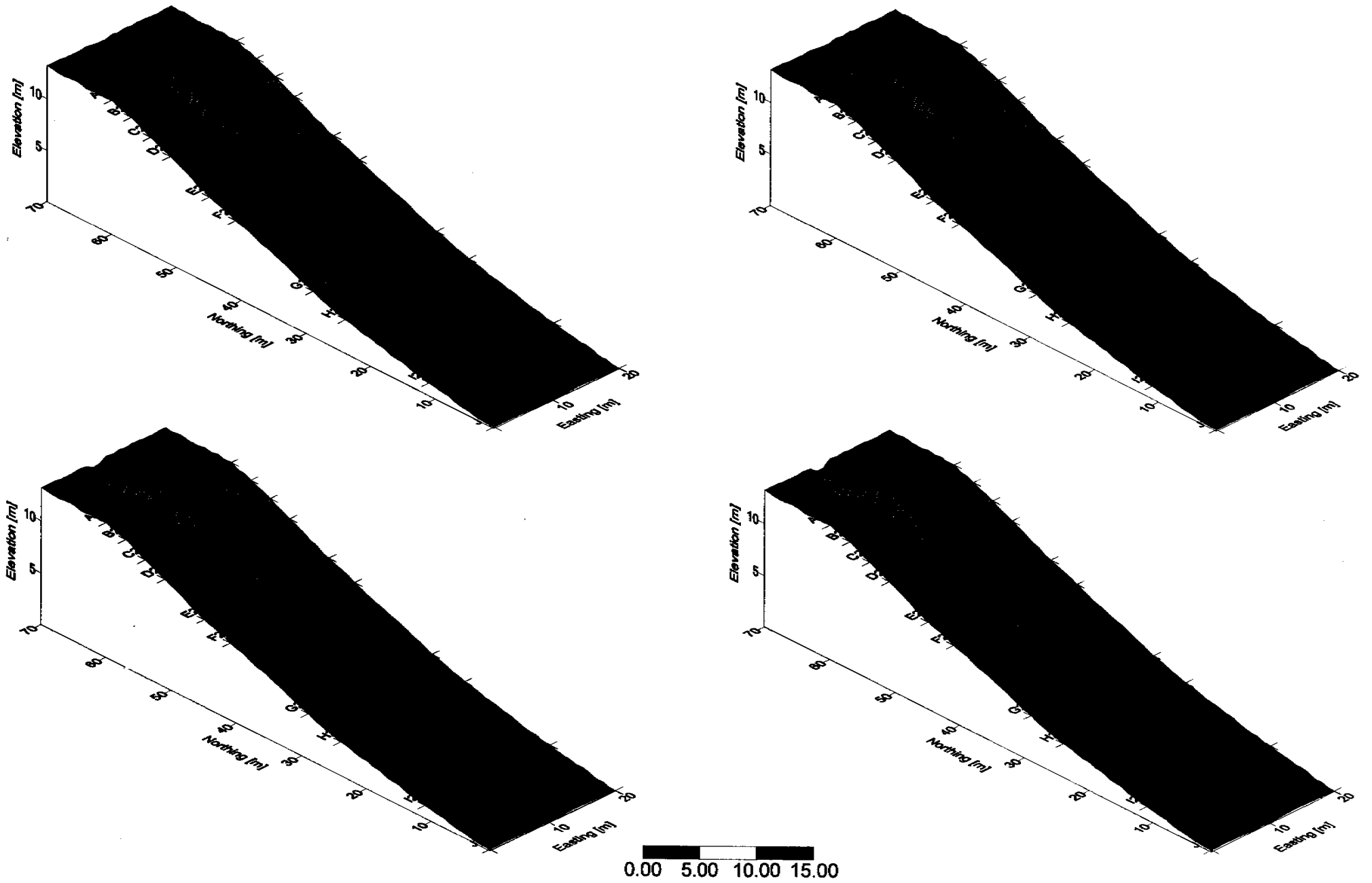


Figure 5.5.8: Simulations for extended batter slope profile with differential erodibility with depth function, at a)1.5 hours, b) 2 hours this represents the second storm event, and c) 2.5 hours and d) 3 hours representing the final storm event.

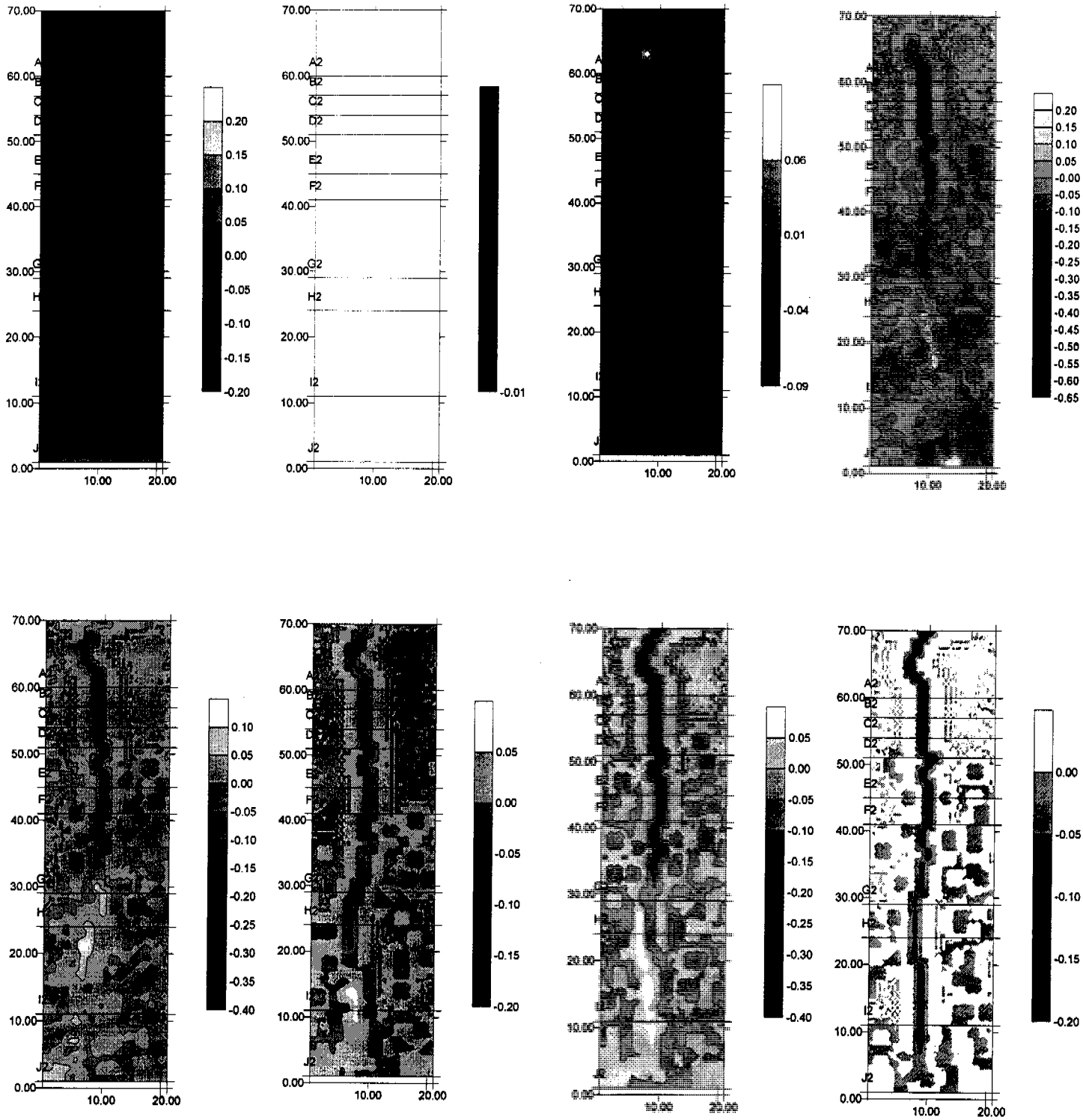


Figure 5.5.9: The morphology contour plots a) initial profile and 10 minutes, b) 10 minutes and 20 minutes, c) 20 minutes and 30 minutes, d) 30 minutes and 1 hour. The difference in elevations are also calculated from the remainder of the simulations with e) difference between 1 hours and 1.5 hours, f) 1.5 and 2 hours, g) 2 and 2.5 hours, and h) 2.5 and 3 hours.

This is observed in Figure $5.1.1_d$ where the gully has developed to beyond Row F, and has incised about 0.5 to 0.8m at this point, whilst the gully in Figure $5.5.4_d$ has developed to Row H with depths of about 40cm at Row F and 10cm noticeable due to the uniform nature of the material. Material deposited at the outlet of the gully in Figure $5.1.1_d$ is not apparent in Figure $5.5.4_d$.

The other observation is made by the comparison between Figure $5.5.4_d$ and $5.5.5_d$ at 60 minutes and 1.5 hours respectively, where material from increased incision of the gully in the upper section smothers the 10cm pathway revealed at the 60 minute time period. This is illustrated in Figure 5.5.6 where about 10 to 15cm of material is deposited over the gully at Row H to Row I. This suggests a change in the overall discharge relationship β_3 from 0.00272 to 0.00199 has an impact on the nature of erosion at these points, with the same observation made comparing Figure $5.5.7_a$ and Figure $5.5.8_a$ with shallow formation at the bottom end of slope smothered by introduction of consequent storm event.

The next considerations were the combination of randomised erodibility and the depth-erodibility coefficient for both the usual cases including increased inlet width, whilst similarities between simulations without inclusion of wide inlet verify previous observations.

The first scenario is illustrated Figure 5.5.10, with Figure 5.5.11 representing the second and third storm events with narrow inlet feed and the combination of characteristics from randomised erodibility and armouring erosion module. Figure 5.5.12 exhibits an obvious combination of characteristics from investigations above. The depth of erosion is similar to that observed in Figure 5.5.4 and Figure 5.5.5, with the nature of pathway being altered due to the randomised erodibility as expected.

The maximum depth of erosion for simulations incorporating the wide inlet point can be considered similar to Figure 5.5.4, and Figure 5.5.5. Below the inlet zone of influence at Row C in Figure 5.5.13, and Figure 5.5.14, the gully congregates into a single flowpath once again with depth of erosion observed to replicate that of comparative figures.

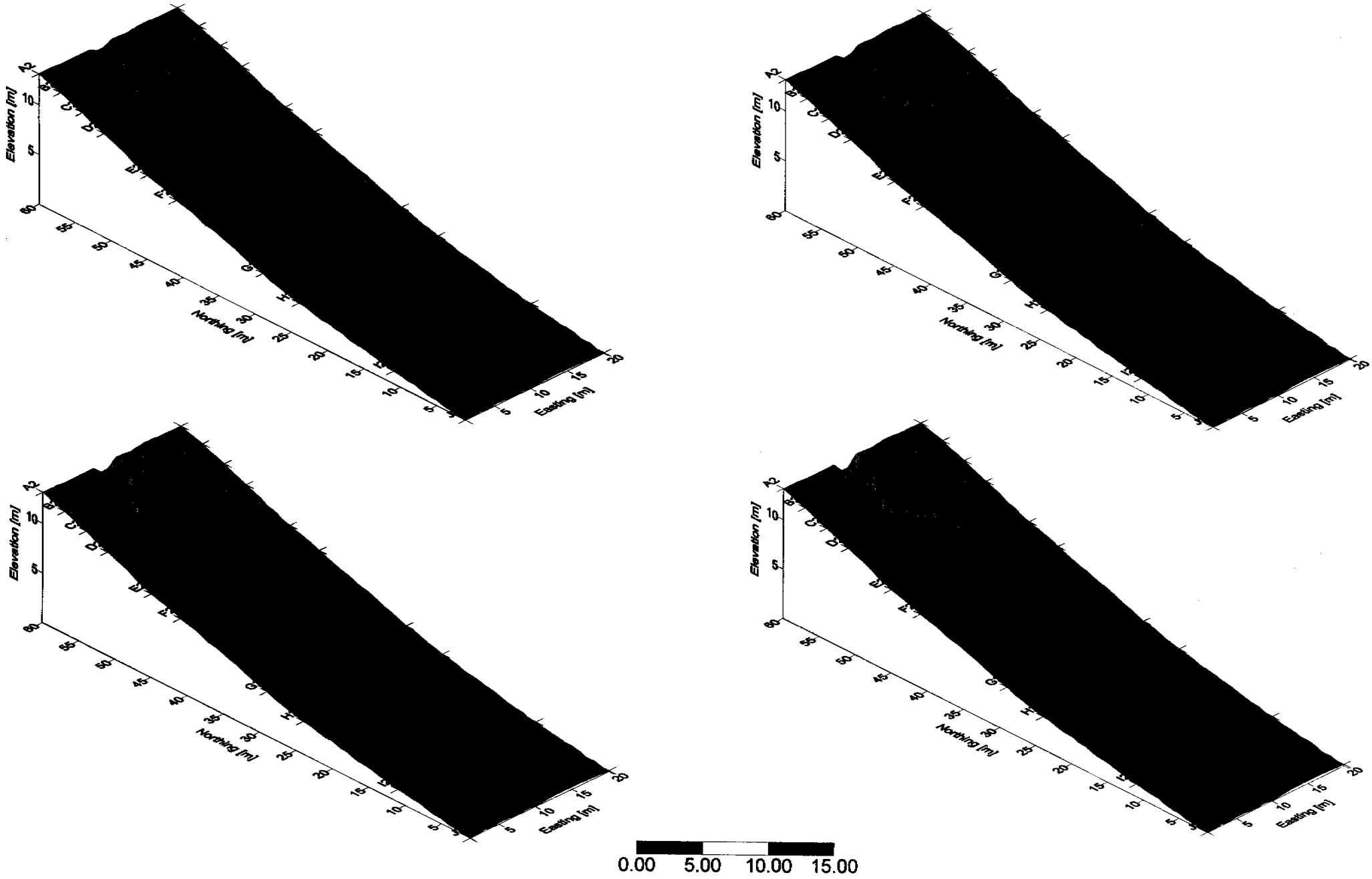


Figure 5.5.10: Simulations for standard batter slope profile with differential erodibility with depth, and randomised erodibility function, at a)10 minutes, b) 20 minutes, c) 30 minutes, and d) 1 hour.

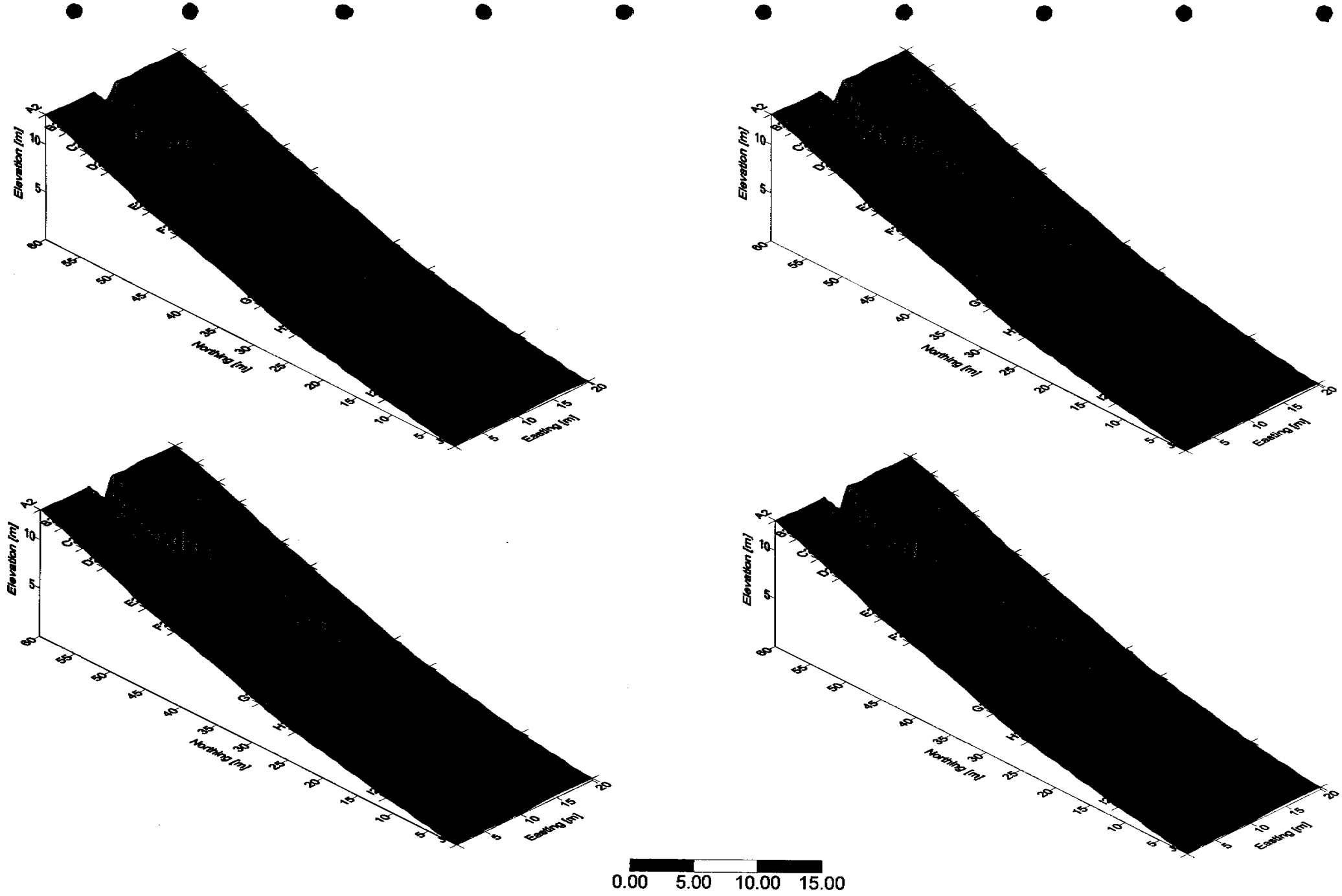


Figure 5.5.11: Simulations standard batter slope profile with differential erodibility with depth, and randomised erodibility function, at a)1.5 hours, b) 2 hours this represents the second storm event, and c) 2.5 hours and d) 3 hours representing the final storm event.

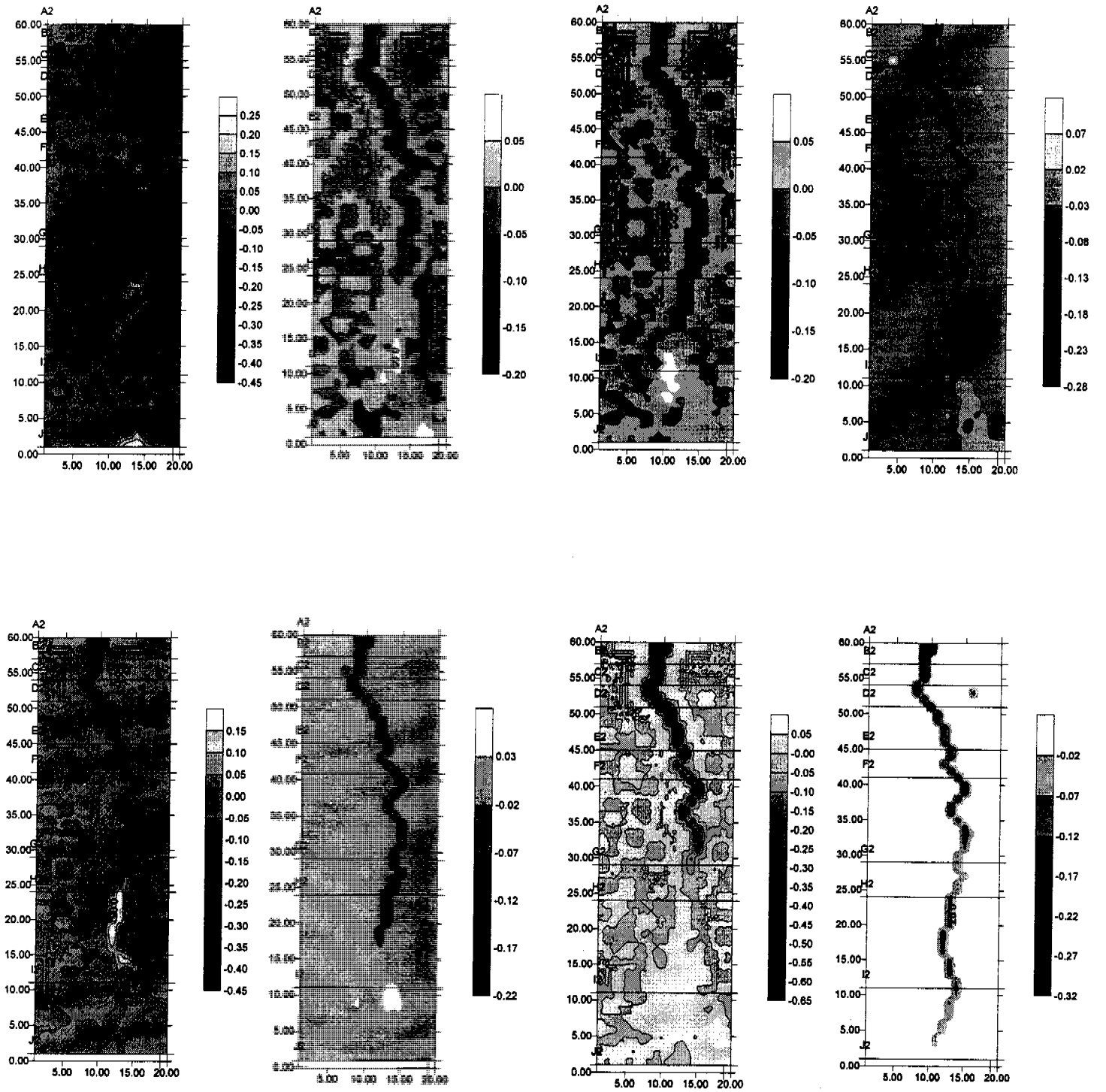


Figure 5.5.12: The morphology contour plots a) initial profile and 10 minutes, b) 10 minutes and 20 minutes, c) 20 minutes and 30 minutes, d) 30 minutes and 1 hour. The difference in elevations are also calculated from the remainder of the simulations with e) difference between 1 hours and 1.5 hours, f) 1.5 and 2 hours, g) 2 and 2.5 hours, and h) 2.5 and 3hours.

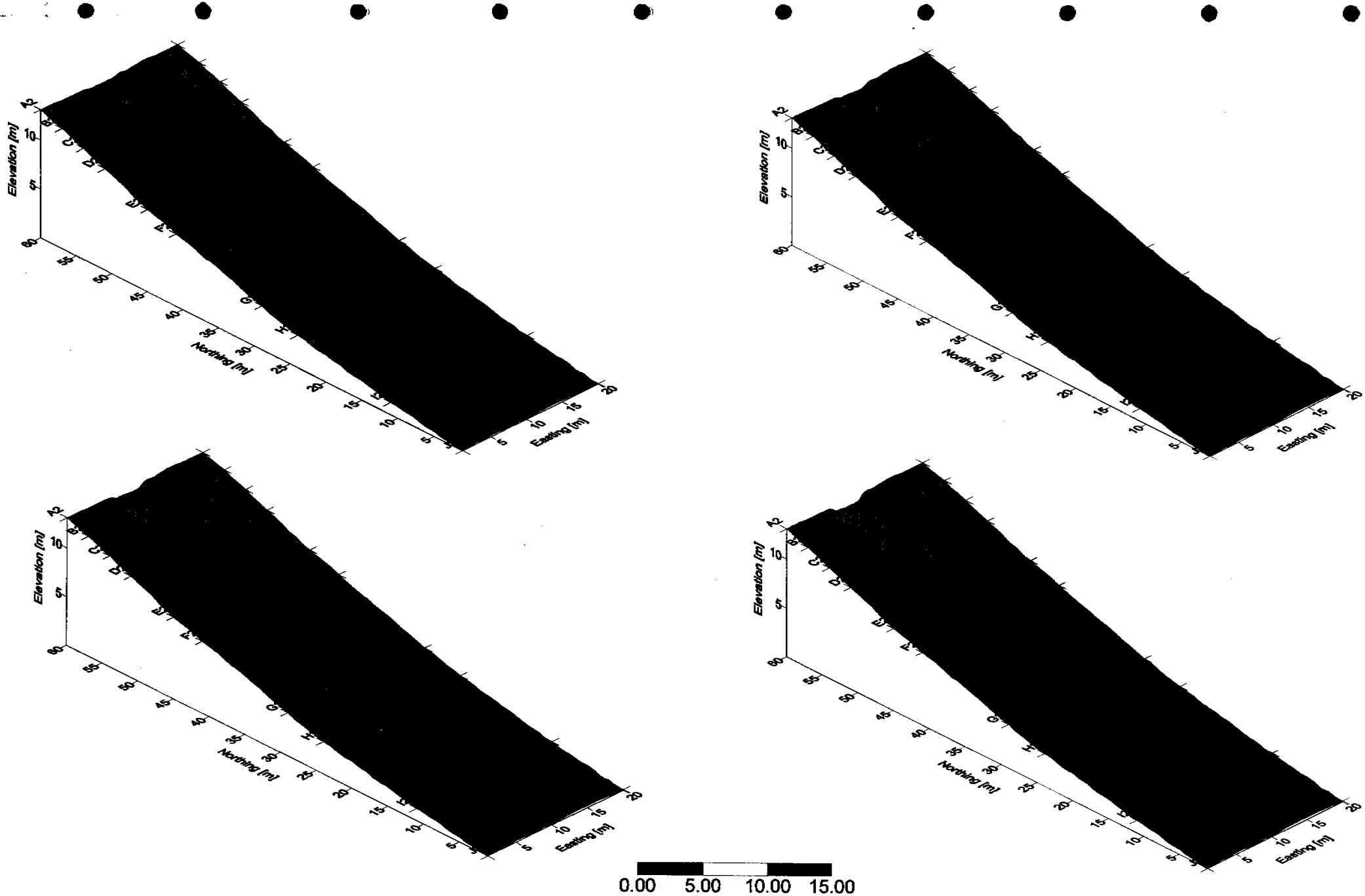


Figure 5.5.13: Simulations for standard batter slope profile with differential erodibility with depth, and randomised erodibility function, as well as wide inlet point, at a)10 minutes, b) 20 minutes, c) 30 minutes, and d) 1 hour.

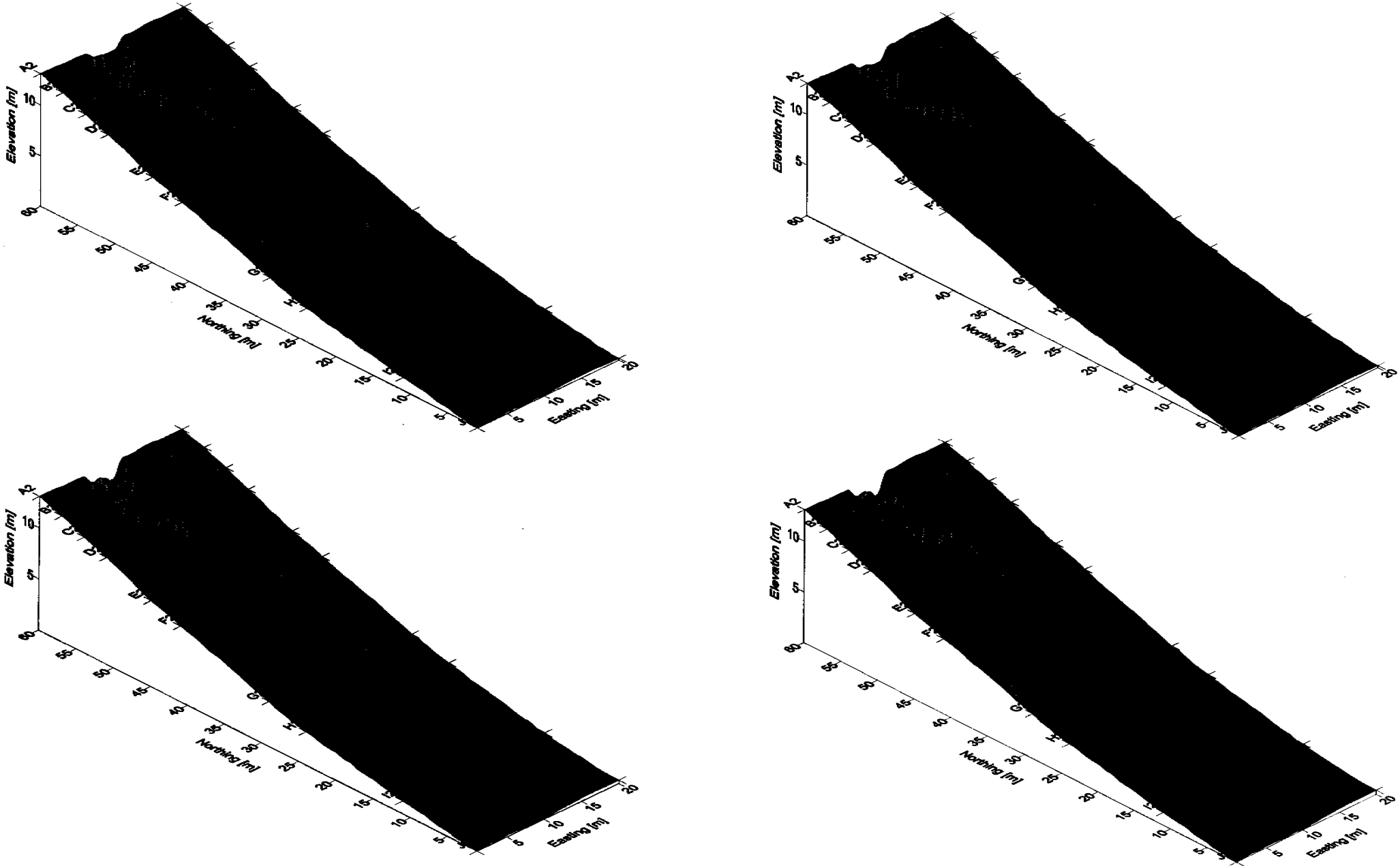


Figure 5.5.14: Simulations standard batter slope profile with differential erodibility with depth, and randomised erodibility function, as well as wide mesh point, at a) 1.5 hours, b) 2 hours this represents the second storm event, and c) 2.5 hours and d) 3 hours representing the final storm event.

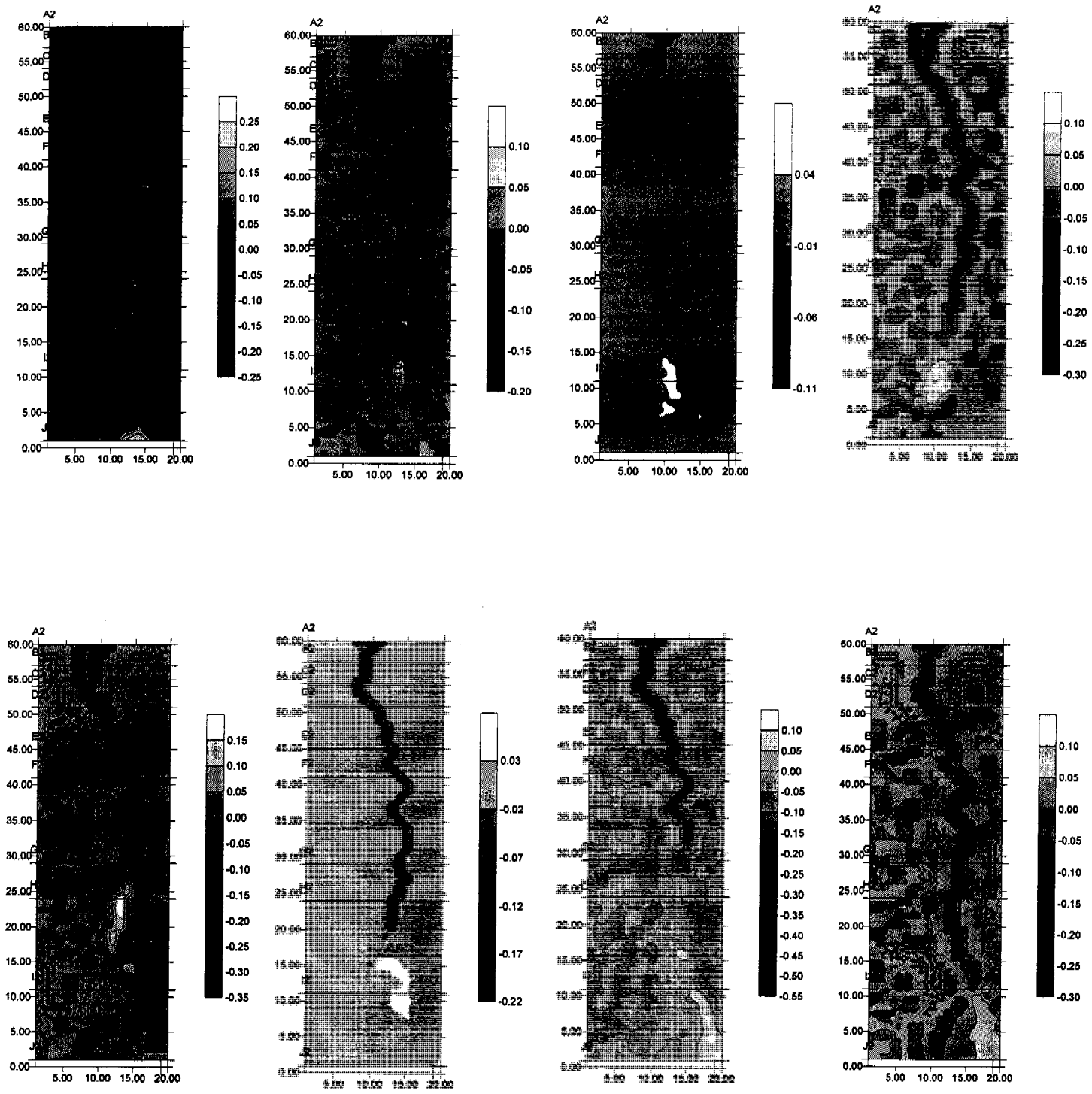


Figure 5.5.15: The morphology contour plots a) initial profile and 10 minutes, b) 10 minutes and 20 minutes, c) 20 minutes and 30 minutes, d) 30 minutes and 1 hour. The difference in elevations are also calculated from the remainder of the simulations with e) difference between 1 hours and 1.5 hours, f) 1.5 and 2 hours, g) 2 and 2.5 hours, and h) 2.5 and 3 hours.

Further investigations consider the same scenarios with the extended batter slope profile, where similar behaviour is exhibited in Figure 5.5.16, Figure 5.5.17 for narrow inlet point, and Figure 5.5.19, and Figure 5.5.20 for wide inlet point respectively.

The gully formation at 60 minutes duration is compared to observations on site in Figure 3.2.6 above, with results of first storm event excavating material between Row B and Row D and gully extending down to Row G. Approximately 40 to 50cm depth of material was transported between Row C to Row D whereas from Figure 5.5.15, a total depth of 60 to 70cm was predicted. It is noted that the initial delay in gully development observed in earlier simulations is repeated in Figure 5.5.19 and Figure 5.5.20 even though final landscapes are of similar extent and magnitude.

The maximum depth of erosion at the head of the gully was 2.2m for the standard case, and 1.9m overall for the extended profile scenario (Figure $5.5.18_d$ and Figure $5.5.20_d$ respectively). This represents an over-prediction with maximum depth observed on site at Row A in the order of 20 to 25cm, however as noted, this transition was considered to be heavily armoured and buffered due to the reservoir.

The formation of shallow tributaries ahead of the main gully was also observed on site, with 10 to 20cm depth seen in Figure 5.5.17d) of comparable magnitude to that seen in Figure 3.2.4, Figure 3.2.5, Figure 3.2.6.

The final landform pictured in Figure $5.5.18_d$ illustrates a few noteworthy characteristics, with depth of gully increasing uniformly in the upper sections of the slope, and movement of the formation down the hillslope, combined with deposition of material observed between Row H to Row I. The development observed on site is comparable, with deposition of material observed between Row H and Row I and excavation of material to a maximum depth of 60 to 70cm at Row G.

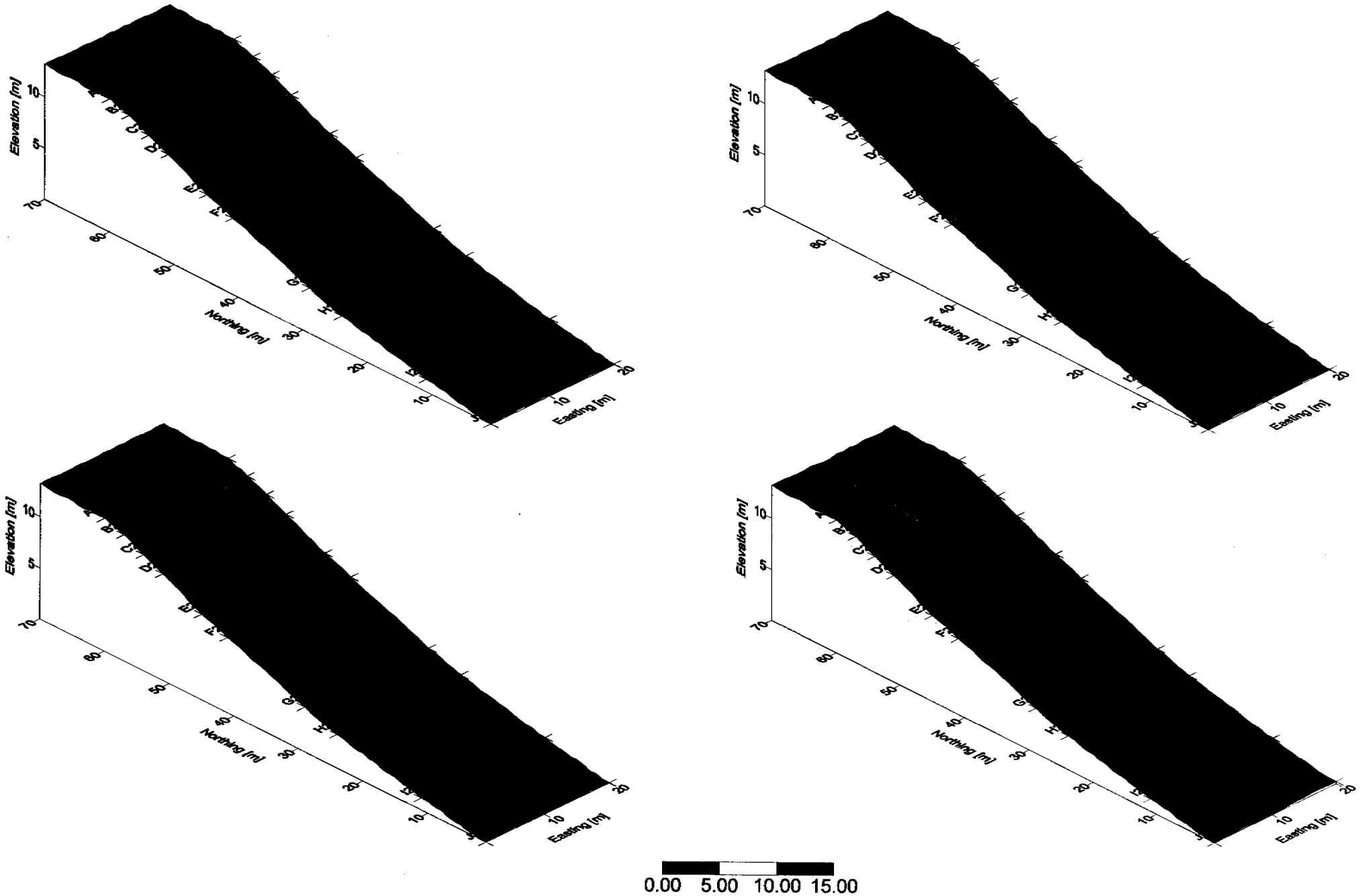


Figure 5.5.16: Simulations for extended batter slope profile with differential erodibility with depth, and randomised erodibility function, at a)10 minutes, b) 20 minutes, c) 30 minutes, and d) 1 hour.

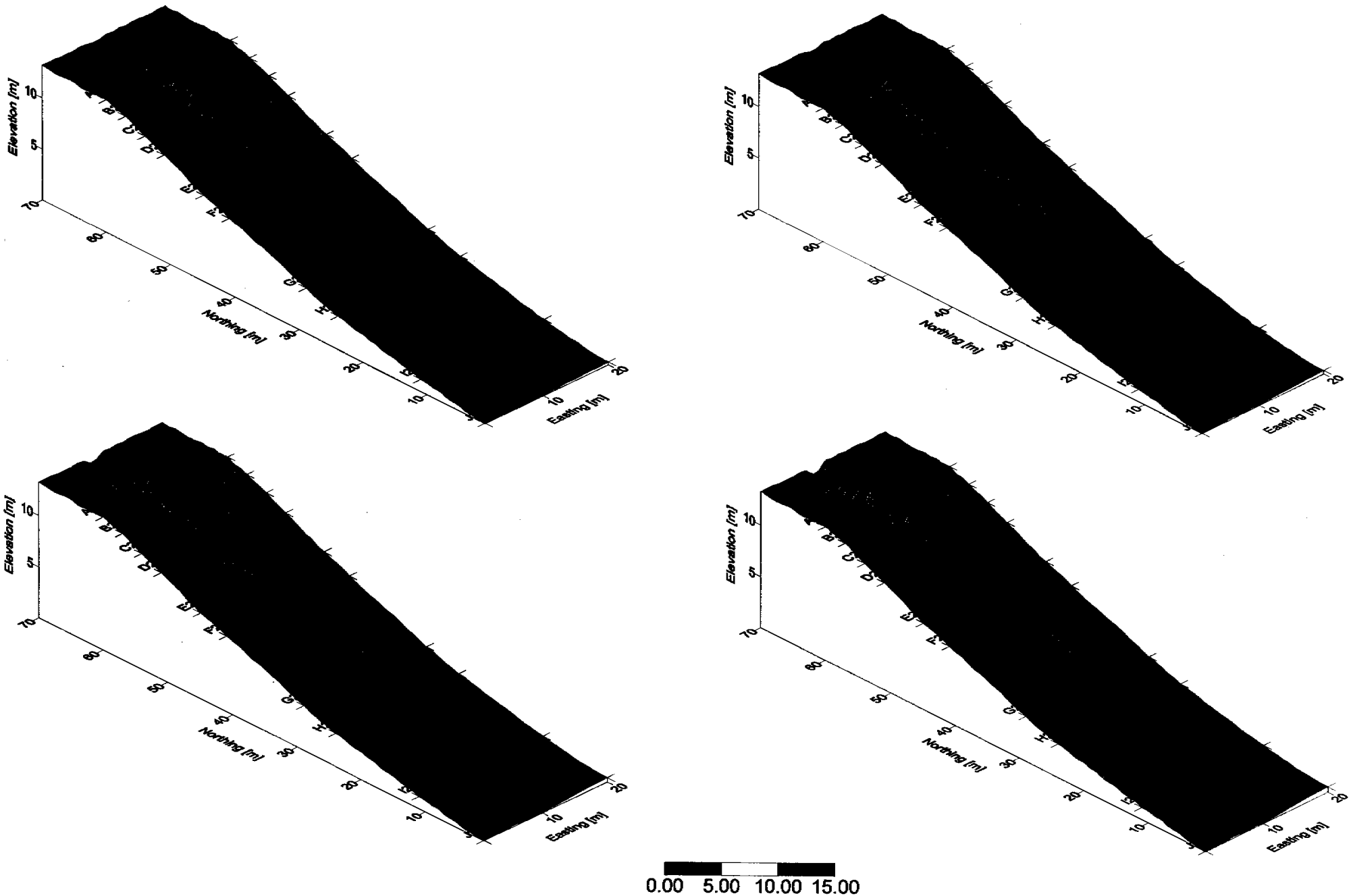


Figure 5.5.17: Simulations extended batter slope profile with differential erodibility with depth, and randomised erodibility function, at a)1.5 hours, b) 2 hours this represents the second storm event, and c) 2.5 hours and d) 3 hours representing the final storm event.

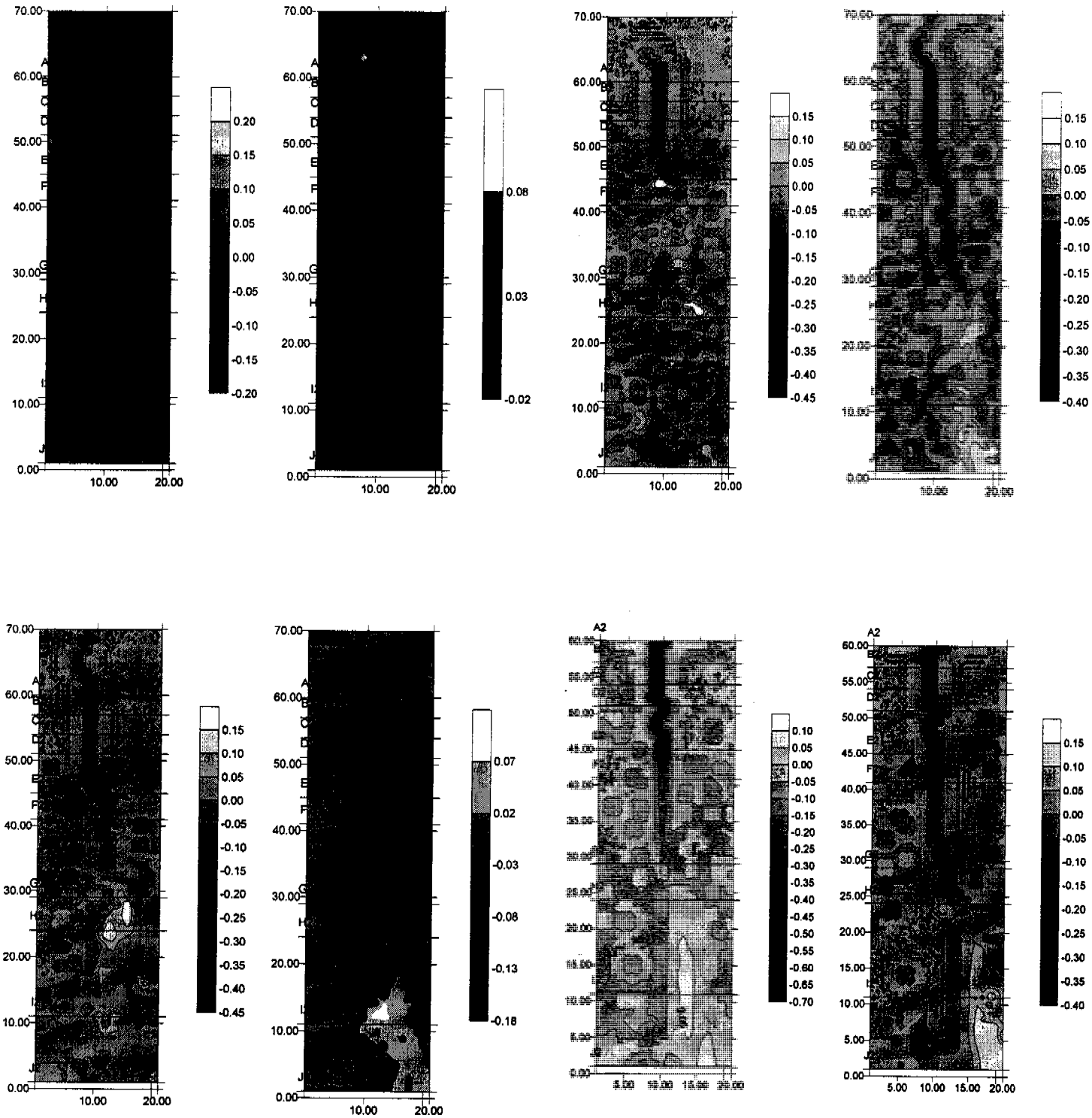


Figure 5.5.18: The morphology contour plots a) initial profile and 10 minutes, b) 10 minutes and 20 minutes, c) 20 minutes and 30 minutes, d) 30 minutes and 1 hour. The difference in elevations are also calculated from the remainder of the simulations with e) difference between 1 hours and 1.5 hours, f) 1.5 and 2 hours, g) 2 and 2.5 hours, and h) 2.5 and 3hours.

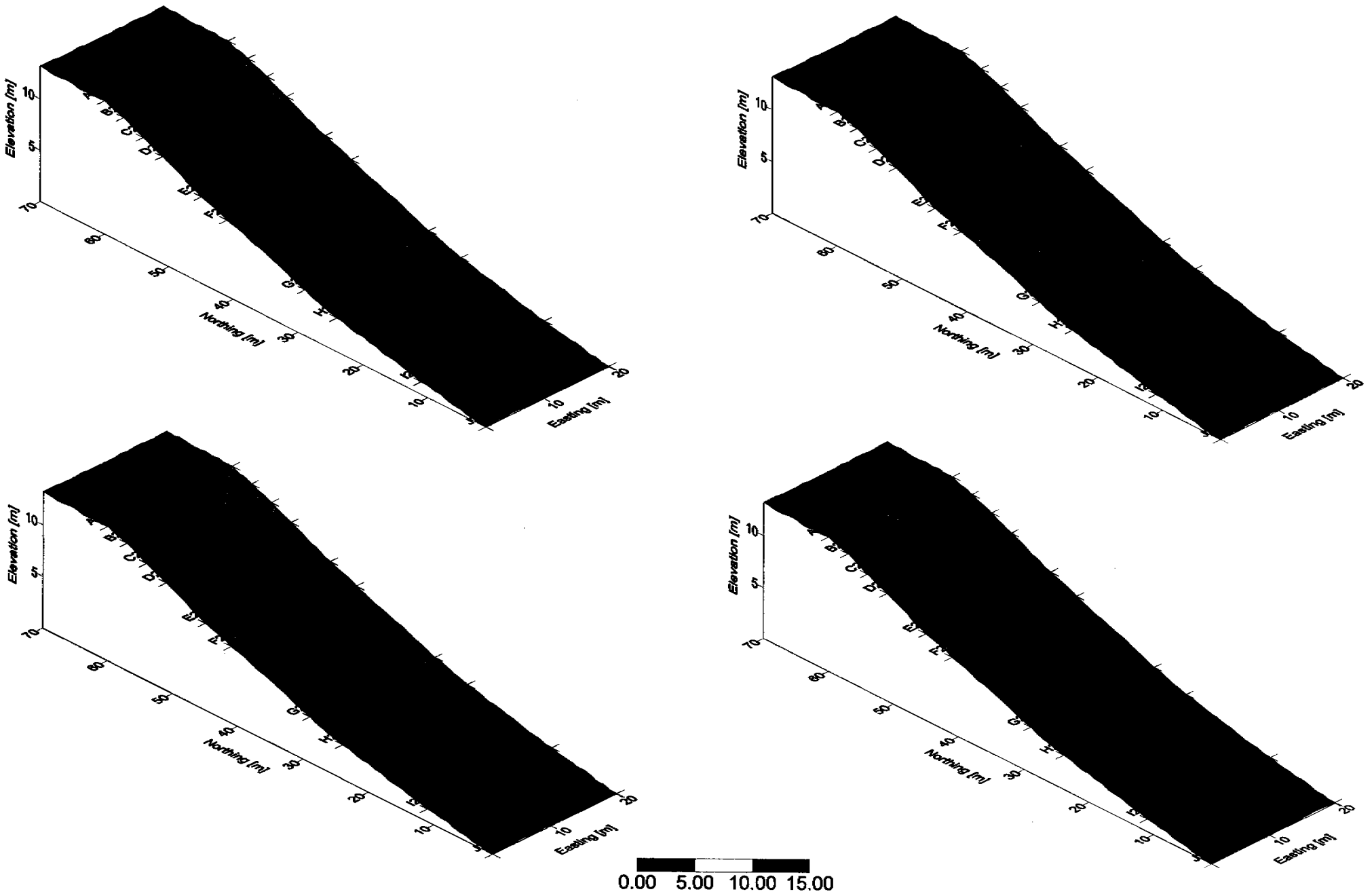


Figure 5.5.19: Simulations for extended batter slope profile with differential erodibility with depth, and randomised erodibility function, as well as wide inlet point, at a)10 minutes, b) 20 minutes, c) 30 minutes, and d) 1 hour.

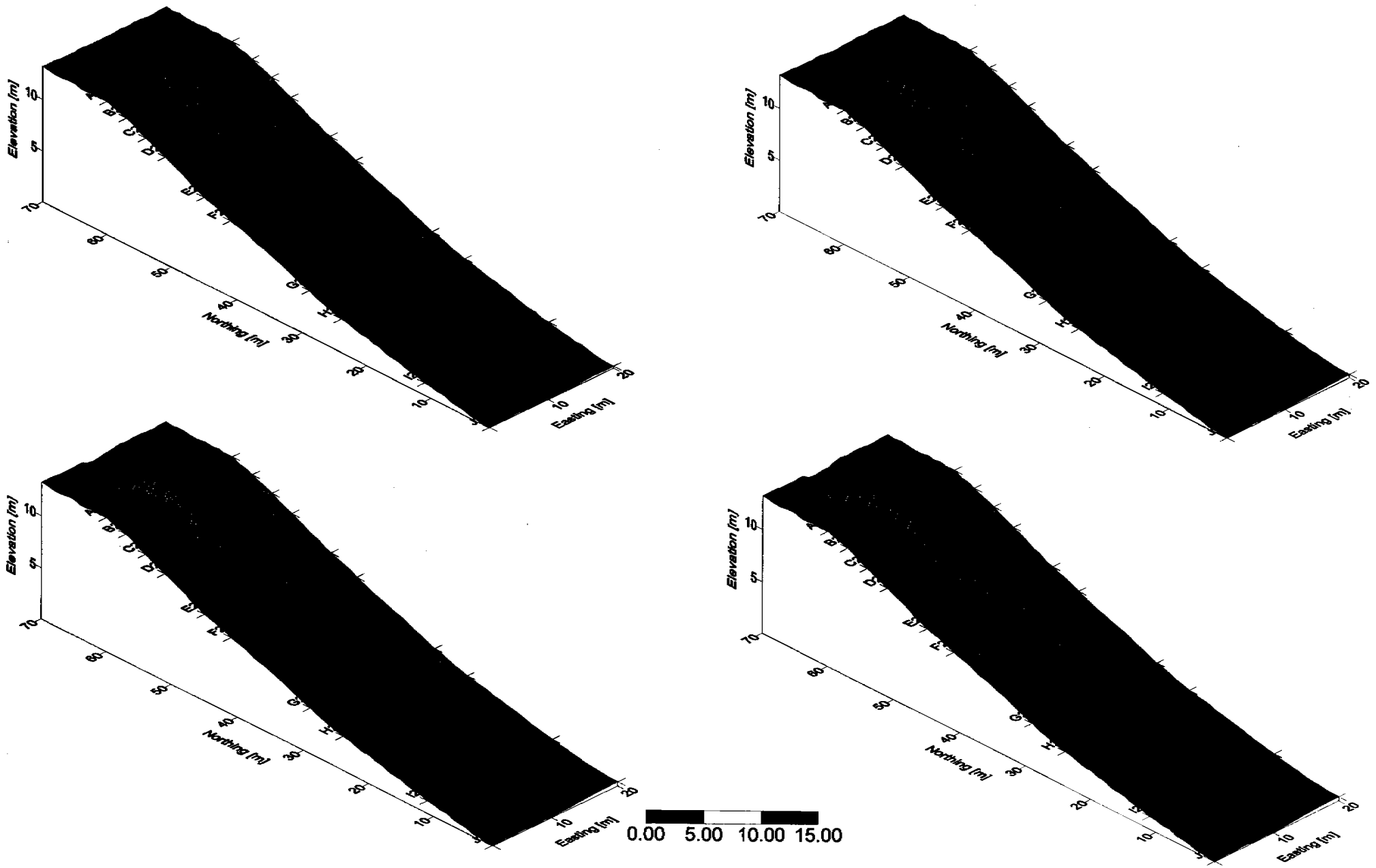


Figure 5.5.20: Simulations extended batter slope profile with differential erodibility with depth, and randomised erodibility function, as well as wide inlet point, at a)1.5 hours, b) 2 hours this represents the second storm event, and c) 2.5 hours and d) 3 hours representing the final storm event.

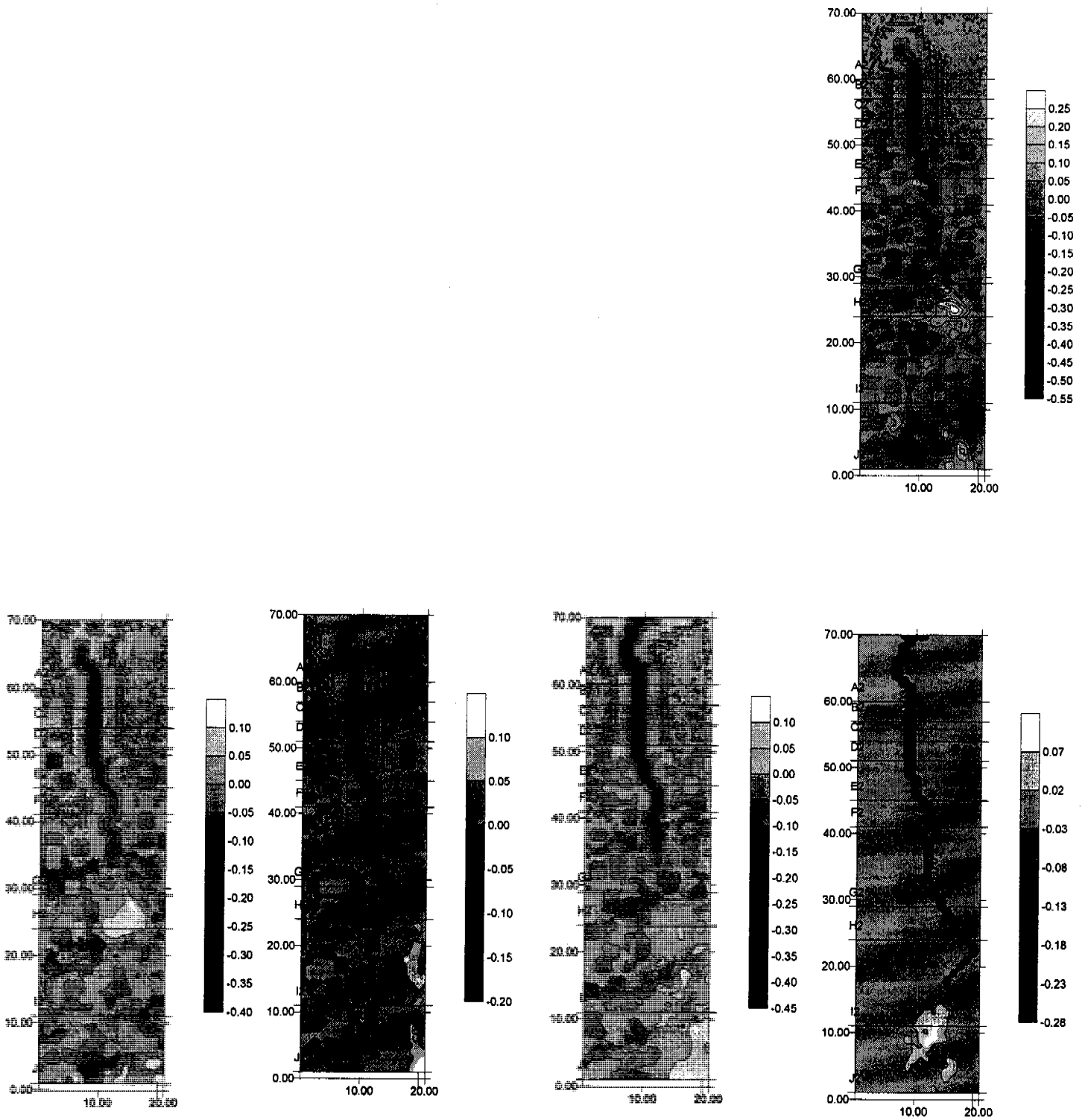


Figure 5.5.21: The morphology contour plots a) initial profile and 10 minutes, b) 10 minutes and 20 minutes, c) 20 minutes and 30 minutes, d) 30 minutes and 1 hour. The difference in elevations are also calculated from the remainder of the simulations with e) difference between 1 hours and 1.5 hours, f) 1.5 and 2 hours, g) 2 and 2.5 hours, and h) 2.5 and 3 hours.

The incision at Row A in Figure 5.5.19, reaches a maximum depth of 1.8m with depth at 60 minutes reaching 60cm. Development of the gully at this point has begun to extend back into the catchment, whilst 20cm shallow tributaries extend down to Row F. Although these figures represent 2 different development scenarios, the overall depth of erosion and extent are similar (Figure 5.5.18, and Figure 5.5.20).

The depth of incision into the catchment reaches 1.5m just before the transition point back to 50cm adjacent to the inlet point, and reflects a similar observation to that seen in Figure 5.1.4 at 60 minute mark. In this figure the pathway adopted is identical, confirming that development follows the same process by extending backward from the incision point. The depth of incision at 60 minutes was only 60cm as stated above, whereas 1.8m was predicted with the standard profile.

These landforms perhaps represent the closest approximation devised from the modelling process, and can be considered a reasonable estimate. Depth within the gully of either of the two important simulations of Figures 5.5.18, or Figure 5.5.20 between 1.8 m and 0.6m for Rows A to Row C with 0.6m gully representing the depth of the secondary tributary observed in Figure 5.5.18.

5.6 Slope Final

The final modelling regime considered was the modification of the exponent on the slope term in the sediment transport equation, n_1. This investigation generated surfaces illustrated in Section 5.2, with none of the additional erosion modules enabled. As noted, the results seen in these figures were considered dramatic with maximum depths of erosion about 11m by end of the monitoring period, with a maximum depth of 5m observed in the extended profile case.

The final model scenarios investigated included all of the erosional modules, with slope exponent n_1 altered from 2.1 to 0.69. The slope exponent n_1 was considered the most sensitive parameter, with field observations indicating a significant change in erodibility with depth. The batter slope profile and extended profile were both investigated, with depths of erosion at the head of the gully reaching 4m, for the standard profile case.

The extended profile, however does not erode significantly, with gully development considerably slower than that observed in previous simulations with inclusion of wide inlet. Maximum depth of erosion, and development behaviour is sporatic, with comparisons favourable between these simulations and observed depths.

Also noted that the gully does not extend from the transition point (Row A) back into the cap site with this simulation, and it is suggested that this is a product of the combination of the armouring component and similar observations in Section 5.3.

As noted, the derivation of this exponent is dependent on mean particle diameter and hence considered subjective. The maximum depth of erosion at the head of the gully was 3 to 4 m, with this prediction greater than that observed in Figure 5.5.14 at about 2 m. owever the depths of erosion below this initial inlet zone, Row C, are comparable, although the rate of development of the gully is much more rapid, with the gully extending to the bottom of the slope within the first storm event. The simulation also exhibits some indication of numerical instability, although for the extended profile, similar behaviour to that observed in Figure 5.2.4, and 5.2.5 where the wide inlet point given the fitted value of n_1 at 0.69 resulted in the gully not developing, as incision at transition point did not occur.

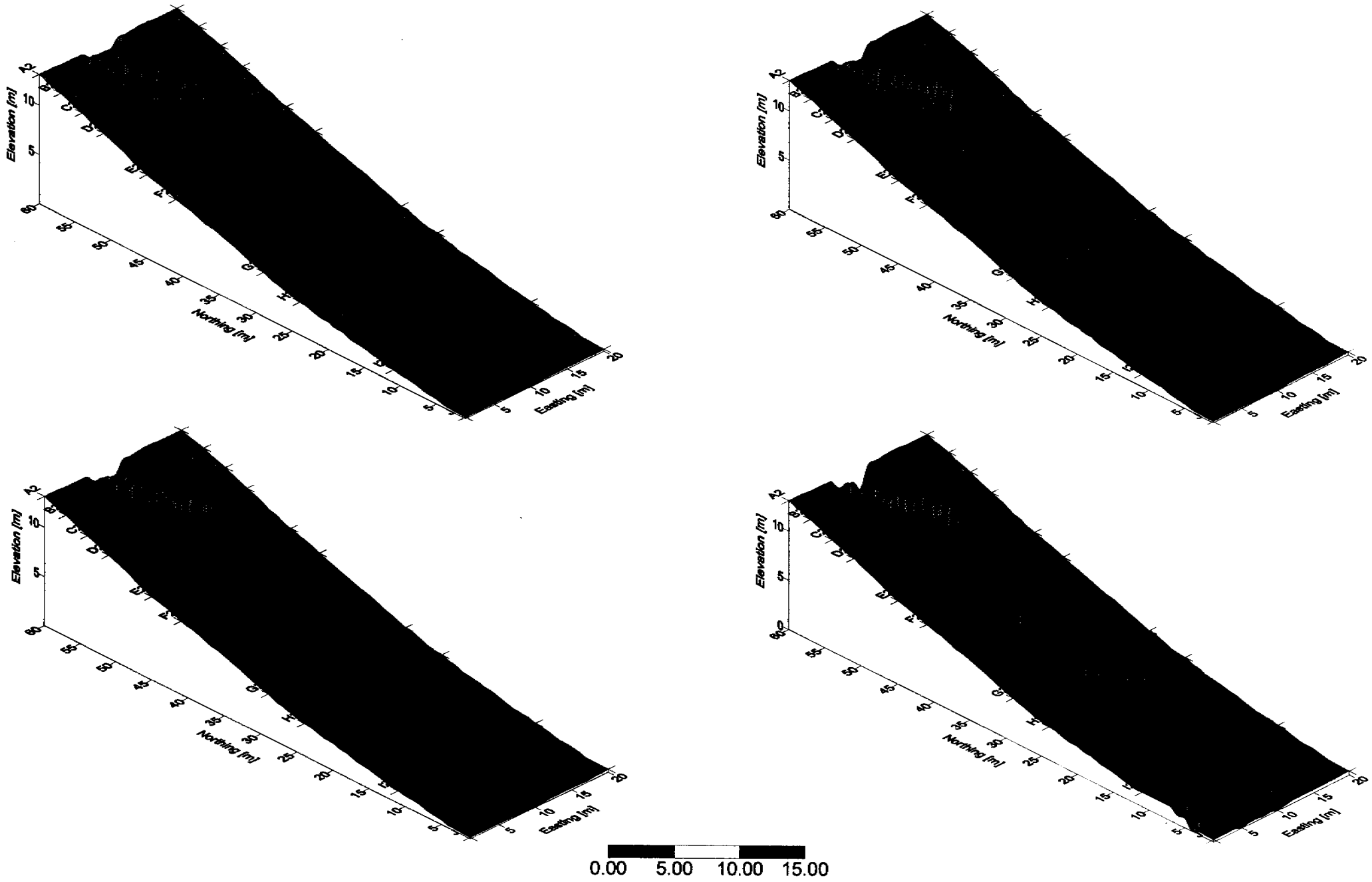


Figure 5.6.1: Simulations for standard batter slope profile with differential erodibility with depth, and randomised erodibility function, together with wide inlet point and n_1 slope exponent at 0.69 instead of 2.1, at a)10 minutes, b) 20 minutes, c) 30 minutes, and d) 1 hour.

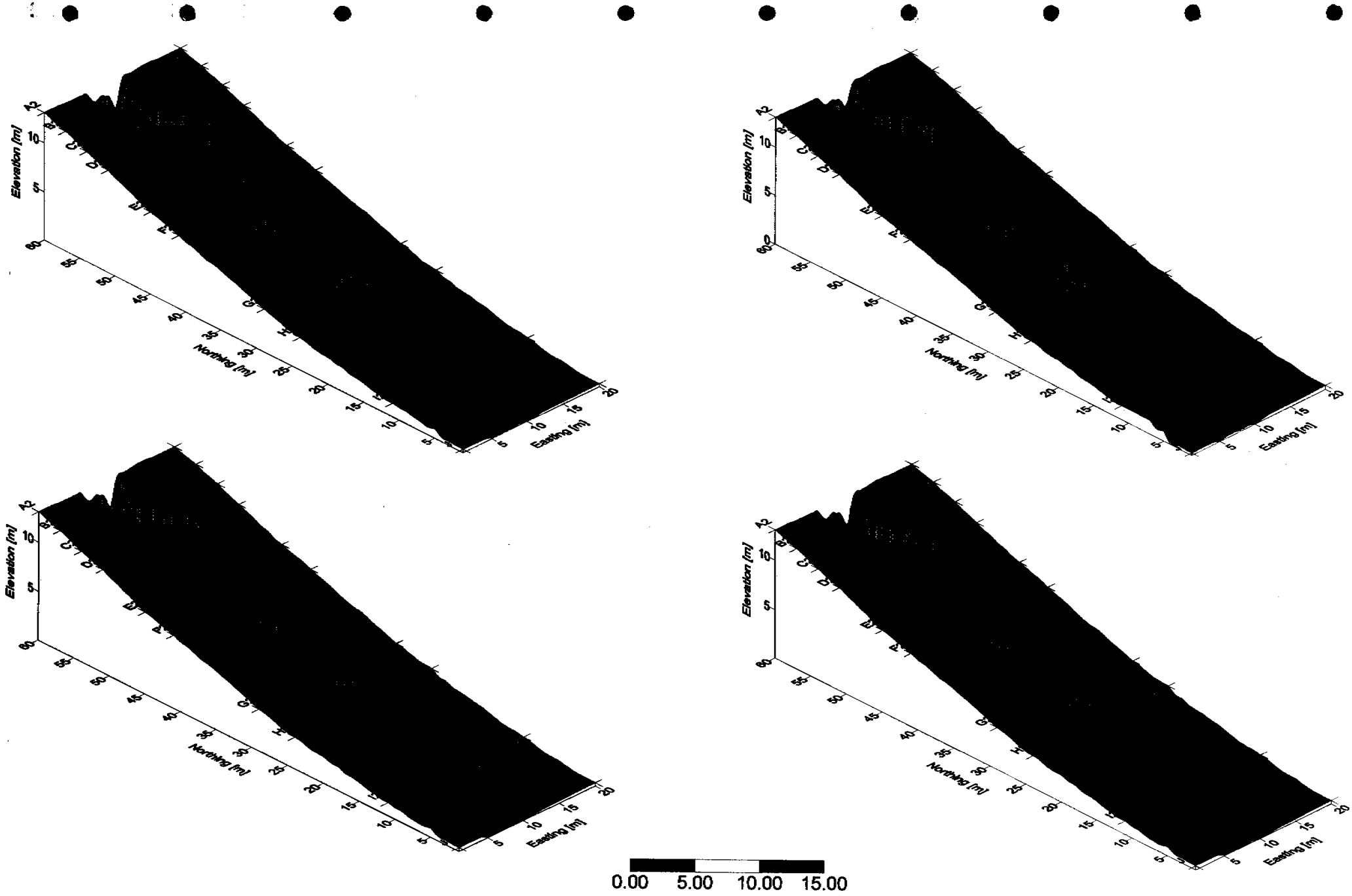


Figure 5.6.2: Simulations standard batter slope profile with differential erodibility with depth, and randomised erodibility function, together with wide inlet point and n_1 slope exponent at 0.69 instead of 2.1, at a)1.5 hours, b) 2 hours this represents the second storm event, and c) 2.5 hours and d) 3 hours representing the final storm event.

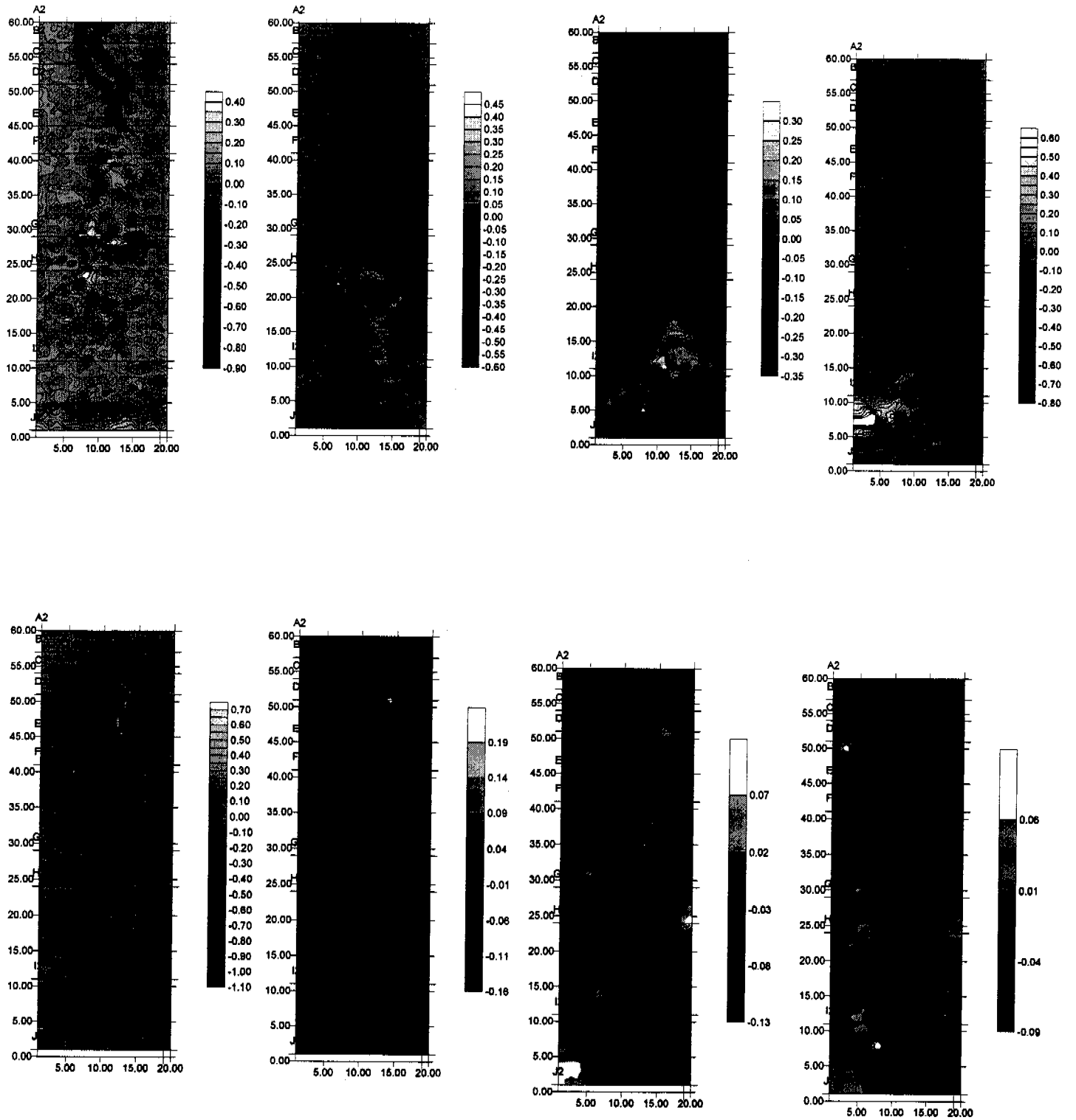


Figure 5.6.3: The morphology contour plots a) initial profile and 10 minutes, b) 10 minutes and 20 minutes, c) 20 minutes and 30 minutes, d) 30 minutes and 1 hour. The difference in elevations are also calculated from the remainder of the simulations with e) difference between 1 hours and 1.5 hours, f) 1.5 and 2 hours, g) 2 and 2.5 hours, and h) 2.5 and 3hours.

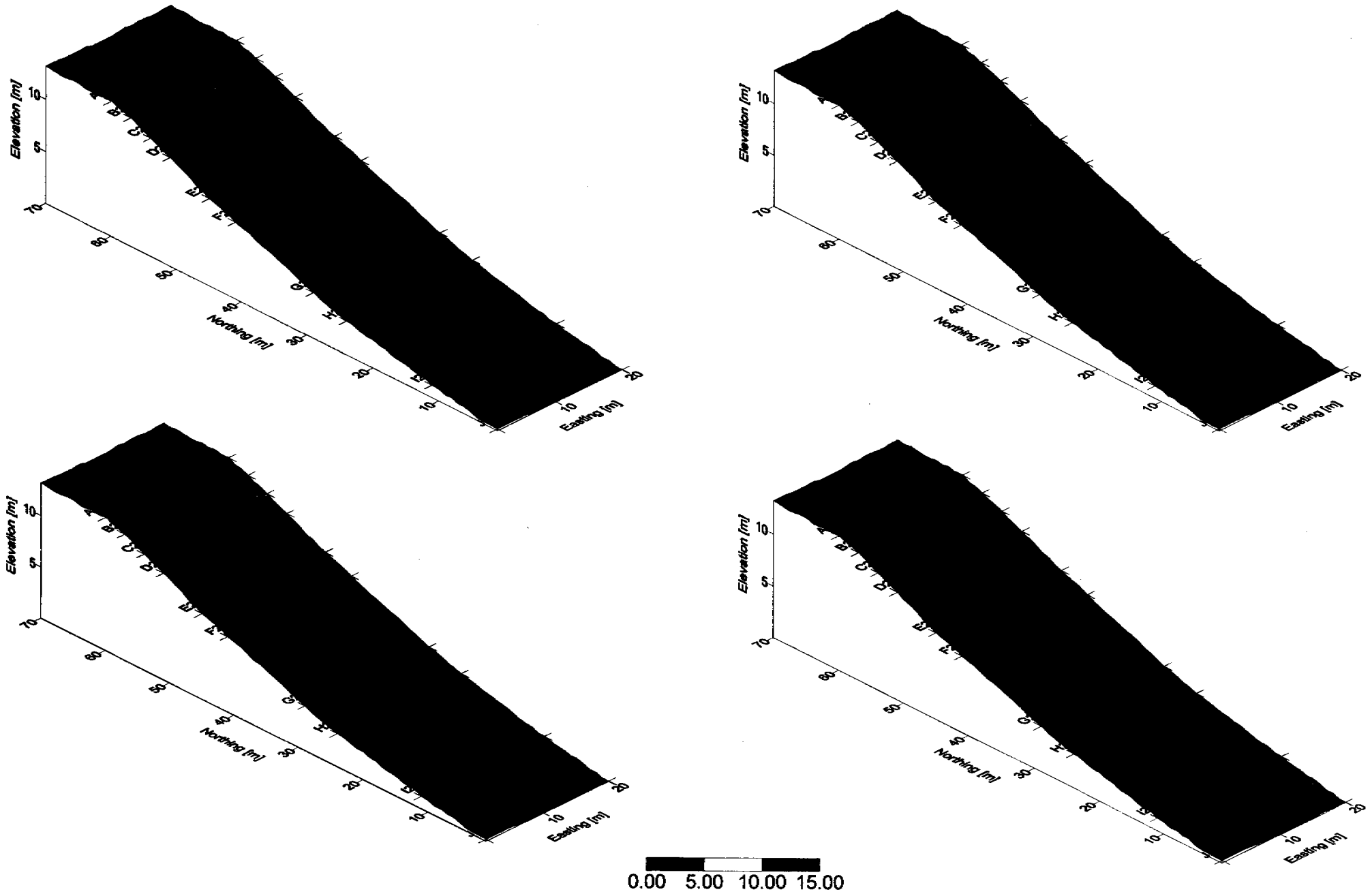


Figure 5.6.4: Simulations for extended batter slope profile with differential erodibility with depth, and randomised erodibility function, together with wide inlet point and n_1 slope exponent at 0.69 instead of 2.1, at a)10 minutes, b) 20 minutes, c) 30 minutes, and d) 1 hour.

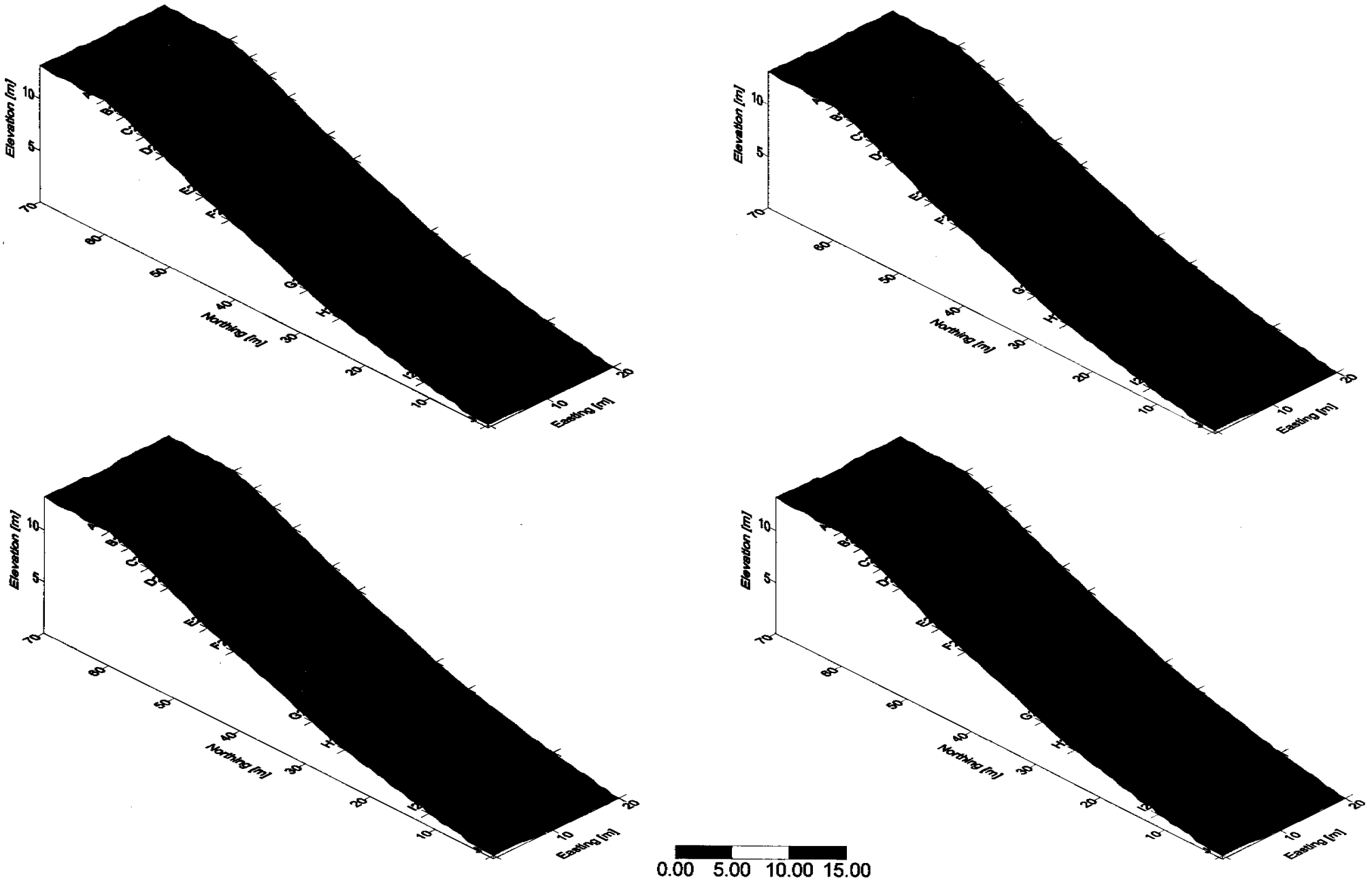


Figure 5.6.5: Simulations extended batter slope profile with differential erodibility with depth, and randomised erodibility function, together with wide inlet point and n_1 slope exponent at 0.69 instead of 2.1, at a)1.5 hours, b) 2 hours this represents the second storm event, and c) 2.5 hours and d) 3 hours representing the final storm event.

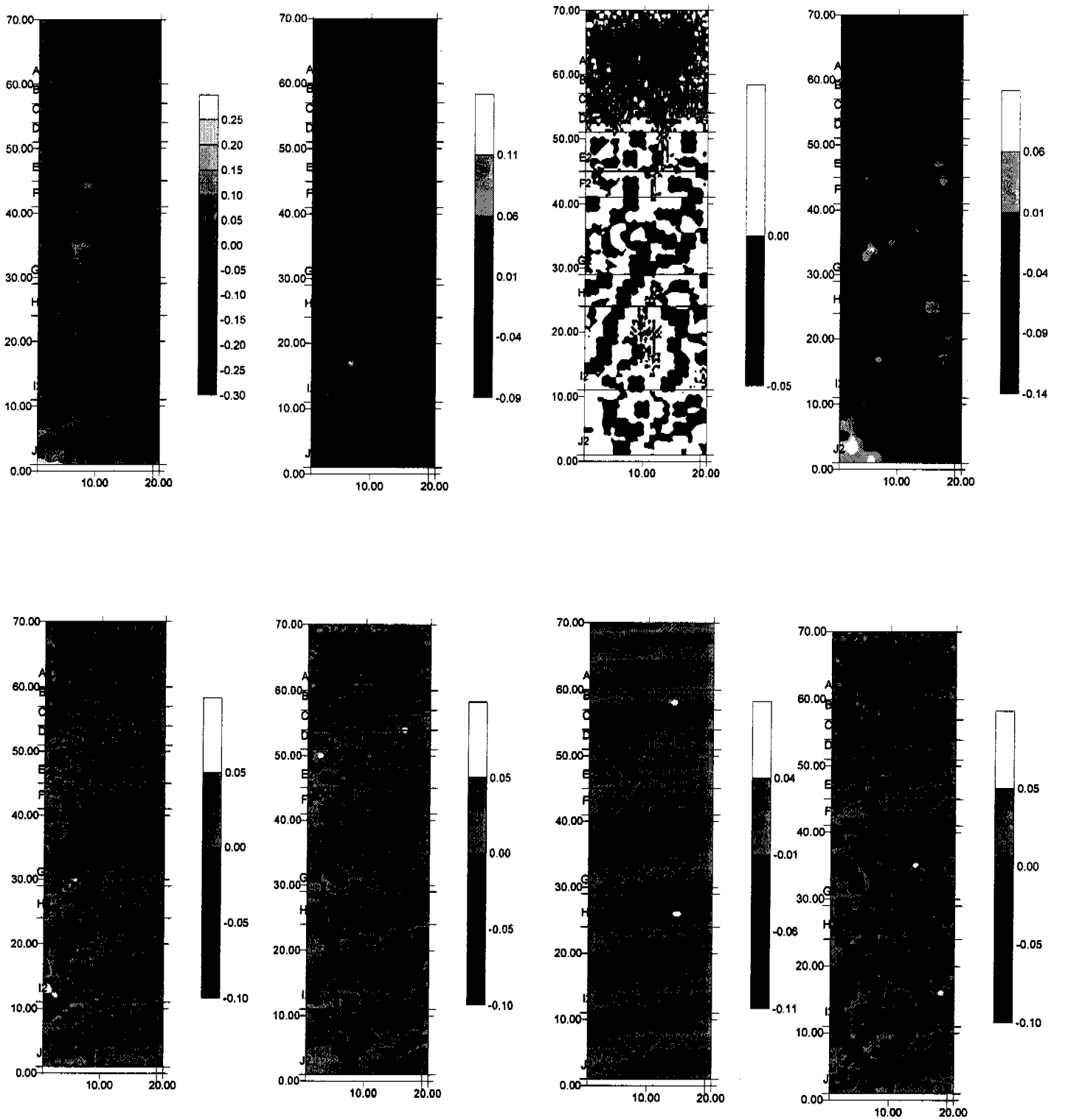


Figure 5.6.6: The morphology contour plots a) initial profile and 10 minutes, b) 10 minutes and 20 minutes, c) 20 minutes and 30 minutes, d) 30 minutes and 1 hour. The difference in elevations are also calculated from the remainder of the simulations with e) difference between 1 hours and 1.5 hours, f) 1.5 and 2 hours, g) 2 and 2.5 hours, and h) 2.5 and 3hours.

6.0 Discussion

The simulations have indicated regions likely to suffer significant erosion, and these have compared favourably with observations of actual gully formation. The development of a gully has been characterised by significant movement of material onto the lower sections whilst maximum depths range between 1.0m and 1.8m for upper sections.

The location of the gully in model simulations is dependent on the development process dictated by which erosion modules were implemented. Gully formation typically reaches between Row H and Row I in almost all approximations.

The depth of erosion is typically 40 to 70cm, ranging along the observed active sections of Row E through to Row G, whereas the depth of gully in upper section Row A to Row D ranges between 1 to 2m. These details are best described schematically, such as in Figure 6.1, Figure 6.2, and Figure 6.3, and Figure 6.4, with erosion depths with differences between simulations on an event by event basis.

Although the model simulations will over-predict the maximum depth of erosion at the top of the batter slope, the upper section activity seems reasonably estimated with overall depth ranging between 50 to 70cm, in Figure 6.2. Incision at this transition point initially and consequent development down the hillslope and back into the catchment are comparable to standard profile observed in Figure 6.1, as expected. The difference in elevations devised between each storm event was estimated by subtracting the upper surface from the newly eroded surface and the volume approximated.

Table 6.1: Volumetric approximation of overall elevation change between consequent storm events. These estimates were conducted for both final simulation scenarios used in Section 5.5, and Section 5.6. Erosion is represented by negative values, whilst deposition is represented by positive values. These calculations appear in Appendix C.

Surface Profile	Randomised, armouring, wide inlet point, with $n_1 = 2.1$.			Randomised erodibility, armouring, and wide inlet point with $n_1 = 0.69$.		
	261296	010197	230197	261296	010197	230197
batter slope	-6.04 m^3	-5.17 m^3	-9.42 m^3	+25.73 m^3	+2.93 m^3	-1.59 m^3
extended profile	+0.58 m^3	-1.04 m^3	-9.04 m^3	-1.11 m^3	-1.28 m^3	-5.07 m^3
experimental	-46.74 m^3	+1.68 m^3	+5.51 m^3			

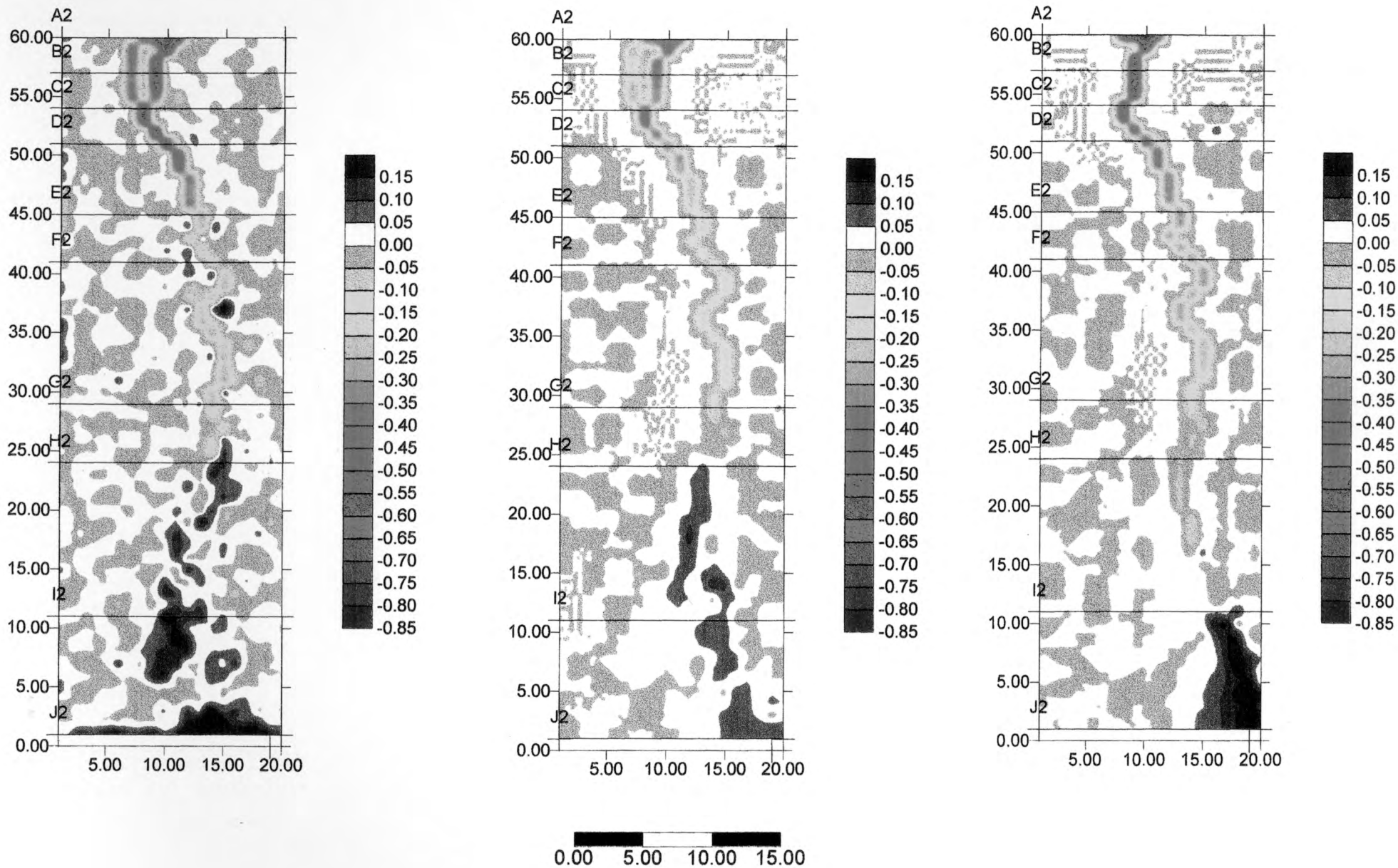


Figure 6.1: The change in elevation from the initial surface is represented by erosion negative, and deposition positive. These simulations are evaluated on a per storm event basis, and include all of the erosion modules as discussed in Section 5.5.

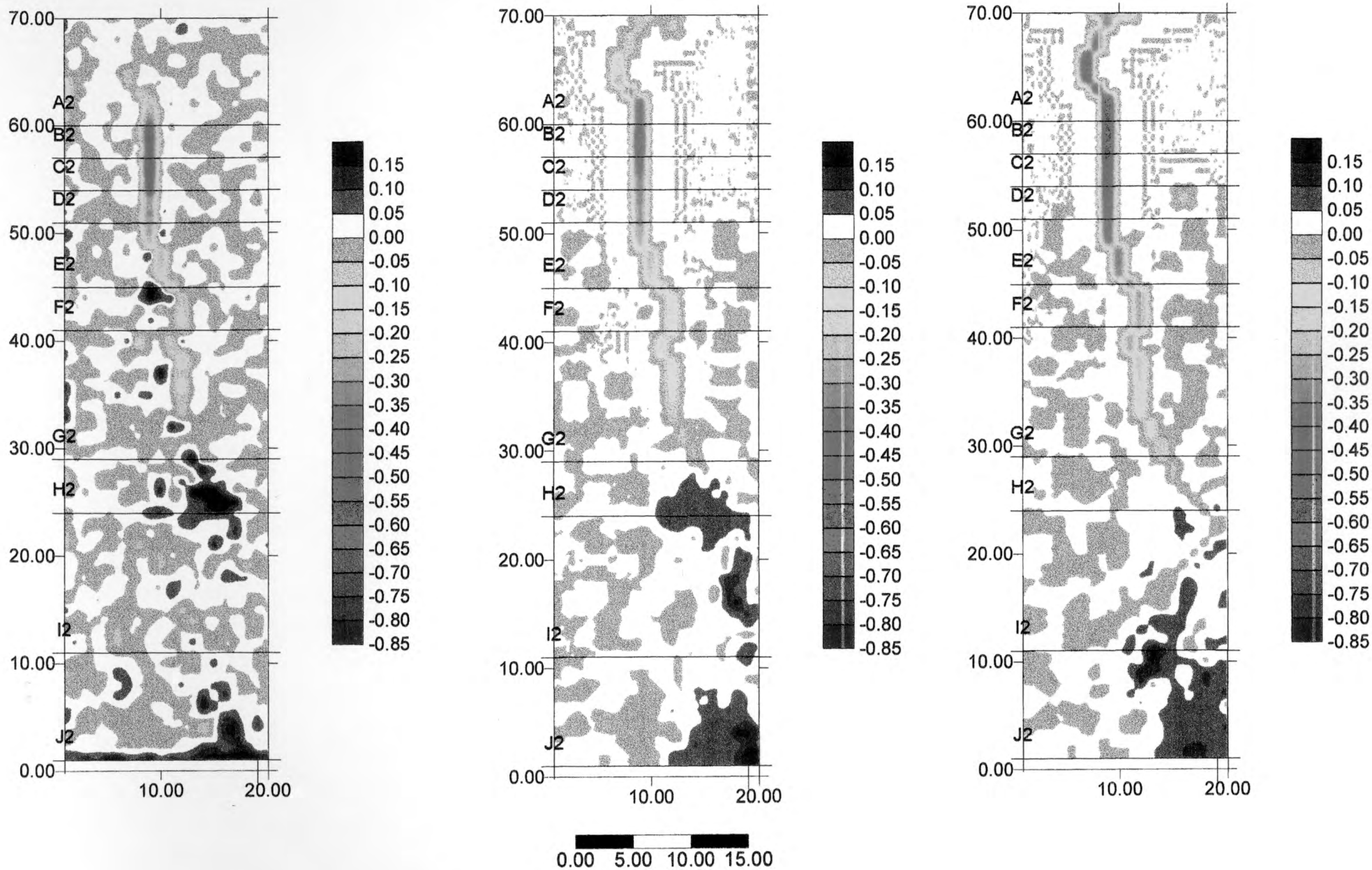


Figure 6.2: The change in elevation between each consequent storm event, is highlighted in this figure, with simulations devised using the erosion modules outlined in Section 5.5. This scenario represents the extended batter slope profile.

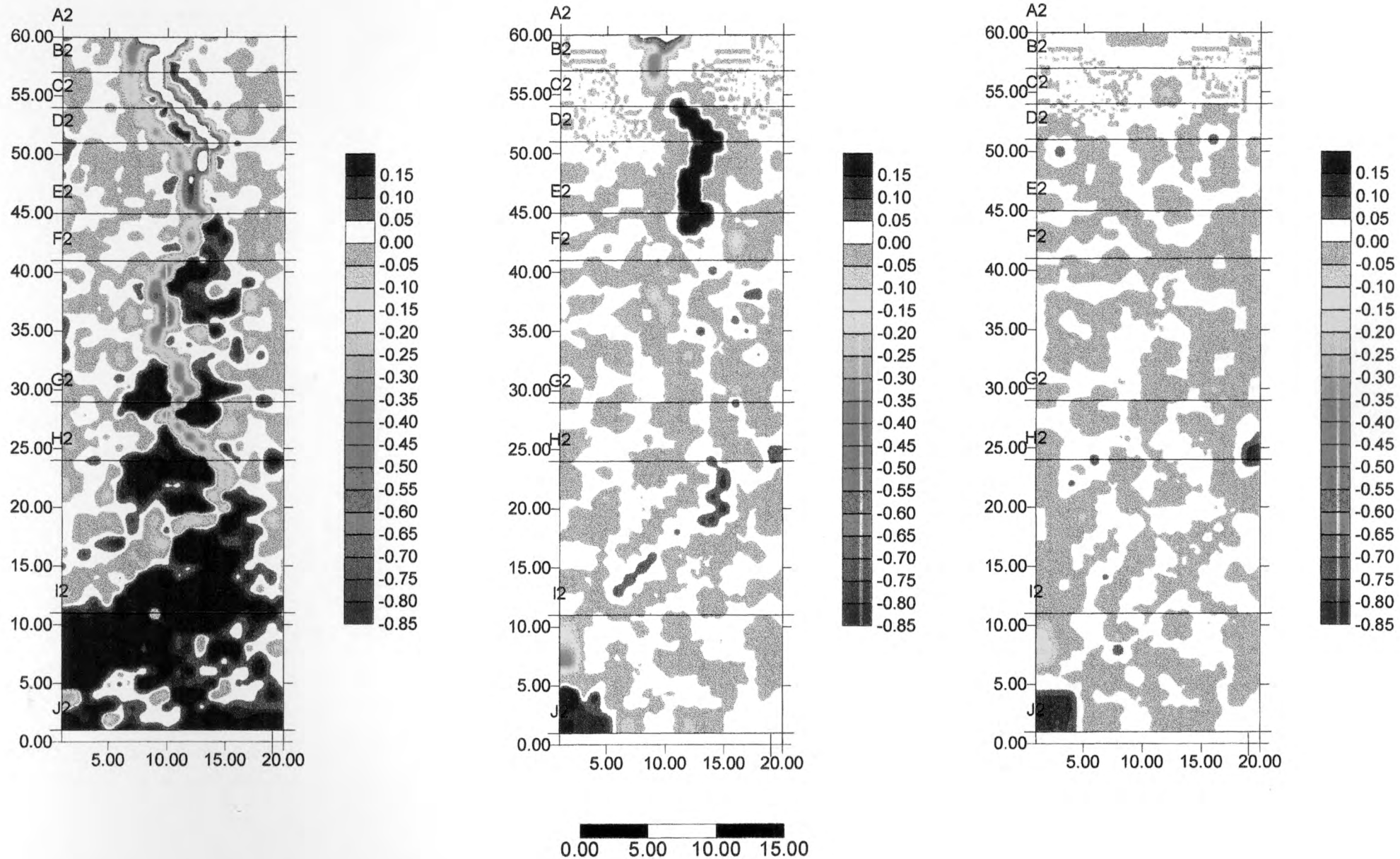


Figure 6.3: The change in elevation between consequent storm events, was evaluated using the simulations from Section 5.6, where this slope is representative of standard batter slope profile.

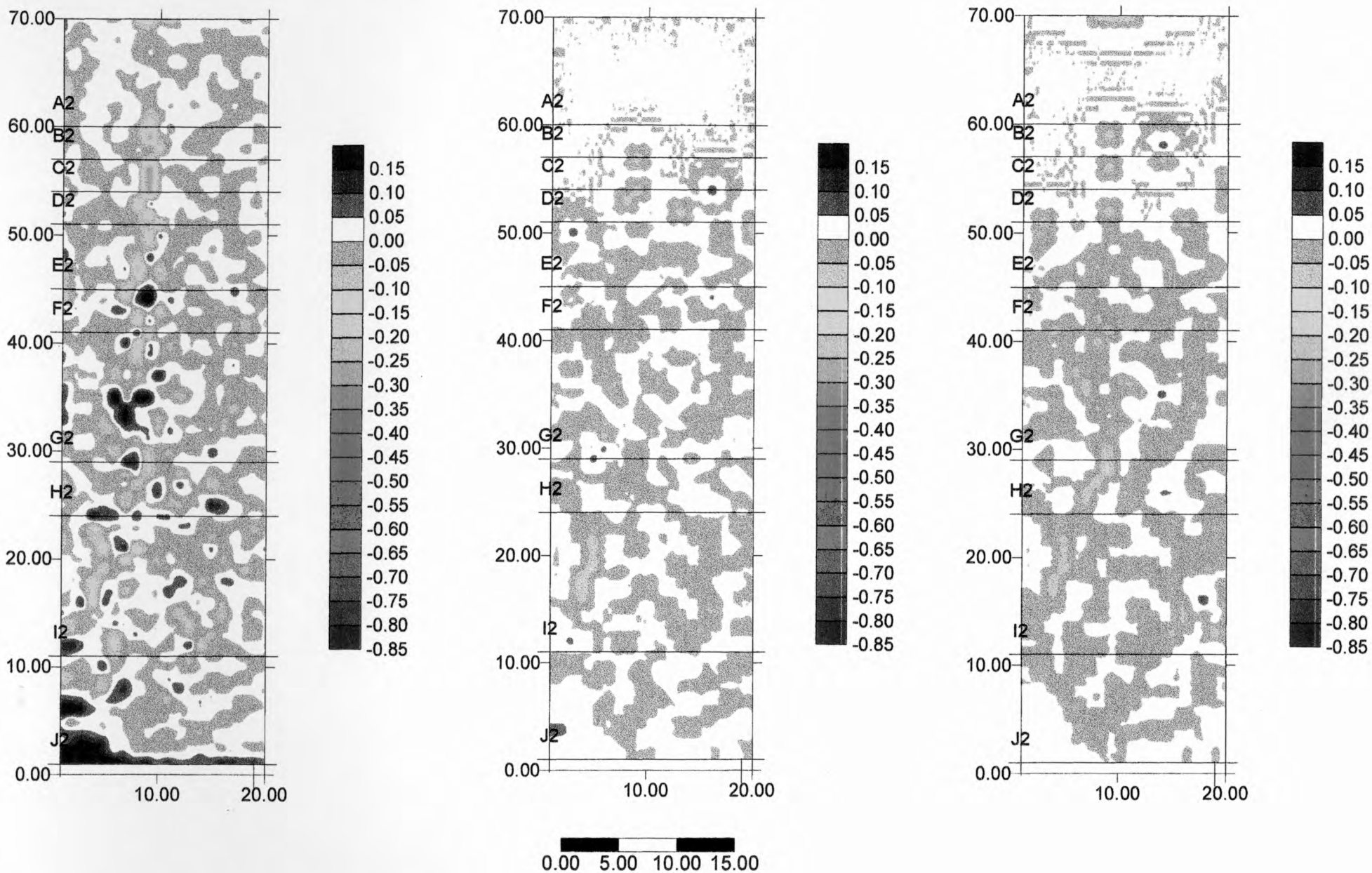


Figure 6.4: The change in elevations between each of the three storm events, are simulated using results from Section 5.6, where the exponent on the slope term in the sediment transport equation is reset to fitted value of 0.69 instead of 2.1.

The comparison of erosional values between experimental results from field trial and model simulations from the two final model scenarios indicate a similar overall result, although development of the gully is considerably different. Given the inherent variability in the surface material and the large scale of the field site, a reasonable comparison between these figures was expected., although the development process in the model simulations was more sequential.

Willgoose and Loch, 1996 notes that the behaviour of the incising erosion model can be quantified by the parameter, α.

$$\alpha = \frac{m_1 m_3 - 1}{n_1} \qquad (6.0.1)$$

where

m_1, m_3 = physical parameter exponents in the sediment transport model.

For the erosion studies previous conducted parameter values obtained of m_1, n_1 and m_3 of 1.68, 0.69 and 0.9 equated to an α of 0.65. These adapted results were used in this study with m_3 taken to be 1, and m_1 = 1.68, whilst the slope parameter n_1 was examined using two cases n_1 = 0.69, and n_1 = 2.1, with model simulations in Section 5.5 having equivalent value of alpha at 0.32 (n_1 = 2.1).

The rate of incision is highly dependent on the armouring of the WRD site, with large boulders exposed in the upper sections of the gully were of significant size, with other considerations such as the with of the formation dependent on the nature of the inlet point.

The sensitivity of the model to parameter choice for $n_1$seems critical, although once the fully developed armouring module is enabled the surface in erosion depths observed in Section 5.6, will be abated, leading to a less incising model.

However detailed examination of particle size profile of the site was not conducted during this time, although this will not present insurmountable difficulties as estimates can be made from exposed side walls such as those appearing in Figure 3.2.19.

As discussed, the development of equilibrium profile of the slope was demonstrated by accumulation of fine material at the very top of the slope, resulting in only several centimetres of erosion before large fragments encountered. Also noted was the dynamic nature of waste rock with geochemical weathering observed during the dry season altering the gully formation significantly.

The dynamic equilibrium between and accumulation of material in the channel beds by weathering may establish a layer of material which is constantly changing, averting maximum erosion depths observed on-site, as well as in model simulations lasting for long periods.

Thus in summary, this investigation has demonstrated that gully development on the steep batter slopes can be feasibly represented by model simulations of SIBERIA without the addition of physically based processes to alter the homogenous initial surface, and allow for the armouring that does occur.

Results for non-armoured surface indicated that depths of the order of 4 to 5m at the top of the slope, although these predictions are highly dependent on slope exponent parameter selection with behaviour of gully development representative of that observed on site. Armouring reduces maximum depth of erosion to 1.8m.

The heterogenous, armoured, and increased width inlet scenario represents the optimal calibration of the model at this stage to the study site. Further investigation into the derivation of the value for the slope component n_1 is warranted, as demonstrated above. However all of the model simulations encapsulate the observed development mechanisms, with the development of a more realistic, less conservative estimate of depth-erodibility relationship, increased grid discretisation and further increasing the accuracy of model predictions.

The combination of aspects such as random erodibility, increased catchment outlet width, and rudimentary armouring module has improved estimate of total erosion depth whilst maintaining the dynamical behaviour observed.

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Acknowedgements

I wish to acknowledge the following persons who have been of invaluable assistance during this project:

Dr Garry Willgoose for his continuing assistance and grateful supervision,

Mr Dene Moliere, Mr Ken Evans, Mr Bryan Smith, and Mr Michael Saynor, as well as the rest of the team outside the Hydrology and Geomorphology Group at ***eriss.***

Mr Peter Woods (ERARM Head Environmental Scientist), Mr Garry Stuart (ERARM), Mr Bill Monaghan (ERARM), Mr Phil Savoury (ERARM), and Mr Jeff Cramb (ERARM - ***eriss*** liason, who made everything happen), for their collective assistance in construction of study site, and kind permission for time allowed on site.

Mr Lyndon Bell, reciprocating honours project conducted simultaneously.

Mr T House, and T Mount for computer equipment assistance whilst at ***eriss.***

Appendix A

During the 96-97 Wet Season numerous storm events were monitored.

Of these events three were considered of significant magnitude and intensity that calibration and prediction hydrographs for the gully catchment were made.

The non-linear regression package NLFIT was used to determine the parameters of the DISTFW model. These parameters were separated into kinematic routing parameters: Cr and e_m (flow geometry, and surface roughness), and infiltration parameters (sorptivity and long term infiltration).

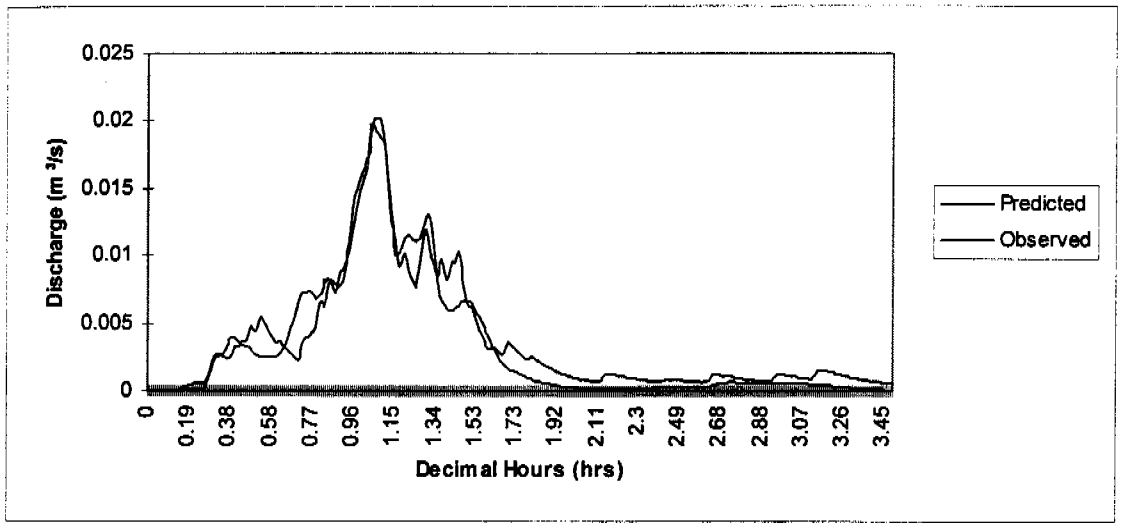
The model was used to fit parameters to each hydrograph from the cap site, and then scaled up from cap site to be representative of gully catchment by a factor of 12.204, as outlined in Section 2.2. The following tables summarise the input files required for operation of the NLFIT DISTFW model, with exact replication of results described in Section 3.0.

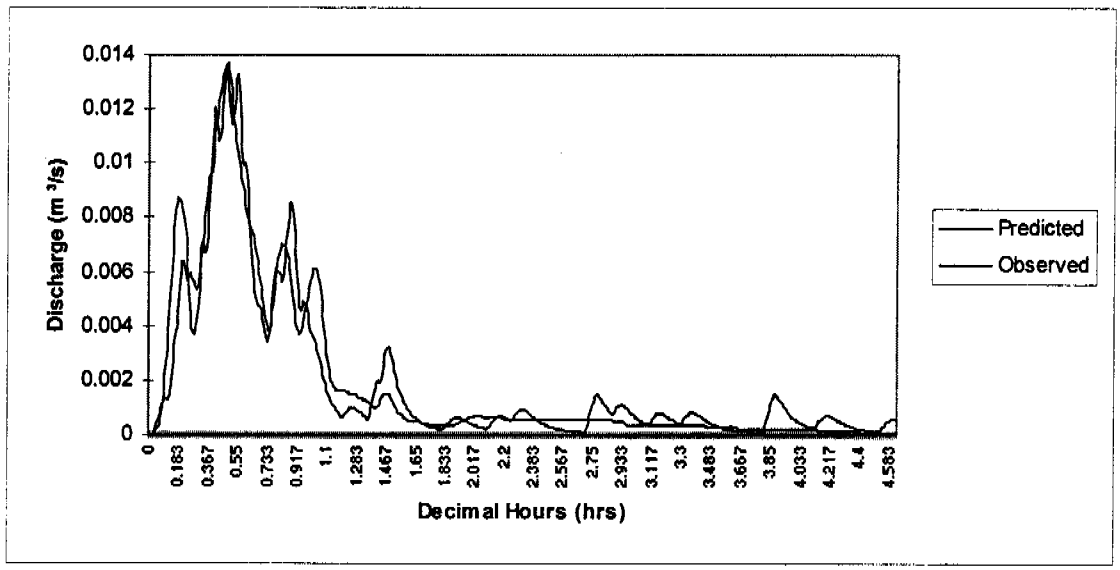
The following files are included:

*.fw the two site input data files. As outlined in Figure 2.3, and Figure 2.5, the discretisation of the catchment and cap site into subcatchments is necessary for input into hydrology model.

*.ro, *.rf runoff, and cumulative rainfall respectively for each of the 3 events.

The results of these 'fits' appear in Table A-1. The fitted hydrographs for individual storm events, and multiple fitting of all three events was conducted for both the cap and gully catchment sites.





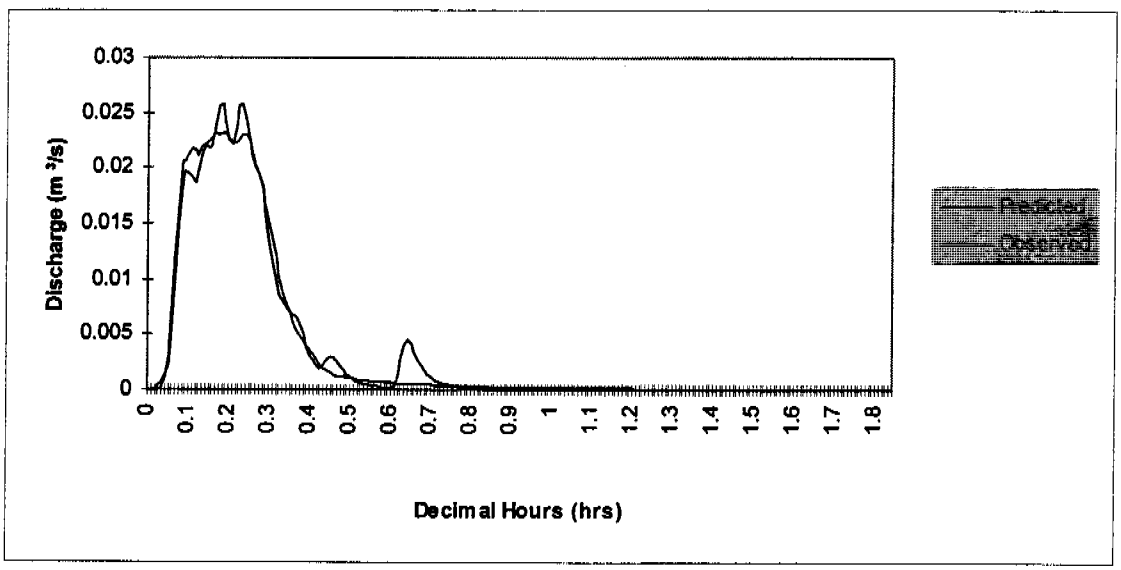
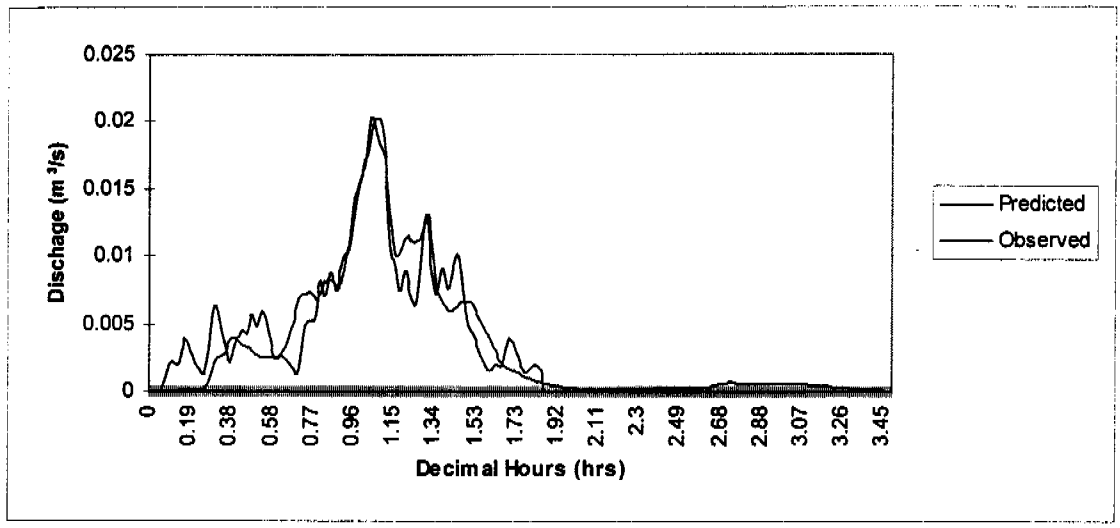
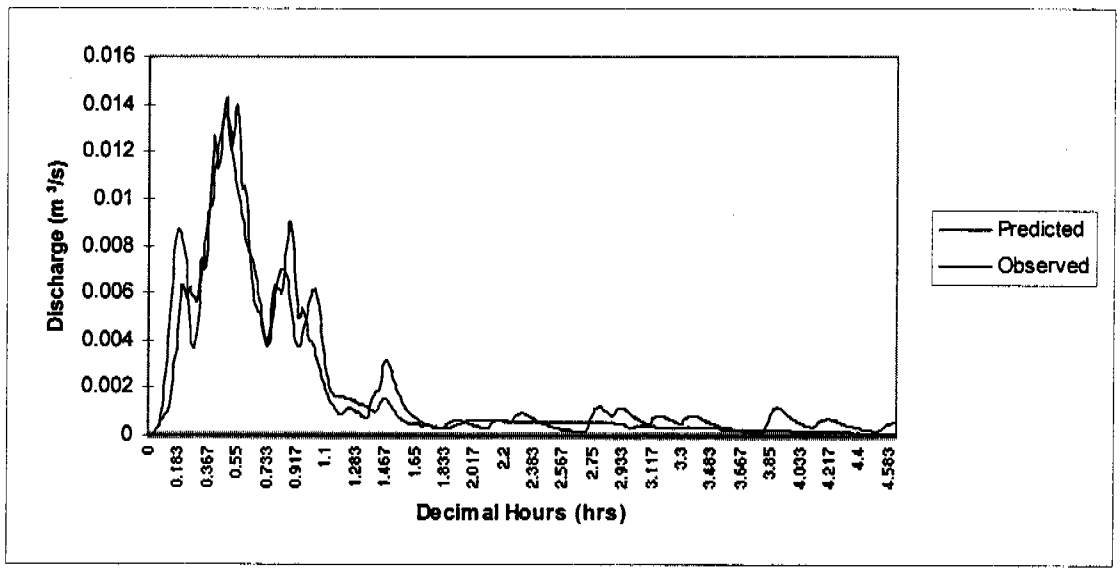


Figure A-1a, b, and c for individually fitted cap site storm events.





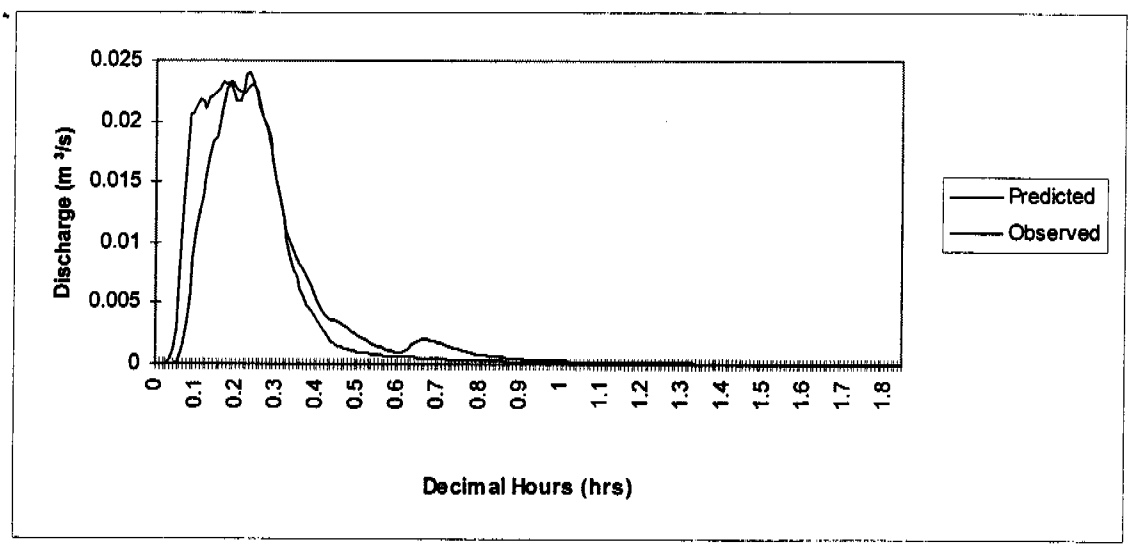
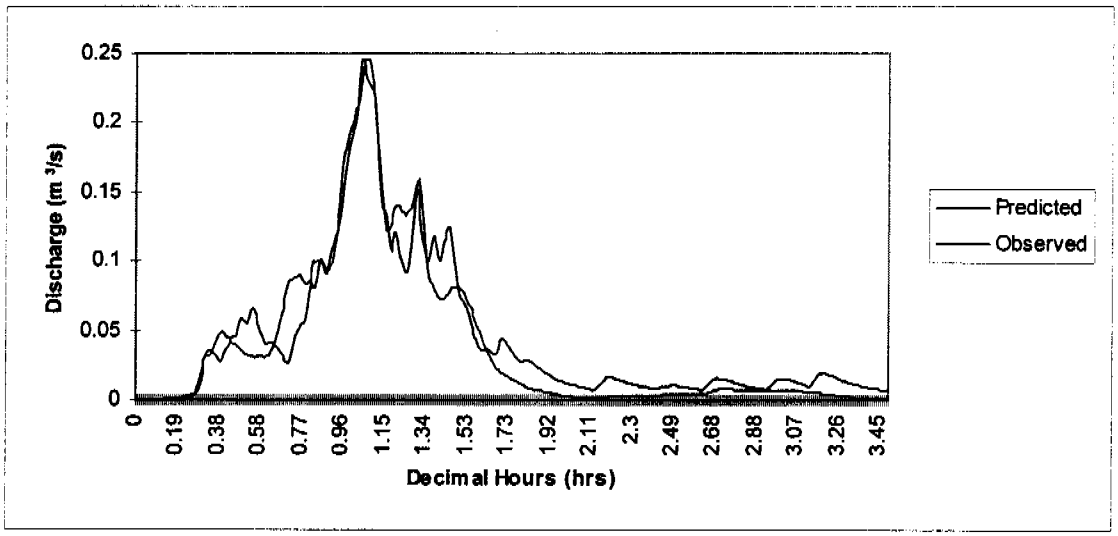
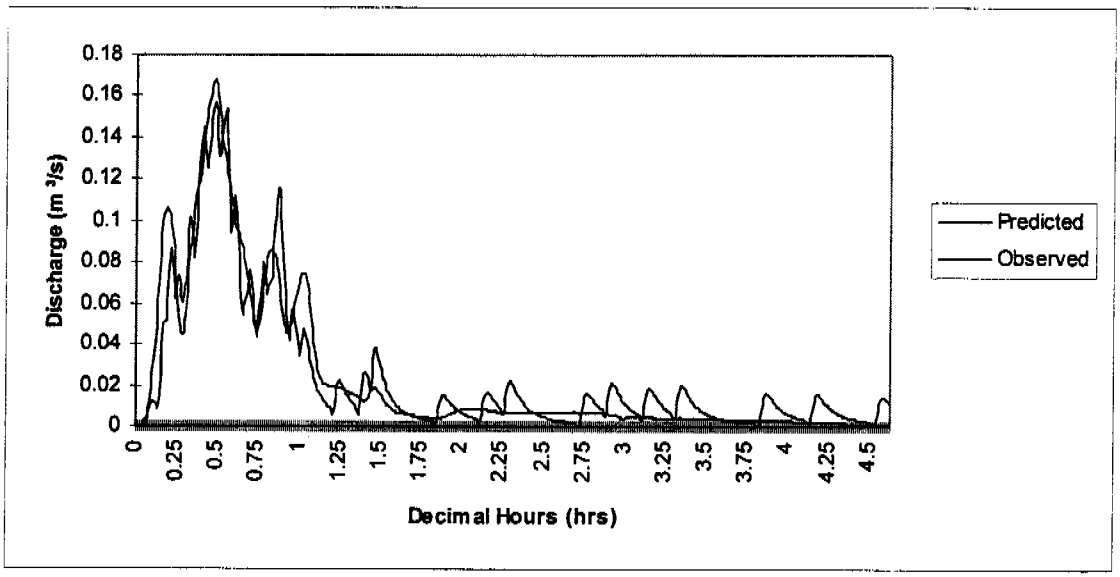


Figure A-2a, b, and c for multiple fitted cap site storm events.





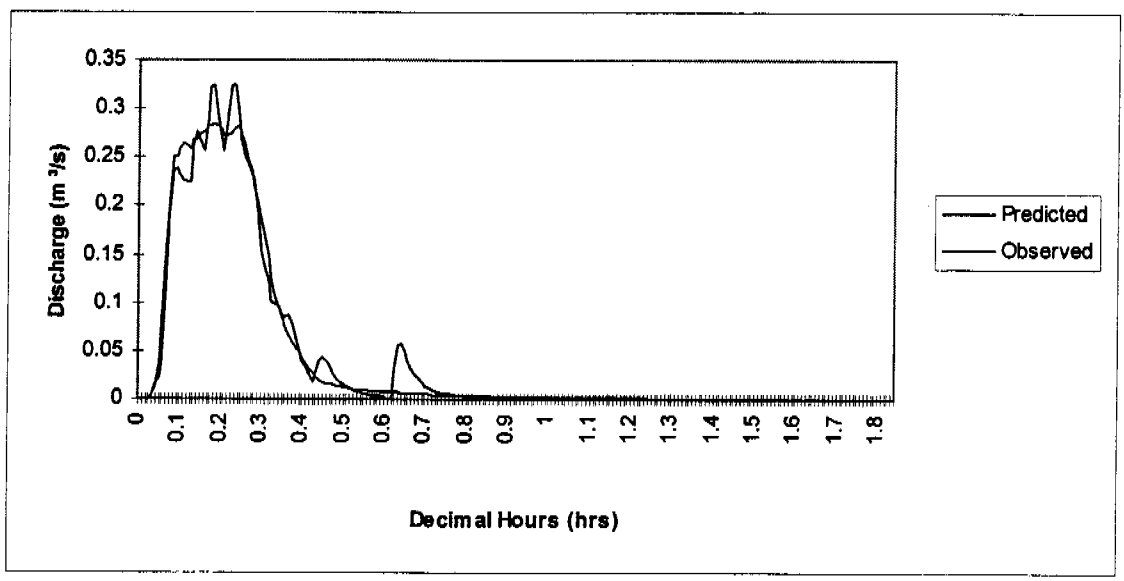
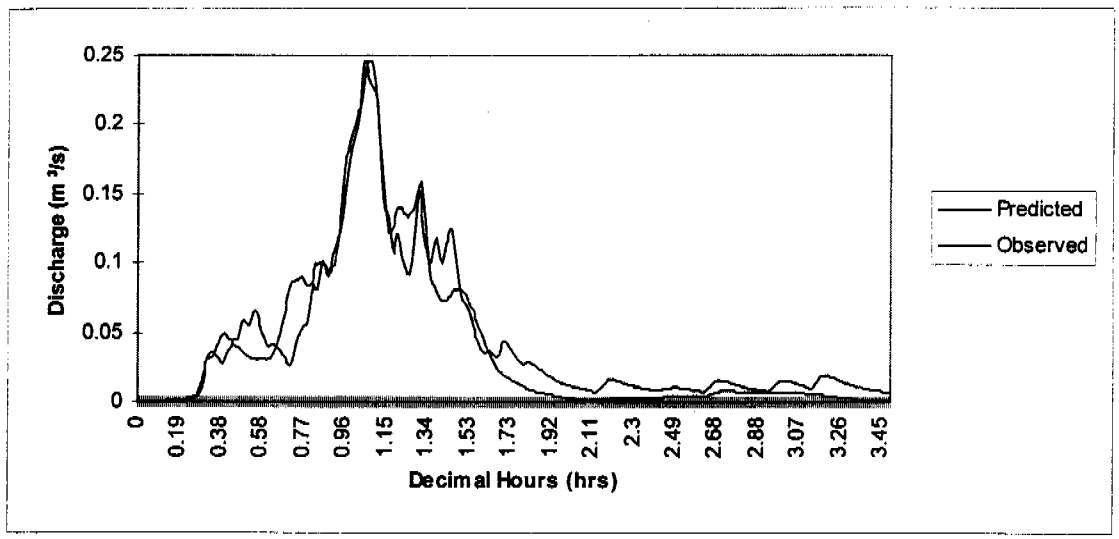
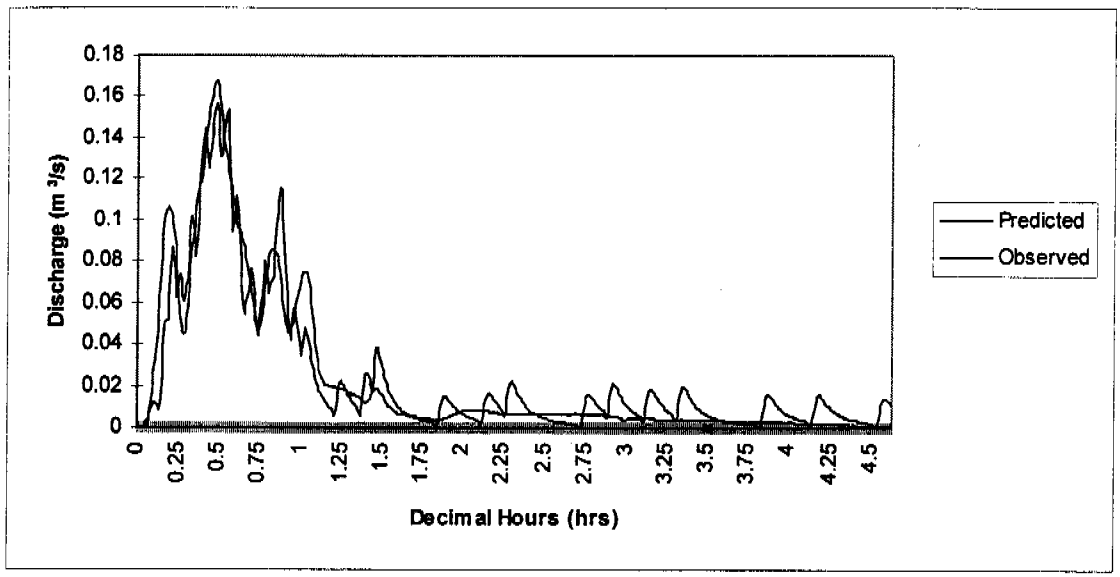


Figure A-3a, b, and c for individually fitted gully catchment events.





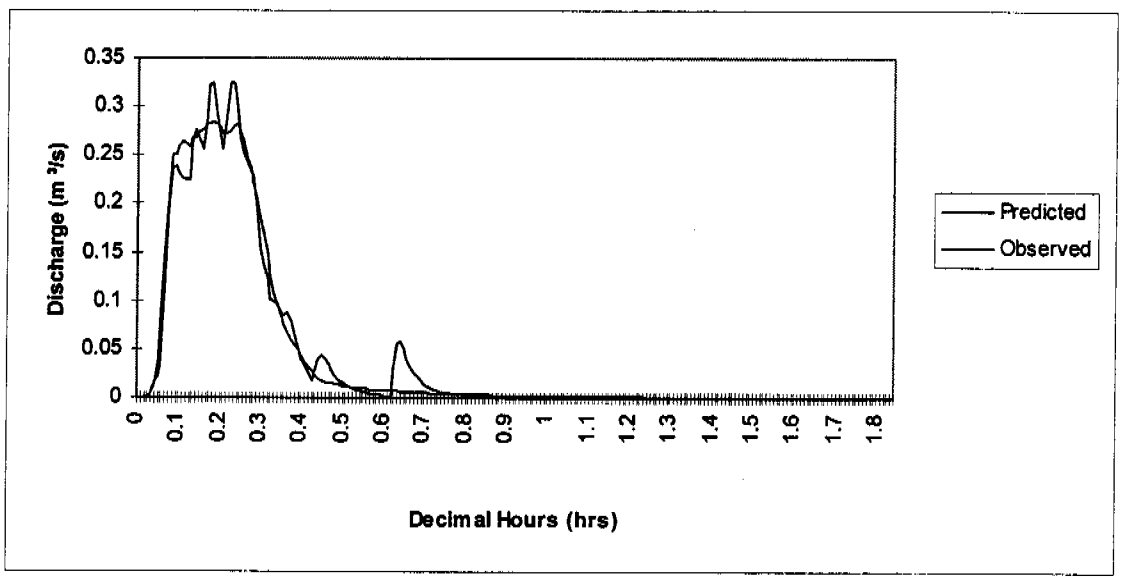


Figure A-4a, b, and c for collectively fitted gully catchment events.

```
Gully Catchment RUM 96-97 Wet Season
3 significant events: 26/12, 01/01, and 23/01.

CATCHMENT
# No of elements, No of reservoirs, no of u/S elements
    6                    0                   3
# No of U/S element draining into D/S elements
#
# zero time (hrs), timestep (minutes), time of duration of storm
(hrs)
#
0   0.5  4.633
# -------------------------------------
#  OUTPUT PARAMETERS
# -------------------------------------
# no of pts for output discharge,psteps
1 1
# subareas at which discharge requested
6
#  maximum discharge on output graph
0.002
#
INCIDENCES
  0    0    0    1    0    2
  0    0    0    3    0    4
  0    0    0    0    0    5
PARAMETERS
# Kind of element
   0
#  No Area Length   U/S       D/S     SWSupply Gamma Sorpt Phi
GWsupply
#                  Elevation Elevation
# ------------------------------------------------------------------------
   1 3091.8 112.10  51.36     50.16     1.0     1.0   1.0  1.0   1.0
   2 1626.0  78.40  51.36     49.88     1.0     1.0   1.0  1.0   1.0
   3  515.7  25.80  50.55     50.16     1.0     1.0   1.0  1.0   1.0
   4  299.4  12.10  50.16     50.00     1.0     1.0   1.0  1.0   1.0
   5 1163.8  46.80  50.72     49.88     1.0     1.0   1.0  1.0   1.0
   6  449.9  21.60  50.00     49.96     1.0     1.0   1.0  1.0   1.0
#  Hillslope and Channel conveyances
#  ------------------------------------
#     1st set are hillslope conveyances
#     2nd set are  channel  conveyances
#  ------------------------------------
#  Element No, No of conveyances
#  CR, EM, CONVEY
#
CONVEYANCES
1 2
0.092        1.        0.
0.092        1.        1000.
2 2
0.125        1.        0.
0.125        1.        1000.
3 2
0.138        1.        0.
0.138        1.        1000.
4 2
0.126        1.        0.
0.126        1.        1000.
5 2
0.086        1.        0.
0.086        1.        1000.
6 2
```

```
0.115          1.          0.
0.115          1.          1000.
#
#  Parameter Multpliers
#  Ch-CR  Ch-EM  SWSupply SWGamma Sorptivity   Phi  GWSupply
timing(sec)
MULTIPLIERS
   7.8    1.33    0.03      0.375  0.00001     6.5     1000.     0.0
1
0.0 0.0
# -------------
# No of pluvios
# -------------
RAINFALL #1
    1
CUMPLUVIO 2612cc.rf
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
RAINFALL #2
    1
CUMPLUVIO 0101ccc.rf
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
RAINFALL #3
    1
CUMPLUVIO 2301cca.rf
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
# --------------------------------
#  No of known initial flows at stations
# --------------------------------
INITIALQ
title line 1
title line 2
title line 3
    1
# stations at which flows known and initial flow (cumecs)
   6  0.0
#  No of stations with known inflows
INFLOWQ NONE
#  Hydrograph to calibrate with (no of values)
CALIB #1 gcat2612.ro
CALIB #2 gcat0101.ro
CALIB #3 gcat2301.ro
END
```

```
Gully Cap Site RUM 96-97 Wet Season
These are fw files on cap site itself using KE, fw as template.
01/01/97c 60mm, 38.53mm/hr, 3.49pm to 5.24pm.
CATCHMENT
# No of elements, No of reservoirs, no of u/S elements
    13                    0                    4
# No of U/S element draining into D/S elements
#
# zero time (hrs), timestep (minutes), time of duration of storm
(hrs)
#
0.0  0.5 4.633
# ------------------------------------
#  OUTPUT PARAMETERS
# ------------------------------------
# no of pts for output discharge,psteps
1 1
# subareas at which discharge requested
13
#  maximum discharge on output graph
0.002
#
INCIDENCES
  0    1    0    0    4    0    0    0    8    0   10    0   11
  0    0    0    0    3    0    0    0    7    0    9    0    2
  0    0    0    0    0    0    0    0    6    0    0    0   12
  0    0    0    0    0    0    0    0    5    0    0    0    0
PARAMETERS
# Kind of element
   0
#  No Area Length   U/S       D/S     SWSupply Gamma Sorpt Phi
GWsupply
#                  Elevation Elevation
# ------------------------------------------------------------------
   1   73.7  18.00   0.690     0.32     1.0     1.0   1.0  1.0   1.0
   2  105.1  17.10   0.320    -0.04     1.0     1.0   1.0  1.0   1.0
   3   31.6  12.45   0.700     0.28     1.0     1.0   1.0  1.0   1.0
   4   37.3  12.00   0.690     0.28     1.0     1.0   1.0  1.0   1.0
   5    5.2   5.25   0.280     0.15     1.0     1.0   1.0  1.0   1.0
   6   39.3  16.05   0.730     0.15     1.0     1.0   1.0  1.0   1.0
   7   62.4  17.40   0.730     0.15     1.0     1.0   1.0  1.0   1.0
   8   30.3   7.50   0.400     0.13     1.0     1.0   1.0  1.0   1.0
   9   55.8   3.75   0.150     0.115    1.0     1.0   1.0  1.0   1.0
  10   44.5  13.95   0.510     0.115    1.0     1.0   1.0  1.0   1.0
  11   61.3   9.75   0.115    -0.08     1.0     1.0   1.0  1.0   1.0
  12   42.6  10.05   0.340    -0.12     1.0     1.0   1.0  1.0   1.0
  13    2.5   1.50  -0.040    -0.11     1.0     1.0   1.0  1.0   1.0
#  Hillslope and Channel conveyances
#  ---------------------------------
#     1st set are hillslope conveyances
#     2nd set are  channel  conveyances
#  ---------------------------------
#  Element No, No of conveyances
#  CR, EM, CONVEY
#
CONVEYANCES
1 2
0.341        1.        0.
0.341        1.        1000.
2 2
0.268        1.        0.
0.268        1.        1000.
3 2
0.484        1.        0.
0.484        1.        1000.
4 2
```

```
0.412          1.          0.
0.412          1.          1000.
5 2
1.587          1.          0.
1.587          1.          1000.
6 2
0.513          1.          0.
0.513          1.          1000.
7 2
0.388          1.          0.
0.388          1.          1000.
8 2
0.386          1.          0.
0.386          1.          1000.
9 2
0.716          1.          0.
0.716          1.          1000.
10 2
0.428          1.          0.
0.428          1.          1000.
11 2
0.276          1.          0.
0.276          1.          1000.
12 2
0.357          1.          0.
0.357          1.          1000.
13 2
0.481          1.          0.
0.481          1.            1000.
#
#  Parameter Multpliers
#  Ch-CR  Ch-EM  SWSupply SWGamma Sorptivity   Phi  GWSupply
timing(sec)
MULTIPLIERS
   7.8    1.33    0.03      0.375  0.00001     6.5     1000.    0.0
1
0.0 0.0
# -------------
# No of pluvios
# -------------
RAINFALL #1
    1
CUMPLUVIO 0101ccc.rf
1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00
# --------------------------------
#  No of known initial flows at stations
# --------------------------------
INITIALQ
title line 1
title line 2
title line 3
    1
# stations at which flows known and initial flow (cumecs)
   13 0.0
#  No of stations with known inflows
INFLOWQ NONE
#  Hydrograph to calibrate with (no of values)
CALIB #1 010197c.ro
END
```

Appendix B

Date 240197.
This is transect information for gully plot.
Graphs drawn in GRAPHER, widths also collated here.

Row	Width m(left)	Width m(right)	Comments
R1-R2 (2.9m)			
1m	10.6	11.4	Width measurements from R1 at 1m and 2m.
	11.6	12.7	distance 2.9m apart.
	13.1	14.6	
2m	10.6	12.8	
	13.3	14.9	
R2-R3 (3.4m)			
1m	11.6	13.4	Width at 1m and 2m.
	14.1	14.5	distance 3.4m apart.
	15.3	16.7	unchanged
2m	11.1	12.6	
	13	14.6	
	15.6	16.7	unchanged
R3-R4 (2.6m)			
1.5m	10.4	11.9	Width at 1.5m,
	12.6	13.7	
	14.1	15.4	
	16.7	18.3	unchanged
R4-EP1(3m) ???			
1.5m	10.5	11.8	Width at 1.5m.
	12.7	14	distance 3m ???
	15.8	16.8	
	17.2	19.6	
EP1-R5 (3.6m).			
2m	6.6	10.5	Assume 2m from EPI, measure from R5.
	11	12.9	Distance 3.6m.
	14.2	17.9	
R5-R6 (3.6m)			
2m	7.9	9.5	At 2m from R5, measure from R5.
	10.8	17.6	Distance 3.6m.
R6-EP2 (7.9m).			
3m	6	7.5	At 3m width measurments from R6.
	7.9	9.9	Distance 7.9m
	11.3	12.2	
	14.3	16.8	
EP2-R7 (3.8m)			
2m	4.8	6.1	Measurent taken from R7, at 2m.
	7.3	9.5	
	9.9	11.7	
	13.9	15.7	
R7-R8 (5.7m)			
2m	5.9	6.7	Measured from R7 at 2m. This interval has changed.
	7.4	8.5	unchanged
	9.5	11.1	
	11.8	13.3	
	13.9	16.2	
R8-EP3 (5.2m)			
2m.	7.6	8.3	Measured from R8 at 2.0 m
	9	9.7	
	10.3	12.1	
	12.7	14.7	
EP3-R9 (7.8m)			
2m	8.7	10.9	Measurements from R9 at 2m. I.e. back up the slope.
	11.4	13.7	both changed, Rest deposited but no gully.
R9-EP4 (6.9m)			
3m	7.6	8.5	Width 3m, Measurements taken from R9. Both of these changed.
	11.2	16	changed
	16.7	17.4	unchanged
EP4-R10(5.7m).			
3m.	7.4	9.2	Measurements taken from R10, at 3m from EP4. Also changed.
	10.4	12.8	changed
	15.95	17.1	changed

2:10:77.

Row 1 — small change

Horizontal Height (m)	small change
5	196 G1-1
6	197 10.70m to 12.70m
7	143
8	147 G1-2
9	117 13.00 to 14.30m
10	144
10.1	168
10.2	193
10.3	158
10.4	169
10.5	190
10.6	192
10.7	176
10.8	175 changed
10.9	182 changed
11	247 changed
11.1	246 changed
11.2	247 changed
11.3	240 changed
11.4	303 changed
11.5	169 changed
11.6	192 changed
11.7	268 changed
11.8	264 changed
11.9	262 changed
12	291 changed
12.1	273 changed
12.2	293 changed
12.3	292 changed
12.4	257 changed
12.5	199 changed
12.6	126 changed
12.7	121 changed
12.8	122 changed
12.9	150 changed
13	212
13.1	237
13.2	226 changed
13.3	231 changed
13.4	242 changed
13.5	250 changed
13.6	250 changed
13.7	232 changed
13.8	278
13.9	269
14	292
14.1	265
14.2	224
14.3	223
14.4	210
14.5	199
14.6	200
14.7	195
14.8	203
14.9	221
15	224
16	280
17	239
18	232
19	246
20	278

Row 2 — slide change

Horizontal Height (m)	slide change
5	152 G2-1
6	95 9.75m to 10.30m
7	106
8	66 G2-2
9	61 10.50m to 12.70m
9.5	45 unchanged
9.6	92 G2-3
9.7	78 12.00 to 14.20m
9.8	49
9.9	124
10	134
10	160
10.1	131
10.2	131
10.3	142 changed
10.4	96 changed
10.5	41 changed
10.6	169 changed
10.7	232 changed
10.8	305 changed
10.9	307 changed
11	346 changed
11.1	376 changed
11.2	353 changed
11.3	404 changed
11.4	371 changed
11.5	357 changed
11.6	398 changed
11.7	372 changed
11.8	398 changed
11.9	432 changed
12	535
12.1	466
12.2	473
12.3	409
12.4	402
12.5	264
12.6	76
12.7	78
12.8	20 changed
12.9	86 changed
13	140 changed
13.1	206 changed
13.2	262 changed
13.3	222 changed
13.4	215 changed
13.5	273 changed
13.6	256 changed
13.7	296 changed
13.8	310 changed
13.9	196 changed
14	133 changed
14.1	114 changed
14.2	127 changed
14.3	172 changed
14.4	150 changed
14.5	164 changed
14.6	167 changed
14.7	237
14.8	256
14.8	293
15	300
15.1	396
15.2	392
15.3	323
15.4	291
15.5	403
15.6	397
15.7	461
15.8	435
15.9	447
16	388
16.1	718
16.2	337
16.3	335
16.4	330
16.5	331
16.6	330
16.7	291
17	295
18	278
19	237
20	229

Row 3 — small change

Horizontal Height (m)	small change
5	227 G3-1
6	214 10.20m to 15.10m
7	201 unchanged
8	197 G3-2
9	93 15.20m to 17.90m
10	56 no changed
10	69
10.1	49
10.2	187
10.3	214
10.4	267
10.5	291
10.6	290
10.7	283
10.8	301
10.9	335
11	341
11.1	347
11.2	327
11.3	323
11.4	345
11.5	319
11.6	189
11.7	251
11.8	237
11.9	240
12	239
12.1	128
12.2	129
12.3	96
12.4	133
12.5	245
12.6	323
12.7	426 changed
12.8	482 changed
12.9	496 changed
13	390 changed
13.1	453 changed
13.2	434 changed
13.3	496 changed
13.4	377 changed
13.5	371 changed
13.6	339 changed
13.7	333 changed
13.8	351 changed
13.9	364 changed
14	396 changed
14.1	402 changed
14.2	296 changed
14.3	305 changed
14.4	267 changed
14.5	179
14.6	189
14.7	127
14.8	86
14.9	109
15	201
15.1	272
15.2	237
15.3	249
15.4	262
15.5	321
15.6	333
15.7	346
15.8	400
15.9	371
16	368
16.1	367
16.2	362
16.3	382
16.4	434
16.5	391
16.6	397
16.7	402
16.8	369
16.9	374
17	356
17.1	281
17.2	332
17.3	312
17.4	348
17.5	316
17.6	352
17.7	347
17.8	340
17.9	369
18	374
18.1	356
18.2	281
18.3	332
18.4	312
18.5	348
18.6	316
18.7	352
18.8	347
18.9	340
19	369
19	374
20	356
21	281

Row 4 — change

Horizontal Height (m)	change
5	242 G4-1
6	196 10.70m to 15.40m.
7	118 unchanged
8	115 G4-2
9	152 16.95m to 19.05m.
10	232
10.1	119
10.2	115
10.3	88
10.4	94
10.5	132
10.6	147
10.7	194
10.8	126
10.9	400
11	435
11.1	263
11.2	343
11.3	339
11.4	208
11.5	178
11.6	198
11.7	209
11.8	227
11.9	214
12	354
12.1	408 changed
12.2	407 changed
12.3	379 changed
12.4	406 changed
12.5	456 changed
12.6	482 changed
12.7	452 changed
12.8	411 changed
12.9	404 changed
13	490 changed
13.1	431 changed
13.2	436 changed
13.3	353 changed
13.4	401 changed
13.5	386 changed
13.6	297 changed
13.7	373 changed
13.8	123 changed
13.9	112 changed
14	120 changed
14.1	96 changed
14.2	85 changed
14.3	92 changed
14.4	126 changed
14.5	158 changed
14.6	147 changed
14.7	151 changed
14.8	153 changed
14.9	249 changed
15	176 changed
15.1	282 changed
15.2	356 changed
15.3	342 changed
15.4	421 changed
15.5	426 changed
15.6	357 changed
15.7	317 changed
15.8	287 changed
15.9	282 changed
16	286 changed
16.1	275 changed
16.2	280 changed
16.3	206 changed
16.4	196 changed
16.5	221 changed
16.6	231 changed
16.7	253 changed
16.8	280 changed
16.9	281 changed
17	372 changed
17.1	305 changed
17.2	345 changed
17.3	423 changed
17.4	640 changed
17.5	732 changed
17.6	766 changed
17.7	661 changed
17.8	678 changed
17.9	662 changed
18	456 changed
18.1	436 changed
18.2	413 changed
18.3	423 changed
18.4	392 changed
18.5	406 changed
18.6	392 changed
18.7	377 changed
18.8	412 changed
18.9	392 changed
19	407 changed
19.1	502 changed
19.2	491 changed
19.3	486 changed
19.4	457 changed
19.5	442 changed
19.6	371 changed
19.7	321 changed
19.8	256 changed
19.9	232 changed
20	286 changed
21	402

Row 5 — changed

Horizontal Height (m)	changed
5	307 G5-A
6	250 6.30m to 7.50m
6.1	204 unchanged
6.2	217 G5-1
6.3	202 8.30m to 10.60m.
6.4	202 changed a bit
6.5	183 G5-2
6.6	227 11.20m to 18.80m
6.7	258 changed
6.8	198
6.9	212
7	179
7.1	153
7.2	126
7.3	135
7.4	142
7.5	163
7.6	178
7.7	196
7.8	232
7.9	176
8	150 changed
8.1	91 changed
8.2	29 changed
8.3	41 changed
8.4	362 changed
8.5	317 changed
8.6	365 changed
8.7	369 changed
8.8	387 changed
8.9	77777
9	342 changed
9.1	298 changed
9.2	217 changed
9.3	242 changed
9.4	215 changed
9.5	191 changed
9.6	95 changed
9.7	113 changed
9.8	151 changed
9.9	143 changed
10	209 changed
10.1	194 changed
10.2	163 changed
10.3	186 changed
10.4	43 changed
10.5	42 changed
10.6	54 changed
10.7	42 changed
10.8	17 changed
10.9	943
11	93 changed
11.1	123 changed
11.2	157 changed
11.3	253 changed
11.4	290 changed
11.5	341 changed
11.6	296 changed
11.7	353 changed
11.8	356 changed
11.9	317 changed
12	320 changed
12.1	196 changed
12.2	214 changed
12.3	148 changed
12.4	184 changed
12.5	197 changed
12.6	217 changed
12.7	214 changed
12.8	351 changed
12.9	341 changed
13	226 changed
13.1	217 changed
13.2	330 changed
13.3	263 changed
13.4	292 changed
13.5	300 changed
13.6	365 changed
13.7	426 changed
13.8	307 changed
13.9	345 changed
14	376 changed
14.1	256 changed
14.2	376 changed
14.3	411 changed
14.4	362 changed
14.5	336 changed
14.6	236 changed
14.7	185 changed
14.8	187 changed
14.9	177 changed
15	220 changed
15.1	252 changed
15.2	235 changed
15.3	225 changed
15.4	236 changed
15.5	426 changed
15.6	451 changed
15.7	493 changed
15.8	437 changed
15.9	401 changed
16	397 changed
16.1	407 changed
16.2	439 changed
16.3	391 changed
16.4	415 changed
16.5	437 changed
16.6	430 changed
16.7	456 changed
16.8	468 changed
16.9	432 changed
17	466 changed
17.1	462 changed
17.2	414 changed
17.3	447 changed
17.4	471 changed
17.5	407 changed
17.6	400 changed
17.7	193 changed
17.8	191 changed
17.9	186 changed
18	112 changed
18.1	146
19	158
20	294
21	273

Row 6 — change

Horizontal Height (m)	change
5	411 G6-1
6	351 6.35m to 9.50m.
6.1	304 unchanged
6.2	344 G6-2
6.3	383 10.35m to 13.50
6.4	376 unchanged
6.5	337 G6-3
6.6	407 14.30m to 17.90
6.7	416
6.8	466 changed continu
6.9	503 changed
7	505 changed
7.1	541 changed
7.2	534 changed
7.3	529 changed
7.4	427 changed
7.5	397 changed
7.6	371 changed
7.7	315 changed
7.8	366 changed
7.9	380 changed
8	378 changed
8.1	431 changed
8.2	521 changed
8.3	569 changed
8.4	553 changed
8.5	615 changed
8.6	585 changed
8.7	574 changed
8.8	617 changed
8.9	518 changed
9	570 changed
9.1	366 changed
9.2	360 changed
9.3	361 changed
9.4	331 changed
9.5	393 changed
9.6	413 changed
9.7	436 changed
9.8	424 changed
9.9	462 changed
10	442 changed
10.1	450 changed
10.2	476 changed
10.3	512 changed
10.4	611 changed
10.5	616 changed
10.6	632 changed
10.7	604 changed
10.8	548 changed
10.9	465 changed
11	436 changed
11.1	420 changed
11.2	478 changed
11.3	432 changed
11.4	507 changed
11.5	522 changed
11.6	557 changed
11.7	516 changed
11.8	499 changed
11.9	616 changed
12	593 changed
12.1	475 changed
12.2	437 changed
12.3	327 changed
12.4	195 changed
12.5	198 changed
12.6	196 changed
12.7	186 changed
12.8	221
12.9	296
13	206 changed
13.1	266 changed
13.2	417 changed
13.3	447 changed
13.4	490 changed
13.5	515 changed
13.6	445 changed
13.7	485 changed
13.8	497 changed
13.9	508 changed
14	509 changed
14.1	526 changed
14.2	386 changed
14.3	396 changed
14.4	417 changed
14.5	429 changed
14.6	474 changed
14.7	436 changed
14.8	444 changed
14.9	421 changed
15	422 changed
15.1	430 changed
15.2	506 changed
15.3	511 changed
15.4	492 changed
15.5	426 changed
15.6	432 changed
15.7	427 changed
15.8	450 changed
15.9	459 changed
16	462 changed
16.1	436 changed
16.2	354 changed
16.3	309 changed
16.4	219 changed
16.5	246 changed
16.6	251 changed
16.7	249 changed
16.8	226 changed
16.9	229 changed
17	210 changed
20	197 changed

Row 7 — change

Horizontal Height (m)	change
3	264 G7-1
4	241 4.95m to 8.10m
4.5	222 no change
4.6	164 G7-2
4.7	96 11.00m to 12.30m
4.8	106 change
4.9	109 G7-3
5	145 13.60m to 16.00m.
5.1	173 new gully Old G7-2
5.2	224
5.3	256 changed
5.4	218 changed
5.5	263 changed
5.6	180 changed
5.7	239 changed
5.8	242 changed
5.9	251 changed
6	161 changed
6.1	169 changed
6.2	182 changed
6.3	192 changed
6.4	195 changed
6.5	208 changed
6.6	203 changed
6.7	204 changed
6.8	229 changed
6.9	265 changed
7	254 changed
7.1	219 changed
7.2	260 changed
7.3	241 changed
7.4	231 changed
7.5	218 changed
7.6	168 changed
7.7	206 changed
7.8	222 changed
7.9	206 changed
8	95 changed
8.1	40 changed
8.2	54 changed
8.3	42 changed
8.4	42 changed
8.5	49 changed
8.6	4
8.7	178
8.8	185 changed
8.9	183 changed
9	256 changed
9.1	186
9.2	217
9.3	215 changed
9.4	206
9.5	237 changed
9.6	244 changed
9.7	220 changed
9.8	222 changed
9.9	251 changed
10	336 changed
10.1	367 changed
10.2	386 changed
10.3	397 changed
10.4	370 changed
10.5	348 changed
10.6	350 changed
10.7	411 changed
10.8	316 changed
10.9	286 changed
11	254 changed
11.1	257 changed
11.2	219 changed
11.3	267 changed
11.4	317
11.5	312
11.6	219
11.7	296
11.8	266
11.9	273
12	267 changed
12.1	303 changed
12.2	200 changed
12.3	272 changed
12.4	362 changed
12.5	427 changed
12.6	392 changed
12.7	491 changed
12.8	497 changed
12.9	414 changed
13	471 changed
13.1	468 changed
13.2	427 changed
13.3	442 changed
13.4	425 changed
13.5	513 changed
13.6	593 changed
13.7	533 changed
13.8	579 changed
13.9	471 changed
14	365 changed
14.1	512 changed
14.2	501 changed
14.3	290 changed
14.4	216 changed
14.5	143 changed
14.6	142 changed
14.7	132 changed
14.8	139 changed
14.9	140
15	337 changed
15.1	289
15.2	297 changed
15.3	286
15.4	243 changed
15.5	227
15.6	230

Row 8 — changed

Horizontal Height (m)	changed
2	202 G8-A
2.5	252 3.65m to 4.30m
3	202 new gully
3.5	163 G8-1
3.6	159 7.00m to 9.30m. 9
3.7	148
3.8	166 G8-2
3.9	189 11.40m to 16.20m
4	204 changed
4.1	228 changed and upw
4.2	230 changed
4.3	180 changed
4.4	174 changed
4.5	137 changed
4.6	132 changed
5	117
5.5	123
6.5	116
6.6	10
6.7	112
6.8	145
6.9	137
7	171 changed
7.1	159 changed
7.2	206 changed
7.3	233 changed
7.4	247 changed
7.5	223 changed
7.6	191 changed
7.7	204 changed
7.8	149 changed
7.9	177 changed
8	234 changed
8.1	202 changed
8.2	189 changed
8.3	195 changed
8.4	187 changed
8.5	227 changed
8.6	251 changed
8.7	252 changed
8.8	263 changed
8.9	224 changed
9	218 changed
9.1	192 changed
9.2	153 changed
9.3	157 changed
9.4	138 changed
9.5	157 changed
9.6	174 changed
9.7	329 changed
9.8	364 changed
9.9	328 changed
10	371
10.1	326
10.2	296 changed
10.3	332
10.4	395
10.5	169
10.6	361
10.7	311
10.8	342 changed
10.9	317
11	186
11.1	191
11.2	200
11.3	239 changed
11.4	263 changed
11.5	296 changed
11.6	361 changed
11.7	342 changed
11.8	284 changed
11.9	310 changed
12	304 changed
12.1	316 changed
12.2	287 changed
12.3	315 changed
12.4	287 changed
12.5	304 changed
12.6	266 changed
12.7	287 changed
12.8	255 changed
12.9	291 changed
13	324 changed
13.1	403 changed
13.2	411 changed
13.3	442 changed
13.4	444 changed
13.5	426 changed
13.6	509 changed
13.7	502 changed
13.8	599 changed
13.9	625 changed
14	636 changed
14.1	640 changed
14.2	652 changed
14.3	641 changed
14.4	657 changed
14.5	576 changed
14.6	591 changed
14.7	549 changed
14.8	536 changed
14.9	317 changed
15	413 changed
15.1	417 changed
15.2	341 changed
15.3	316 changed
15.4	310 changed
15.5	285 changed
15.6	284 changed
15.7	264 changed
15.8	256 changed
15.9	316 changed
16	307 changed
16.1	263 changed
16.2	242 changed
16.3	260 changed
16.4	276 changed
16.5	227 changed
16.6	403 changed
17	371 changed
17.5	420
18	393 changed
18.5	315
19	291 changed
19.9	283
20	changed

Row 9 — changed

Horizontal Height (m)	changed
2	182 G9-1
2.5	341 9.10m to 14.65m
3	61 changed
3.5	162 G9-2
4	65 15.90m to 17.20
4.5	124 changed
5	139 changed
5.5	117
6	148 changed
6.5	115
7	124 changed
7.5	72
8	160 changed
8.5	139 changed
8.8	169 changed
8.9	254 changed
9.0	241 changed
9.5	173 changed
9	138 changed
9.1	139 changed
9.2	154 changed
9.3	127 changed
9.4	117 changed
9.5	146 changed
9.6	192 changed
9.7	185 changed
9.8	163 changed
9.9	166 changed
10	145 changed
10.1	193 changed
10.2	100 changed
10.3	81 changed
10.4	33 changed
10.5	86 changed
10.6	84 changed
10.7	113 changed
10.8	105 changed
10.9	90 changed
11	83 changed
11.1	22 changed
11.2	26 changed
11.3	24 changed
11.4	23 changed
11.5	9 changed
11.6	15 changed
11.7	50 changed
11.8	117 changed
11.9	90 changed
12	126 changed
12.1	126 changed
12.2	154 changed
12.3	200 changed
12.4	243 changed
12.5	240 changed
12.6	206 changed
12.7	175 changed
12.8	155 changed
12.9	42 changed
13	76 changed
13.1	58 changed
13.2	6 changed
13.3	7 changed
13.4	26 changed
13.5	43 changed
13.6	49 changed
13.7	46 changed
13.8	50 changed
13.9	92 changed
14	98 changed
14.1	85 changed
14.2	83 changed
14.3	82 changed
14.4	88 changed
14.5	104 changed
14.6	45 changed
14.7	22 changed
14.8	110 changed
14.9	126 changed
15	92 changed
15.1	74
15.2	52
15.3	41
15.4	17
15.5	32
15.6	44 changed
15.7	49 changed
15.8	125 changed
15.9	95 changed
16	126 changed
16.1	141 changed
16.2	156 changed
16.3	111 changed
16.4	104 changed
16.5	110 changed
16.6	135 changed
16.7	188 changed
16.8	167 changed
16.9	184 changed
17	190 changed
17.1	91 changed
17.2	76 changed
17.3	40 changed
17.4	75 changed
17.5	131 changed
18	173 changed
18.5	224
19	236 changed

Row 10 — changed

Horizontal Height (m)	changed
2	227 G10-1
2.5	174 5.55m to 7.70m, Lot
3	154 change depositing
3.5	212 G10-2
4	290 9.50 to 12.80m. 9.5
4.5	249 change
5	224 G10-3
5.2	267 15.35m to 17.70m, 1
5.3	378 change
5.4	280 change
5.5	267 change
5.6	264 change
5.7	268 change
5.8	249 change
5.9	252 change
6	330 change
6.1	235 change
6.2	237 change
6.3	229 change
6.4	232 change
6.5	226 change
6.6	230 change
6.7	271 change
6.8	218 change
6.9	193 change
7	190 change
7.1	194 change
7.2	197 change
7.3	203 change
7.4	164 change
7.5	180 change
7.6	204 change
7.7	218 change
7.8	216 change
7.9	214 change
8	208 change
8.1	208 change
8.5	175 change
9	181 change
9.2	167 change
9.3	141 change
9.4	187 change
9.5	150 change
9.6	161 change
9.7	182 change
9.8	159 change
9.9	187 change
10	187 change
10.1	178 change
10.2	141 change
10.3	169 change
10.4	142 change
10.5	161 change
10.6	161 change
10.7	142 change
10.8	149 change
10.9	163 change
11	139 change
11.1	172 change
11.2	175 change
11.3	212 change
11.4	224 change
11.5	226 change
11.6	205 change
11.7	191 change
11.8	147 change
11.9	132 change
12	120 change
12.1	83 change
12.2	69 change
12.3	123 change
12.4	162 change
12.5	145 change
12.6	123 change
12.7	136 change
12.8	136 change
12.9	135 change
13	132 change
13.1	166 change
13.2	154 change
13.5	121 change
14	142 change
14.5	198 change
15	149 change
15.1	156 change
15.2	170 change
15.3	141 change
15.4	180 change
15.5	213 change
15.6	220 change
15.7	233 change
15.8	237 change
15.9	252 change
16	246 change
16.1	250 change
16.2	243 change
16.3	223 change
16.4	225 change
16.5	253 change
16.6	256 change
16.7	264 change
16.8	272 change
16.9	267 change
17	293 change
17.1	280 change
17.2	280 change
17.3	288 change
17.4	284 change
17.5	276 change
18	306 change
18.5	256
19	362
19.5	321
20	237

Date **230197.**
This is transect information for gully plot.
Graphs drawn in GRAPHER, widths also collated here.

Row	*Width m(left)*	*Width m(right)*	*Comments*

no width measurements taken.

2/10/07.

Row 1	230107. no change	
Horizontal	Height (m)	small change
5	196	G1-1
6	157	10.65 to 12.65m
7	143	
8	147	G1-3
9	117	13.00 to 14.30m
10	144	
10.1	168	
10.2	169	
10.3	159	
10.4	189	
10.5	190	
10.6	192	
10.7	176	
10.8	150	
10.9	166	
11	173	
11.1	165	
11.2	156	
11.3	186	
11.4	239	
11.5	265	
11.6	294	
11.7	321	
11.8	316	
11.9	233	
12	272	
12.1	282	
12.2	302	
12.3	274	
12.4	127	
12.5	149	
12.6	123	
12.7	131	
12.8	221	
12.9	217	
13	212	
13.1	257	
13.2	250	
13.3	296	
13.4	268	
13.5	257	
13.6	266	
13.7	296	
13.8	278	
13.9	269	
14	292	
14.1	263	
14.2	224	
14.3	223	
14.4	216	
14.5	199	
14.6	200	
14.7	195	
14.8	203	
14.9	221	
15	224	
16	260	
17	238	
18	232	
19	246	
20	278	

Row 2	no change	
Horizontal	Height (m)	
5	152	G2-1
6	95	9.75m to 10.30m
7	108	
8	86	G2-2
9	61	10.70m to 12.65m
9.5	45	
9.6	92	G2-3
9.7	79	12.90 to 14.10m.
9.8	124	
9.9	134	
10	180	
10.1	131	
10.2	131	
10.3	122	
10.4	45	
10.5	19	
10.6	9	
10.7	0	
10.8	161	
10.9	169	
11	163	
11.1	260	
11.2	253	
11.3	329	
11.4	229	
11.5	359	
11.6	410	
11.7	312	
11.8	365	
11.9	619	
12	535	
12.1	486	
12.2	473	
12.3	405	
12.4	402	
12.5	264	
12.6	18	
12.7	78	
12.8	79	
13	267	
13.1	264	
13.2	234	
13.3	272	
13.4	223	
13.5	337	
13.6	307	
13.7	247	
13.8	219	
13.9	317	
14	150	
14.1	167	
14.2	171	
14.3	156	
14.4	185	
14.5	203	
14.6	231	
14.7	232	
14.8	256	
14.9	299	
15	300	
15.1	396	
15.2	392	
15.3	323	
15.4	291	
15.5	409	
15.6	397	
15.7	481	
15.8	430	
15.9	447	
16	380	
16.1	210	
16.2	337	
16.3	335	
16.4	330	
16.5	331	
16.6	330	
16.7	291	
16.8	293	
16.9	278	
17	237	
17.1	229	

Row 3	no change	
Horizontal	Height (m)	
5	229	G3-1
6	274	10.20m to 15.10m.
7	261	
8	197	G3-2
9	95	15.20m to 17.90m.
10	58	
10.1	88	
10.2	49	
10.3	167	
10.4	214	
10.5	267	
10.6	251	
10.7	296	
10.8	262	
10.9	281	
11	305	
11.1	341	
11.2	342	
11.3	337	
11.4	329	
11.5	321	
11.6	343	
11.7	319	
11.8	199	
11.9	251	
12	237	
12.1	240	
12.2	229	
12.3	129	
12.4	129	
12.5	96	
12.6	130	
12.7	245	
12.8	323	
12.9	336	
13	373	
13.1	360	
13.2	353	
13.3	508	
13.4	537	
13.5	491	
13.6	447	
13.7	401	
13.8	399	
13.9	412	
14	429	
14.1	315	
14.2	312	
14.3	333	
14.4	325	
14.5	239	
14.6	249	
14.7	178	
14.8	178	
14.9	189	
15	127	
15.1	86	
15.2	186	
15.3	291	
15.4	272	
15.5	237	
15.6	212	
15.7	249	
15.8	267	
15.9	321	
16	339	
16.1	344	
16.2	400	
16.3	371	
16.4	366	
16.5	367	
16.6	382	
16.7	434	
16.8	391	
16.9	387	
17	402	
17.1	369	
17.2	293	
17.3	392	
17.4	353	
17.5	342	
17.6	348	
17.7	363	
17.8	374	
17.9	356	
18	291	
18.1	332	
18.2	317	
18.3	345	
18.4	318	
18.5	329	
18.6	326	
18.7	276	
18.8	269	
18.9	275	
19	324	
20	177	

Row 4	no change	
Horizontal	Height (m)	
5	242	G4-1
6	196	10.4m to 16.0m.
7	118	
8	115	G4-2
9	152	16.95m to 19.05m.
10	232	
10.1	113	
10.2	115	
10.3	89	
10.4	84	
10.5	132	
10.6	147	
10.7	194	
10.8	175	
10.9	400	
11	435	
11.1	353	
11.2	343	
11.3	239	
11.4	208	
11.5	179	
11.6	198	
11.7	209	
11.8	227	
11.9	214	
12	354	
12.1	371	
12.2	452	
12.3	436	
12.4	327	
12.5	351	
12.6	319	
12.7	375	
12.8	400	
12.9	549	
13	493	
13.1	341	
13.2	426	
13.3	348	
13.4	246	
13.5	389	
13.6	254	
13.7	224	
13.8	183	
13.9	132	
14	294	
14.1	317	
14.2	293	
14.3	329	
14.4	368	
14.5	377	
14.6	282	
14.7	235	
14.8	227	
14.9	201	
15	248	
15.1	332	
15.2	281	
15.3	248	
15.4	332	
15.5	284	
15.6	304	
15.7	283	
15.8	259	
15.9	356	
16	319	
16.1	385	
16.2	286	
16.3	374	
16.4	328	
16.5	323	
16.6	318	
16.7	308	
16.8	338	
16.9	322	
17	361	
17.1	461	
17.2	458	
17.3	533	
17.4	606	
17.5	679	
17.6	641	
17.7	688	
17.8	579	
17.9	553	
18	522	
18.1	505	
18.2	473	
18.3	502	
18.4	457	
18.5	432	
18.6	417	
18.7	529	
18.8	477	
18.9	434	
19	456	
19.1	324	
19.2	508	
19.3	492	
19.4	467	
19.5	456	
19.6	351	
19.7	306	
19.8	352	
19.9	370	
20	284	
21	402	

Row 5	some change	
Horizontal	Height (m)	
5	307	G5-A
6	238	8.35m to 7.50m.
6.1	206	
6.2	217	G5-1
6.3	202	9.70 to 10.60m.
6.4	203	unchanged
6.5	183	G5-2
6.6	227	11.20m to 16.20m
6.7	256	
6.8	198	G5-3
6.9	297	15.35m to 17.80m
7	129	
7.1	153	
7.2	126	
7.3	135	
7.4	142	
7.5	163	
7.6	126	
7.7	196	
7.8	232	
7.9	176	
8	203	change
8.1	61	change
8.2	34	change
8.3	141	change
8.4	320	change
8.5	429	change
8.6	452	change
8.7	467	change
8.8	435	change
8.9	342	change
9	395	change
9.1	431	change
9.2	451	change
9.3	472	change
9.4	359	change
9.5	347	change
9.6	241	change
9.7	255	change
9.8	260	change
9.9	251	change
10	312	change
10.1	242	change
10.2	220	change
10.3	259	change
10.4	101	change
10.6	125	change
10.6	158	change
10.7	145	change
10.8	113	change
10.9	143	
11	78	
11.1	83	change
11.2	112	change
11.3	147	change
11.4	196	change
11.5	370	change
11.6	496	change
11.7	478	change
11.8	511	change
11.9	499	change
12	490	change
12.1	493	change
12.2	409	change
12.3	374	change
12.4	464	change
12.5	462	change
12.6	412	change
12.7	368	change
12.8	252	change
12.9	249	
13	347	
13.1	301	change
13.2	328	change
13.3	346	change
13.4	471	change
13.5	513	change
13.6	492	change
13.7	505	change
13.8	491	change
13.9	455	change
14	309	change
14.1	356	change
14.2	371	
14.3	468	change
14.4	475	change
14.5	431	change
14.6	578	change
14.7	626	change
14.8	631	change
14.9	637	change
15	666	change
15.1	696	change
15.2	284	change
15.3	250	change
15.4	267	
15.5	312	change
15.6	560	change
15.7	483	change
15.8	542	change
15.9	546	change
16	812	change
16.1	634	change
16.2	602	change
16.3	616	change
16.4	605	change
16.5	619	change
16.6	587	change
16.7	611	change
16.8	617	change
16.9	574	change
17	546	change
17.1	570	change
17.2	520	change
17.3	578	change
17.4	506	change
17.5	491	change
17.6	501	change
17.7	277	change
17.8	278	change
17.9	220	change
18	213	change
18.1	146	change
19	136	
20	256	
21	273	

Row 6	change	
Horizontal	Height (m)	
6	415	G6-1
6.1	387	8.55m to 9.50m.
6.2	362	change
6.4	349	G6-2
6.5	349	10.40m to 13.30
6.6	340	
6.7	350	G6-3
6.8	375	14.20m to 17.80
6.9	496	
7	497	
7.1	502	
7.2	409	
7.3	491	
7.4	372	
7.5	429	
7.6	412	
7.7	384	
7.8	401	
7.9	393	
8	350	change
8.1	385	change
8.2	479	change
8.3	496	change
8.4	572	change
8.5	496	change
8.6	432	change
8.7	648	change
8.8	474	change
8.9	540	change
9	592	change
9.1	457	change
9.2	476	change
9.3	379	change
9.4	336	change
9.5	226	change
9.6	213	change
9.7	214	change
9.8	205	change
9.9	197	change
10	218	
10.1	248	
10.2	274	change
10.3	397	change
10.4	360	change
10.5	422	change
10.6	424	change
10.7	464	change
10.8	443	change
10.9	367	change
11	460	change
11.1	472	
11.2	494	
11.3	536	
11.4	614	
11.5	639	
11.6	604	
11.7	561	
11.8	549	
11.9	528	
12	561	
12.1	598	
12.2	546	change
12.3	572	change
12.4	482	change
12.5	496	change
12.6	624	change
12.7	705	change
12.8	500	change
12.9	350	change
13	488	change
13.1	452	change
13.2	352	change
13.3	294	change
13.4	201	change
13.5	206	change
13.6	228	
13.7	217	
13.8	197	
13.9	231	
14	296	change
14.1	282	change
14.2	264	change
14.3	387	change
14.4	453	change
14.5	476	change
14.6	591	change
14.7	500	change
14.8	476	change
14.9	507	change
15	516	change
15.1	491	change
15.2	496	change
15.3	395	change
15.4	400	change
15.5	442	change
15.6	474	
15.7	483	
15.8	411	
15.9	360	
16	435	
16.1	437	
16.2	451	
16.3	434	
16.4	417	
16.5	456	
16.6	660	
16.7	692	
16.8	645	
16.9	548	
17	427	
17.1	488	
17.2	500	
17.3	367	
17.4	367	
17.5	390	
17.6	395	
17.7	183	
17.8	253	
17.9	268	
18	249	
18.1	240	
18.2	247	
19	281	
20	192	

Row 7	change	
Horizontal	Height (m)	
3	264	G7-1
4	341	4.80 to 8.10m
4.5	272	no change
4.7	155	G7-2
4.8	103	10.80m to 16.10m
4.9	72	change
5	83	
5.1	182	
5.2	180	
5.3	169	
5.4	219	
5.5	192	
5.6	183	
5.7	200	
5.8	242	
5.9	269	
6	211	
6.1	260	
6.2	215	
6.3	217	
6.4	213	change
6.5	311	change
6.6	227	change
6.7	232	change
6.8	253	change
6.9	275	change
7	335	change
7.1	351	change
7.2	368	change
7.3	394	change
7.4	321	change
7.5	302	change
7.6	296	change
7.7	307	change
7.8	291	change
7.9	211	change
8	64	change
8.1	55	change
8.2	49	change
8.3	31	
8.4	14	
8.5	4	
8.6	178	
8.7	176	
8	176	
9.5	199	
10	201	
10.3	186	
10.4	212	
10.5	191	
10.6	206	
10.7	196	
10.8	141	
10.9	276	
11	250	
11.1	252	
11.2	312	
11.3	367	
11.4	196	
11.5	236	
11.6	232	
11.7	296	
11.8	364	
11.9	366	
12	459	
12.1	444	
12.2	269	
12.3	239	
12.4	246	
12.5	195	
12.6	307	
12.7	317	
12.8	313	
12.9	219	
13	292	
13.1	296	
13.2	279	
13.3	282	
13.4	275	
13.5	196	
13.6	329	
13.7	388	
13.8	257	change
13.9	312	change
14	320	change
14.1	342	change
14.2	472	change
14.3	464	change
14.4	483	change
14.5	462	change
14.6	494	change
14.7	485	change
14.8	500	change
14.9	521	
15	569	
15.1	606	
15.2	630	
15.3	615	
15.4	584	change
15.5	479	change
15.6	421	change
15.7	463	change
15.8	275	change ????
15.8	392	change
16	120	change
16.1	124	change
16.2	130	change
16.3	159	change
16.4	197	
16.5	152	
16.6	140	
17	306	
17.5	289	
18	342	
18.5	286	
19	291	
19.5	227	
20	230	

Row 8	change	
Horizontal	Height (m)	
2	282	G8-1
2.5	253	6.95m to 9.15m.
3	202	unchanged
3.5	161	G8-2
4	203	9.30m to 11.70m.
4.5	153	unchanged
5	117	G8-3
5.5	129	13.40m to 16.20
6	107	unchanged
6.5	116	
6.8	10	
6.7	121	
6.8	121	
6.9	166	
7	144	change
7.1	150	change
7.2	202	change
7.3	247	change
7.4	253	change
7.5	242	change
7.6	198	change
7.7	155	change
7.8	182	change
7.9	201	change
8	191	change
8.1	210	change
8.2	247	change
8.3	236	change
8.4	222	change
8.5	234	change
8.6	221	change
8.7	237	change
8.8	212	change
8.9	203	change
9	226	change
9.1	226	change
9.2	247	
9.3	243	
9.4	264	
9.5	280	
9.6	237	
9.7	329	change
9.8	364	change
10	359	change
10.1	371	change
10.2	376	change
10.3	296	change
10.4	332	change
10.5	346	change
10.6	365	change
10.7	371	change
10.8	342	change
10.9	337	change
11	333	change
11.1	325	change
11.2	468	change
11.3	489	change
11.4	506	change
11.5	410	change
11.6	365	change
11.7	343	change
11.8	295	change
11.9	272	change
12	293	change
12.1	300	
12.2	294	
12.5	269	
13	271	
13.1	226	
13.2	233	change
13.3	237	change
13.4	217	change
13.5	224	change
13.6	409	change
13.7	422	change
13.8	503	change
13.9	509	change
14	496	change
14.1	439	change
14.2	486	change
14.3	472	change
14.4	462	change
14.5	500	change
14.6	412	change
14.7	380	
14.8	362	
14.9	348	
15	322	
15.1	287	change
15.2	281	change
15.3	304	change
15.4	294	change
15.5	295	change
15.6	311	change
15.7	312	change
15.8	304	change
15.9	360	change
16	341	change
16.1	331	change
16.2	273	change
16.3	222	change
16.4	278	change
16.5	290	change
16.6	221	
17	400	
17.5	371	
18	490	
18.5	353	
19	321	
19.5	291	
20	283	

Row 9	small change	
Horizontal	Height (m)	
2	197	G9-1
2.5	241	11.35m to 13.30
3	61	unchanged
3.5	162	G9-2
4	65	13.6m to 17.2m
4.5	124	
5	116	
5.5	117	
6	133	
6.5	115	
7	98	
7.5	77	
8	123	
8.5	116	
8	112	
9.5	93	
9.8	95	
9.9	82	
10	93	
10.1	17	
10.2	45	
10.3	0	
10.4	91	
10.5	162	
10.6	130	
10.7	130	
10.8	152	
10.9	139	
11	117	
11.1	120	change
11.2	122	change
11.3	118	change
11.4	142	change
11.5	242	change
11.6	237	change
11.7	282	change
11.8	289	change
11.9	293	change
12	287	change
12.1	264	change
12.2	254	change
12.3	264	change
12.4	299	change
12.5	165	
12.6	157	
12.7	158	
12.8	136	
12.9	94	
13	83	
13.1	81	
13.2	70	
13.3	78	
13.4	76	
13.5	74	
13.6	96	
13.7	72	
13.8	84	
13.9	61	
14	76	
14.1	57	
14.2	63	
14.3	63	
14.4	36	
14.5	9	
14.6	0	
14.7	10	
14.8	37	
14.9	42	
15	63	
15.1	74	
15.2	92	
15.3	41	
15.4	17	
15.5	32	
15.6	52	
15.7	12	
15.8	31	
15.9	107	
16	105	
16.1	114	
16.2	132	
16.3	160	
16.4	100	
16.5	98	
16.6	146	
16.7	207	
16.8	214	
16.9	200	
17	141	
17.1	88	
17.2	50	
17.3	30	
17.4	66	
17.5	111	
18	153	
18.5	224	
19	207	

Row 10	no change	
Horizontal	Height (m)	
2	277	G10-1
2.5	174	6.00m to 7.20m
3	154	
3.5	272	G10-2
4	290	10.30m to 12.50m.
4.5	249	
5	263	G10-3
5.7	281	15.35 to 18.90
5.8	241	
5.9	362	
6	293	
6.1	300	
6.2	331	
6.3	307	
6.4	326	
6.5	322	
6.6	331	
6.7	342	
6.8	311	
6.9	362	
7	238	
7.1	207	
7.3	185	
7.3	186	
7.4	190	
7.5	186	
8	204	
8.5	171	
9	201	
9.5	207	
10	196	change
10.1	190	change
10.2	196	change
10.3	195	change
10.4	191	change
10.5	187	change
10.6	171	change
10.7	173	change
10.8	179	change
10.9	166	change
11	151	change
11.1	154	change
11.2	175	change
11.3	176	change
11.4	171	change
11.5	97	change
11.6	76	change
11.7	62	change
11.8	136	change
11.9	122	change
12	136	change
12.1	131	change
12.2	124	change
12.3	114	change
12.4	145	change
12.5	120	change
12.6	125	change
12.7	146	change
12.8	132	change
12.9	146	change
13	141	change
13.5	103	change
14	129	
14.5	96	
15	107	
15.2	140	
15.3	161	
15.4	182	
15.5	162	
15.6	214	
15.7	222	
15.8	297	change
15.9	266	change
16	339	change
16.1	395	change
16.2	362	change
16.3	366	change
16.4	395	change
16.5	402	change
16.6	411	change
16.7	380	change
16.8	305	change
16.9	271	change
17	297	change
17.1	279	change
17.2	286	change
17.3	262	
17.4	295	
17.5	267	
18	237	
18.5	256	
19	362	
19.5	321	
20	291	

Date **130197**
This is transect information for gully plot.
Graphs drawn in GRAPHER, widths also collated here.

Row	*Width m(left)*	*Width m(right)*	*Comments*

no width measurements were taken.

Daily Measurements 130197.

Row 1	130197. change	Row 2	change	Row 3	small change	Row 4	small change	Row 5	no change	Row 6	no change	Row 7	no change	Row 8	change	Row 9	change	Row 10	change
Horizontal Height (m	small change	Horizontal Height (m)		Horizontal Height (m)		Horizontal Height (m)		Horizontal Height (m)		Horizontal Height (m)		Horizontal Height (m)		Horizontal Height (m)		Horizontal Height (m)		Horizontal Height (m)	
5	196 G1-1	5	152 G2-1	5	229 G3-1	5	242 G4-1	5	307 G5-A	5	415 G6-1	3	264 G7-1	2	282 G8-1	2	182 G9-1	2	227 G10-1
6	197 10.65 to 12.65m	6	95 9.75m to 10.30m	6	274 10.30m to 10.90m	6	196 10.4m to 10.0m.	6	230 8.35m to 7.80m.	6	367 8.50m to 9.30m	4	241 4.95 to 8.15m	2.5	292 8.95m to 9.15m	2.5	241 11.30m to 13.20	2.5	124 8.00m to 7.70m
7	143 unchanged width	7	106	6	201 unchanged	7	118 unchanged	6.1	206 new gully.	6.3	382	4.5	222 unchanged	3	202 unchanged	3	61 unchanged	3	184 unchanged
8	147 G1-2	8	66 G2-2	6	197 G3-2	8	115 G4-2	6.2	217 G6-1	6.4	345 G6-2	4.7	155 G7-2	3.5	183 G8-2	3.5	102 G9-2	3.5	272 G10-2
9	117 13.00 to 14.30m	9	61 10.70m to 12.65m	8	95 10.30m to 12.90m	9	152 16.95m to 18.05m.	6.3	201 9.20 to 10.60m.	6.8	349 10.3 to 13.3m	4.8	105 10.70m to 15.95m	4	203 9.30m to 11.70m	4	65 13.6m to 17.2m	4	290 10.30m to 12.50m.
10	144 no change in here at	9.5	45	10	56	10	232 unchanged	6.4	263 unchanged	6.6	340	4.9	72 change	4.5	153 unchanged	4.5	124 unchanged	4.5	249 changed
10.1	168	9.6	52 G2-3	10.1	69	10.3	119 though it was 19.35m	6.5	183 G5-2	6.7	350 G6-3	5	95	5	172 G8-3	5	116	5	263 G10-3
10.2	193	9.7	79 12.90 to 16.10m.	10.2	49	10.4	118	6.6	222 11.15m to 15.10m	6.8	375 14.3 to 17.7m.	5.1	182	5.5	123 13.35m to 16.20	5.5	117	5.7	261 15.35 to 14.90
10.3	198	9.8	124 unchanged	10.3	161	10.5	88	6.7	256 unchanged	6.9	494	5.2	180	6	107 unchanged	6	133	5.8	241
10.4	189	9.8	134	10.4	214	10.6	84	6.8	196 G6-3	7	497	5.3	169	6.5	118	6.5	115	5.9	267
10.5	190	10	160	10.5	287	10.7	132	6.9	217 15.35m to 17.75m	7.1	502	5.4	218	6.6	10	7	89	6	293
10.6	192	10.1	131	10.6	261 change	10.8	147	7	179 unchanged	7.2	409	5.5	192	6.7	121	7.5	77	6.1	300
10.7	176	10.2	131	10.7	290 change	10.9	194	7.1	153 change upwards a	7.3	451	5.6	183	6.8	171	8	123	6.2	331
10.8	160	10.3	122	10.8	282 change	11	126	7.2	128 change	7.4	372	5.7	200	6.9	196	8.5	116	6.3	307
10.9	186	10.4	45	10.9	301 change	11.1	468	7.3	135 change	7.5	429	5.8	243	7	181	9	132	6.4	326
11	172	10.5	10	11	339 change	11.2	435	7.4	142 change	7.6	412	5.9	209	7.1	150	9.5	93	6.5	322
11.1	146	10.6	9	11.1	341 change	11.3	383	7.5	163 change	7.7	384	6	211	7.2	201	9.8	85	6.6	331
11.2	156	10.7	9	11.2	347 change	11.4	343	7.6	176 change	7.8	401	6.1	260	7.3	236	9.8	82	6.7	347
11.3	168	10.8	101	11.3	327 change	11.5	238	7.7	196 change	7.9	397	6.2	215	7.4	272	10	93	6.8	311
11.4	235	10.9	169	11.4	323 change	11.6	208	7.8	232 change	8	432	6.3	217	7.5	266	10.1	117	6.9	342
11.5	262	11	163	11.5	321 change	11.7	178	7.9	176 change	8.1	357	6.4	212	7.6	222	10.2	45	7	236
11.6	294	11.1	260	11.6	345	11.8	199	8	231 change	8.2	432	6.5	209	7.7	201	10.3	0	7.1	207
11.7	221 changed	11.2	253	11.7	318	11.9	299	8.1	95 change	8.3	454	6.6	190	7.8	176	10.4	87	7.2	183
11.8	214 changed	11.3	259	11.8	285	12	227	8.2	182 change	8.4	552	6.7	191	7.9	212	10.5	162	7.3	196
11.9	235 changed	11.4	228	11.9	257	12.1	214	8.3	141 change	8.5	624	6.8	232	8	204 change	10.6	130	7.4	190
12	273 changed	11.5	299	12	237	12.2	394	8.4	219 change	8.6	651	6.9	274	8.1	246 change	10.7	130	7.5	186
12.1	282 changed	11.6	418	12.1	346	12.3	371	8.5	413 change	8.7	591	7	305	8.2	240 change	10.8	152	8	204
12.2	302 changed	11.7	512	12.2	239	12.4	452	8.6	474 change	8.8	535	7.1	323	8.3	263 change	10.9	129	8.5	171
12.3	274 changed	11.8	585	12.3	129	12.5	439	8.7	522 change	8.9	498	7.2	343	8.4	236 change	11	117 change	9	201
12.4	127 change	11.9	619	12.4	129	12.6	327	8.8	372 change	9	529	7.3	339	8.5	233 change	11.1	132 change	9.5	207
12.5	140 change	12	536	12.5	96	12.7	361	8.9	417 change	9.1	492	7.4	291	8.6	279 change	11.2	127 change	10	196 change
12.6	123 change	12.1	486	12.6	133	12.8	313	9	457 change	9.2	334	7.5	295	8.7	268 change	11.3	145 change	10.1	198 change
12.7	131 change	12.2	475	12.7	245	12.9	373	9.1	486 change	9.3	298	7.6	281	8.8	223 change	11.4	206 change	10.2	196 change
12.8	221	12.3	409	12.8	323	13	400	9.2	456 change	9.4	212	7.7	335	8.9	196 change	11.5	246 change	10.3	195 change
12.9	217	12.4	403	12.9	336	13.1	549	9.3	512 change	9.5	248	7.8	357	9	233 change	11.6	295 change	10.4	191 change
13	212	12.5	364	13	373 change	13.2	459	9.4	545 change	9.6	218	7.9	249	9.1	223 change	11.7	315 change	10.5	182 change
13.1	257	12.6	16	13.1	360 change	13.3	341	9.5	387 change	9.7	253	8	247	9.2	247	11.8	282 change	10.6	171 change
13.2	258	12.7	78	13.2	353 change	13.4	426	9.6	293 change	9.8	235	8.1	175	9.3	241	11.9	289 change	10.7	173 change
13.3	296	12.8	78	13.3	508 change	13.5	348	9.7	307 change	9.9	242	8.2	41	9.4	264	12	251 change	10.8	179 change
13.4	269	12.9	79	13.4	517 change	13.6	246	9.8	230 change	10	215	8.3	27	9.5	260	12.1	182 change	10.9	166 change
13.5	257	13	267	13.5	491 change	13.7	369	9.9	321 change	10.1	249	8.4	31	9.6	237	12.2	199 change	11	154 change
13.6	266	13.1	284	13.6	447 change	13.8	234	10	236 change	10.2	272	8.5	14	10	332	12.3	162 change	11.1	154 change
13.7	298	13.2	334	13.7	481 change	13.9	224	10.1	241 change	10.3	357	8.6	4	10.1	397	12.4	156 change	11.2	175 change
13.8	276	13.3	372 change	13.8	399 change	14	183	10.2	257 change	10.4	419	8.7	178	10.2	402	12.5	166 change	11.3	176 change
13.9	269	13.4	323 change	13.9	412 change	14.1	132	10.3	232 change	10.5	415	8.8	176	10.3	329	12.6		11.4	121 change
14	292	13.5	317 change	14	473 change	14.2	294	10.4	139 change	10.6	454	9	199	10.4	348	12.7		11.5	87 change
14.1	265	13.6	307 change	14.1	315	14.3	317	10.5	246 change	10.7	480	9.2	201	10.5	341	12.8	136	11.6	76 change
14.2	224	13.7	347 change	14.2	312	14.4	293	10.6	166 change	10.8	497	9.4	186	10.6	353	12.9	84	11.7	82 change
14.3	223	13.8	318 change	14.3	333	14.5	339	10.7	148 change	10.9	509	9.5	217	10.7	387	13	83	11.8	130 change
14.4	210	13.9	211 change	14.4	235	14.6	360	10.8	142 change	11	524	9.6	236 change	10.8	351 change	13.1	81	11.9	122 change
14.5	199	14	150 change	14.5	233	14.7	327	10.9	143 change	11.1	472	9.7	232 change	10.9	378 change	13.2	70	12	134 change
14.6	202	14.1	167 change	14.6	248	14.8	382	11	79	11.2	494	9.8	298 change	11	345 change	13.3	78	12.1	131 change
14.7	199	14.2	171 change	14.7	179	14.9	227	11.1	104	11.3	526	9.9	368 change	11.1	346 change	13.4	76	12.2	124 change
14.8	203	14.3	156 change	14.8	178	15	332	11.2	138	11.4	544	10	439 change	11.2	488 change	13.5	74	12.3	114 change
14.9	221	14.4	185 change	14.9	189	15.1	281	11.3	173 change	11.5	539	10.1	444 change	11.3	517 change	13.6	96	12.4	145 change
15	224	14.5	209 change	15	127	15.2	240	11.4	215 change	11.6	504	10.2	369 change	11.4	508 change	13.7	72	12.5	120 change
15.6	260	14.6	221 change	15.1	86	15.3	334	11.5	386 change	11.7	551	10.3	292 change	11.5	478 change	13.8	84	12.6	125 change
15.7	239	14.7	232 change	15.2	188	15.4	326	11.6	454 change	11.8	543	10.4	312 change	11.6	379 change	13.9	91	12.7	146 change
15.8	232	14.8	256 change	15.3	281	15.5	284	11.7	495 change	11.9	526	10.5	267 change	11.7	196 change	14	76	12.8	132 change
15.9	248	14.9	292 change	15.4	272	15.6	334	11.8	492 change	12	561	10.6	232 change	11.8	297 change	14.1	57	12.9	146 change
16	278	15	300 change	15.5	237	15.7	283	11.9	506 change	12.1	599	10.7	296 change	11.9	282	14.2	63	13	141 change
		15.1	396 change	15.6	212	15.8	299	12	473 change	12.2	604	10.8	364 change	12	320	14.3	63	13.5	103 change
		15.2	392 change	15.7	249	15.9	356	12.1	504 change	12.3	599	10.9	368 change	12.1	300	14.4	36	14	109
		15.3	323 change	15.8	262 change	16	319	12.2	488	12.4	619	11	439 change	12.2	286	14.5	9	14.5	96
		15.4	291 change	15.9	321 change	16.1	285	12.3	470	12.5	557	11.1	444 change	12.5	299	14.6	0	15	107
		15.5	403 change	16	323 change	16.2	294	12.4	488	12.6	587	11.2	369 change	13	271	14.7	10	15.2	140
		15.6	397 change	16.1	346 change	16.3	374	12.5	458	12.7	510	11.3	292 change	13.1	226 change	14.8	37	15.3	161
		15.7	461 change	16.2	400 change	16.4	326	12.6	456	12.8	496	11.4	239 change	13.2	241 change	14.9	42	15.4	182
		15.8	435 change	16.3	371 change	16.5	323	12.7	314	12.9	591	11.5	246 change	13.3	247 change	15	63	15.5	182
		15.9	447 change	16.4	366 change	16.6	318	12.8	304	13	499	11.6	195 change	13.4	266 change	15.1	74	15.6	214
		16	380 change	16.5	367 change	16.7	306 change	12.9	249	13.1	362	11.7	307 change	13.5	338 change	15.2	92	15.7	222
		16.1	710 change	16.6	382 change	16.8	330 change	13	347	13.2	274	11.8	312 change	13.6	496 change	15.3	41	15.8	254 change
		16.2	397 change	16.7	434 change	16.9	322 change	13.1	330	13.3	227	11.9	219 change	13.7	496 change	15.4	17	15.9	266 change
		16.3	335 change	16.8	381 change	17	361 change	13.2	326	13.4	219	12	292 change	13.8	531 change	15.5	32	16	339 change
		16.4	330 change	16.9	301 change	17.1	481 change	13.3	491	13.5	219	12.1	296 change	13.9	515 change	15.6	92	16.1	385 change
		16.5	391 change	17	402 change	17.2	499 change	13.4	523	13.6	225	12.2	296 change	14	492 change	15.7	17	16.2	382 change
		16.6	330 change	17.1	363 change	17.3	433 change	13.5	517	13.7	217	12.3	273 change	14.1	577 change	15.8	31	16.3	366 change
		16.7	291	17.2	293 change	17.4	800 change	13.6	504	13.8	197	12.4	282 change	14.2	531 change	15.9	107	16.4	395 change
		16.8	295	17.3	382 change	17.5	879 change	13.7	520	13.9	221	12.5	275 change	14.3	516 change	16	105	16.5	402 change
		16.9	278	17.4	352 change	17.6	841 change	13.8	543	14	199	12.6	196 change	14.4	477 change	16.1	114	16.6	411 change
		17	232	17.5	347 change	17.7	686 change	13.9	497	14.1	234	12.7	378 change	14.5	492 change	16.2	132	16.7	399 change
		17.1	229	17.6	348 change	17.8	923 change	14	493	14.2	291	12.8	300 change	14.6	426 change	16.3	160	16.8	395 change
				17.7	363 change	17.9	953 change	14.1	472	14.3	320	12.9	333 change	14.7	380 change	16.4	100	16.9	271 change
				17.8	374 change	18	923 change	14.2	571	14.4	492	13	313 change	14.8	382 change	16.5	98	17	247 change
				17.9	356 change	18.1	908	14.3	522	14.5	497	13.1	382 change	14.9	348 change	16.6	140	17.1	279 change
				18	281 change	18.2	473	14.4	482 change	14.6	492	13.2	475 change	15	322 change	16.7	207	17.2	286 change
				18.1	332 change	18.3	502	14.5	447 change	14.7	454	13.3	316 change	15.1	284 change	16.8	214	17.3	262
				18.2	317 change	18.4	457	14.6	569 change	14.8	504	13.4	483 change	15.2	292 change	16.9	203	17.4	293
				18.3	348	18.5	432	14.7	573 change	14.9	847	13.5	907 change	15.3	321 change	17	141	17.5	287
				18.4	316	18.6	517	14.8	551 change	15	557	13.6	511 change	15.4	312 change	17.1	68	18	247
				18.5	328	18.7	523	14.9	536 change	15.1	519	13.7	472 change	15.5	302 change	17.2	50	18.5	236
				18.6	326	18.8	477	15	512 change	15.2	434	13.8	526 change	15.6	316 change	17.3	30	19	367
				18.7	270	18.9	434	15.1	282 change	15.3	428	13.9	521 change	15.7	325 change	17.4	66	19.5	321
				18.8	269	19	466	15.2	276 change	15.4	441	14	509 change	15.8	323 change	17.5	111	20	297
				19	275	19.1	524	15.3	286 change	15.5	517	14.1	606 change	15.9	347 change	18	153		
				20	177	19.2	508	15.4	287	15.6	474	15.1	630 change	16	356 change	18.5	224		
						19.3	492	15.5	561	15.7	482	15.2	615 change	16.1	321 change	19	207		
						19.4	467	15.6	563	15.8	411	15.3	487 change	16.2	296 change				
						19.5	456	15.7	513	15.9	360	15.4	541 change	16.3	242 change				
						19.6	351	15.8	517	16	435	15.5	471 change	16.4	290 change				
						19.7	306	15.9	648	16.1	437	15.6	267 change	16.5	290 change				
						19.8	352	16	545	16.2	457	15.7	373 change	16.6	227				
						19.9	370	16.1	530	16.3	434	15.8	175 change	17	400				
						20	394	16.2	598 change	16.4	417	15.9	130 change	17.5	371				
						21	402	16.3	585 change	16.5	450	16	161 change	18	490				
								16.4	616 change	16.6	660	16.1	129 change	18.5	363				
								16.5	664 change	16.7	992	16.2	126 change	19	327				
								16.6	600	16.8	645	16.3	126 change	19.5	291				
								16.7	652 change	16.9	548	16.4	192 change	20	283				
								16.8	556 change	17	477	16.5	152						
								16.9	603 change	17.1	488	16.6	140						
								17	628	17.2	508	16.7	306						
								17.1	648	17.3	367	16.8	288						
								17.2	612	17.4	367	16.9	247						
								17.3	553	17.5	398	17	286						
								17.4	528	17.6	193	17.5	231						
								17.5	488	17.7	183	18	227						
								17.6	499	17.8	253	19.5	230						
								17.7	391	17.9	369								
								17.8	268	18	249								
								17.9	220	18.1	240								
								18	184	18.2	247								
								18.1	187	19	291								
								19	158	20	192								
								20	256										
								21	273										

Gully Measurements: 070197.

Date 070197.
This is transect information for gully plot.
Graphs drawn in GRAPHER, widths also collated here.

Row	*Width m(left)*	*Width m(right)*	*Comments*
R1-R2 (2.9m)			
1m	10.65	12.7	Width measurements from R1 at 1m and 2m.
	13	14.6	distance 2.9m apart.
2m	10.65	12.7	
	13	15.3	
R2-R3 (3.4m)			
1m	11.3	13.75	Width at 1m and 2m.
	15.37	16.5	distance 3.4m apart.
2m	10.9	14.25	10.90m unchanged.
	15.25	17.1	
R3-R4 (2.6m)			
1m			no change.
R4-EP1(3m) ???			
1.5m	10.15	15.54	Width at 1.5m, sound good.
	16.6	18.25	distance 3m ???
EP1-R5 (3.6m).			
2m	8.7	10.8	Width measurements made at 2m from EPin 1, measmt taken from Row 5.
	11.2	16.9	Distance 3.6m.
R5-R6 (3.6m)			
2m			no change.
R7-R8 (5.7m)			
2m	5.8	6.55	Measured from R7 at 2m.
	7.25	8.55	
	13.85	16.1	
R8-EP3 (5.2m)			
2.5m.	7.45	8.15	Measured from R8 at 2.5m
	8.9	11.75	
	13.6	15.7	
EP3-R9 (7.8m)			
3m.	9.2	10.9	Measurements from R9 at 3m. i.e. back up the slope.
	15.65	16.85	
R9-EP4 (6.9m)			
3m	7.55	8.1	
	11.2	13.05	
	15.05	15.75	
	15.5	16.15	Check this out ??
EP4-R10(5.7m).			
3m.	7.35	8.6	Measurements taken from R10, at 3m from EP4.
	11.35	12.35	
	14.65	17.4	
R10-EP5 (9.2m).			
			No change.

Filename: 070197.wb1

By Measure

Row 1	979197. change	Row 2	no change	Row 3	change	Row 4	change	Row 5	change	Row 6	no change	Row 7	change	Row 8	change	Row 9	change	Row 10	change
Horizontal	Height (m) small change	Horizontal	Height (m)	Horizontal	Height (m)	Horizontal	Height (m)	Horizontal	Height (m)	Horizontal	Height (m)	Horizontal	Height (m)	Horizontal	Height (m)	Horizontal	Height (m)	Horizontal	Height (m)
5	156 G1-1	5	152 G2-1	5	229 G3-1	5	242 G4-1	5	307 G5-A	5	415 G6-1	3	264 G7-1	2	282 G8-1	2	182 G9-1	2	237 G10-A
6	157 10.65 to 12.70m	6	99 9.75m to 10.30m	6	274 10.15m to 13.65m	6	196 10.4m to 16.0m	6	230 8.35m to 7.90m.	6	367 4.50m to 9.30m.	4	241 4.95 to 8.15m	2.5	252 6.95m to 9.20m	2.5	249 11.35m to 13.30	2.5	174 6.00m to 7.20m.
7	143 unchanged width	7	106	7	201	7	178 unchanged	6.2	286 new gully.	6.3	362	4	222 unchanged	3	202 unchanged	3	61 unchanged	3	154 new gully.
8	147 G1-2	8	86 G2-2	8	197 G3-2	8	115 G4-2	6.3	217 G5-1	6.4	349 G6-2	4.5	155 G7-2	2.5	161 G8-2	2.5	102 G9-2	3.5	272 G10-1
9	117 13.00 to 14.30m	9	61 16.20m to 12.65m	9	95 15.20m to 17.90m.	9	152 16.95m to 19.55	6.4	202 unchanged	6.5	340	4.7	163 10.70m to 15.95m.	3	85 13.95m to 17.2m	4	290 11.50m to 12.50m
10	144 no change in here at	10	45	10	96	10	232	6.5	163 G5-2	6.7	350 G6-3	4.8	72 change	3.5	124 unchanged	4.5	249 unchanged
10.1	168	9.8	52 G2-3	10.1	69	10.3	113	6.6	227 11.15m to 15.70m	6.9	375 14.3 to 17.7m.	5	182			5	116	5	263 G10-2
10.2	193	9.7	78 12.90 to 16.20m.	10.2	49	10.4	115	6.7	296 unchanged	6.9	484	5.1	180			5.5	117	5.7	291 15.35 to 16.90
10.3	196	9.6	124	10.3	167	10.5	99	7	199 G5-3	7	497	5.3	169			6	107 unchanged	5.8	341 unchanged
10.4	199	9.9	134	10.4	214	10.6	94	7.1	217 15.35m to 17.75m	7.1	502	5.4	219			6.5	116	5.9	362 change
10.5	180	10	131	10.5	287	10.7	132	7.2	178 unchanged	7.2	489	5.5	192			6.5	115	6	293 change
10.6	192	10.1	131	10.6	307	10.8	147	7.3	153 change upwards a	7.5	451	5.6	183			6.6	98	6.1	300 change
10.7	176	10.2	131	10.7	328	10.9	184	7.4	136 change	7.6	372	5.7	208			6.8	77	6.2	331 change
10.8	150	10.3	122	10.8	321	11	178	7.5	142 change	7.7	429	5.8	242			7	61 change	6.3	307 change
10.9	166	10.4	45	10.9	360	11.1	400	7.6	163 change	7.8	413	5.9	209			7.1	150 change	6.4	326 change
11	172	10.5	19	11	366	11.2	425	7.7	178 change	7.9	394	6	211			7.2	201 change	6.5	322 change
11.1	146	10.6	9	11.1	321	11.3	343	7.8	186 change	8	401	6.1	260			7.3	236 change	6.6	331 change
11.2	136	10.7	6	11.2	328	11.5	238	7.9	202 change	8.1	397	6.2	215			7.4	222 change	6.7	347 change
11.3	148	10.6	181	11.3	347	11.8	208	7.8	233 change	8.2	422	6.3	217			7.5	208 change	6.8	311 change
11.4	228 changed	10.9	169	11.5	348	11.7	179	7.9	176 change	8.3	357	6.4	212			7.6	222 change	6.9	362 change
11.5	265 changed	11	183	11.6	345	11.8	198	8	221 change	8.4	432	6.5	203			7.7	232 change	7	236 change
11.6	234 changed	11.1	260	11.7	219	11.9	209	8.1	95 change	8.5	454	6.6	180			7.8	176 change	7.1	297 change
11.7	248 changed	11.2	252	11.8	198	12	227	8.2	102 change	8.6	352	6.7	191			7.9	212 change	7.2	185 change
11.8	256 changed	11.3	298	11.9	209	12.1	214	8.3	141 change	8.7	524	6.8	232			8	221 change	7.3	186 change
11.9	261 changed	11.4	229	12	227	12.2	354	8.4	215 change	8.8	534	6.9	271			8.1	216 change	7.4	190 change
12	307 changed	11.5	359	12.1	214	12.3	371	8.5	412 change	8.9	524	7	301			8.2	255 change	7.5	186 change
12.1	322 changed	11.6	410	12.2	354	12.4	452	8.6	474 change	9	529	7.1	325			8.3	290 change	8	0
12.3	338 changed	11.7	512	12.3	371	12.5	436	8.7	522 change	9.1	492	7.2	343			8.4	262 change	8.5	204
12.8	246 changed	11.8	565	12.4	452	12.6	337	8.8	372 change	9.2	334	7.3	319			8.5	282 change	9	171
12.4	172	11.9	619	12.5	436	12.7	291	8.9	417 change	9.3	298	7.4	291			8.6	271 change	9.5	201
12.9	174	12	539	12.6	337	12.8	313	9	457 change	9.4	212	7.5	255			8.7	236 change	9.7	267
12.6	160	12.1	486	12.7	291	12.9	373	9.1	466 change	9.5	248	7.6	254			8.8	254 change	10	160
12.7	180	12.2	475	12.8	313	13	408	9.2	456 change	9.6	218	7.7	335			8.9	232 change	10.5	152
12.8	221	12.3	409	12.9	373	13.1	549	9.3	512 change	9.7	253	7.8	357			9	226 change	11	151
12.9	217	12.4	403	13	408	13.2	493	9.4	343 change	9.8	235	7.9	245			9.1	206 change	11.3	102 change
13	212	12.5	264	13.1	549	13.3	341	9.5	367 change	9.9	242	8	247			9.2	247 change	11.4	100 change
13.1	257	12.6	16	13.2	493	13.4	426	9.6	393 change	10	215	8.1	175			9.3	241 change	11.5	101 change
13.2	256	12.7	78	13.3	341	13.5	346	9.7	302 change	10.1	248	8.2	41			9.4	260 change	11.6	104 change
13.3	296	12.8	78	13.4	426	13.6	346	9.8	230 change	10.2	212	8.3	27			9.5	237 change	11.7	72 change
13.4	288	12.9	29	13.5	346	13.7	369	9.9	321 change	10.3	357	8.4	31			9.6	332 change	11.8	91 change
13.5	257	13	267	13.6	346	13.8	234	10	236 change	10.4	418	8.5	14			10	337 change	11.9	131 change
13.6	256	13.1	264	13.7	369	13.9	224	10.1	241 change	10.5	415	8.6	4			10.1	297 change	12	146 change
13.7	256	13.2	234	13.8	234	14	163	10.2	297 change	10.6	454	8.7	178			10.2	402 change	12.1	183 change
13.8	278	13.3	240	13.9	224	14.1	132	10.3	252 change	10.7	480	8	176			10.3	328 change	12.3	209 change
13.9	269	13.4	234	14	132	14.2	294	10.4	139 change	10.8	497	8.9	199			10.4	340 change	12.5	165 change
14	292	13.5	266	14.1	313	14.3	317	10.5	246 change	10.9	509	9.5	10			10.5	341 change	12.6	182 change
14.1	265	13.6	242	14.2	312	14.4	293	10.6	166 change	11	524	10	201			10.6	353 change	12.7	197 change
14.2	224	13.7	219	14.3	333	14.5	339	10.7	146 change	11.1	472	10.3	186			10.7	397 change	12.8	106 change
14.3	223	13.8	277	14.4	235	14.6	360	10.8	142 change	11.2	524	10.4	212			10.8	347 change	12.9	184 change
14.4	210	13.9	187	14.5	233	14.7	377	10.9	79	11.3	526	10.5	191 change			10.9	305 change	13	126
14.5	199	14	125	14.6	248	14.8	362	11	104	11.4	539	10.6	206 change			11	342 change	13.1	103
14.6	200	14.1	161	14.7	179	14.9	235	11.1	138	11.5	639	10.7	156 change			11.1	354 change	13.2	129
14.7	195	14.2	146	14.8	189	15	222	11.2	173 change	11.6	604	10.8	141 change			11.2	481 change	14	96
14.8	209	14.3	124	14.9	127	15.1	332	11.3	215 change	11.7	551	10.9	278 change			11.3	517 change	14.5	96
14.9	221	14.4	119	15	88	15.2	281	11.4	386 change	11.8	543	11	250 change			11.4	509 change	15	107
15	224	14.5	171	15.1	188	15.3	240	11.5	484 change	11.9	528	11.1	444 change			11.5	431 change	15.3	140 change
15	280	14.6	210	15.2	201	15.4	332	11.6	495 change	12	561	11.2	269 change			11.6	387 change	15.3	161 change
15.1	229	14.7	233	15.3	372	15.5	284	11.7	492 change	12.1	598	11.3	367 change			11.7	340 change	15.4	182 change
15.2	233	14.8	263	15.4	237	15.6	334	11.8	508 change	12.2	604	11.4	196 change			11.8	304 change	15.5	162 change
15.3	263	14.9	278	15.5	212	15.7	263	11.9	473 change	12.3	490	11.5	236 change			11.9	263 change	15.6	214 change
15.4	210	15	365	15.6	249	15.8	259	12	504 change	12.4	619	11.6	232 change			11.9	320 change	15.7	222 change
15.5	197	15.1	349	15.7	262 change	15.9	356	12.1	486	12.5	557	11.7	396 change			12	300	15.8	245 change
15.6	199	15.2	219	15.8	321 change	16	319	12.2	466	12.6	581	11.8	364 change			12.1	286	15.9	243 change
15.7	258	15.3	258	15.9	333 change	16.1	285	12.3	478	12.7	510	11.9	366 change			12.2	269	16	323 change
15.8	224	15.4	224	16	346 change	16.2	286	12.4	466	12.8	496	12	459 change			12.5	269	16.1	356 change
15.9	364	15.5	355	16.1	400 change	16.3	274	12.5	456	12.9	591	12.1	444 change			13	271	16.2	369 change
16	355	15.6	419	16.2	371 change	16.4	326	12.6	456	13	498	12.2	269 change			13.1	246 change	16.3	368 change
15.9	409	15.7	409	16.3	366 change	16.5	323	12.7	914	13.1	382	12.3	229 change			13.2	244 change	16.4	368 change
16	409	15.8	409	16.4	367 change	16.6	318	12.8	304	13.2	224	12.4	246 change			13.3	231 change	16.5	390 change
16.1	392	15.9	409	16.5	263 change	16.7	322	12.9	348	13.3	227	12.5	195 change			13.4	257 change	16.6	387 change
16.2	317	16	409	16.6	434 change	16.8	335 change	13	347	13.4	219	12.6	307 change			13.5	314 change	16.7	372 change
16.3	300	16.1	392	16.7	391 change	16.9	347 change	13.1	336	13.5	219	12.7	317 change			13.6	446 change	16.8	329 change
16.4	305	16.2	317	16.8	382 change	17	323 change	13.2	328	13.6	225	12.8	312 change			13.7	472 change	16.9	317 change
16.5	313	16.3	300	16.9	402 change	17.1	378 change	13.3	497	13.7	212	12.9	219 change			13.8	492 change	17	290 change
16.6	290	16.4	305	17	363 change	17.2	414 change	13.4	523	13.8	187	13	292 change			13.9	947 change	17.1	271 change
16.7	251	16.5	313	17.1	353 change	17.3	467 change	13.5	517	13.9	221	13.1	296 change			14	572 change	17.2	269 change
17	265	16.6	290	17.2	392 change	17.4	805 change	13.6	504	14	198	13.2	279 change			14.1	557 change	17.3	262 change
16	276	16.7	251	17.3	352 change	17.5	788 change	13.7	530	14.1	234	13.3	292 change			14.2	527 change	17.4	281 change
19	232	17	265	17.4	347 change	17.6	886 change	13.8	542	14.2	291	13.4	275 change			14.3	490 change	17.5	267 change
20	229	17.1	276	17.5	349 change	17.7	742 change	13.9	497	14.3	328	13.5	196 change			14.4	472 change	17.6	317
		17.2	232	17.6	363 change	17.8	633 change	14	493	14.4	492	13.6	270 change			14.5	469 change	18	0
		17.3	229	17.7	334 change	17.9	537 change	14.1	472	14.5	487	13.7	300 change			14.6	431 change	18.1	356
				17.8	358 change	18	804 change	14.2	371	14.6	482	13.8	272 change			14.7	407 change	18.2	362
				17.9	331 change	18.1	903 change	14.3	522	14.7	454	13.9	333 change			14.8	377 change	18.3	321
				18	332 change	18.2	473 change	14.4	482 change	14.8	504	14	313 change			14.9	363 change		
				18.1	317 change	18.3	457 change	14.5	447 change	14.9	547	14.1	382 change			15	341 change		
				18.2	348	18.4	457	14.6	569 change	15	557	14.2	475 change			15.1	323 change		
				18.3	316	18.5	432	14.7	573 change	15.1	919	14.3	516 change			15.2	300 change		
				18.4	329	18.6	517	14.8	551 change	15.2	434	14.4	480 change			15.3	324 change		
				18.5	328	18.7	523	14.9	536 change	15.3	639	14.5	507 change			15.4	317 change		
				18.6	270	18.8	427	15	592 change	15.4	441	14.6	511 change			15.5	326 change		
				18.7	269	18.9	434	15.1	293 change	15.5	617	14.7	472 change			15.6	311 change		
				18.8	272	19	466	15.2	286 change	15.6	474	14.8	326 change			15.7	327 change		
				18.9	277	19.1	524	15.3	726 change	15.7	482	14.9	321 change			15.8	356 change		
				19	394	19.2	509	15.4	297	15.8	411	15	529 change			15.9	347 change		
				19.1	492	19.3	492	15.5	561	15.9	360	15.1	606 change			16	356 change		
				19.2	467	19.4	467	15.6	563	16	435	15.2	630 change			16.1	352 change		
				19.3	456	19.5	456	15.7	612	16.1	437	15.3	645 change			16.2	271 change		
				19.4	351	19.6	351	15.8	648	16.2	457	15.4	487 change			16.3	272 change		
				19.5	306	19.7	306	15.9	549	16.3	434	15.5	543 change			16.4	235 change		
				19.6	352	19.8	352	16	530	16.4	417	15.6	471 change			16.5	280 change		
				19.7	370	19.9	370	16.1	596 change	16.5	450	15.7	282 change			16.6	227 change		
				20	394	20	394	16.2	595 change	16.6	660	15.8	371 change			17	400		
				21	402	21	402	16.3	616 change	16.7	492	15.9	175 change			17.5	371		
								16.4	644 change	16.8	645	16	130 change			18	499		
								16.5	600	16.9	548	16.1	161 change			18.5	353		
								16.6	652 change	17	472	16.2	129 change			19	327		
								16.7	558 change	17.1	488	16.3	126 change			19.5	291		
								16.8	603 change	17.2	500	16.4	192 change			20	283		
								16.9	629	17.3	367	16.5	152						
								17	640	17.4	367	16.6	140						
								17.1	612	17.5	292	16.7	306						
								17.2	553	17.6	195	17	289						
								17.3	528	17.7	183	17.5	247						
								17.4	480	17.8	253	18	286						
								17.5	495	17.9	268	18.1	231						
								17.6	381	18	245	18.2	227						
								17.7	268	18.1	240	19.5	230						
								17.8	220	18.2	247	20							
								17.9	184	19	251								
								18	187	20	192								
								18.1	158										
								19	256										
								20	373										
								21											

Filename: 070197.wb1

Date **020197.**
This is transect information for gully plot.
Graphs drawn in GRAPHER, widths also collated here.

Row	*Width m(left)*	*Width m(right)*	*Comments*

no width measurements taken.

Gully Mines 4 97

Row 1 020197

Horizontal	Height (m)
5	156 G1-1
6	157 16.63 to 12.70m
7	143
8	147 G1-2
9	117 13.00 to 14.30m
10	144
10.1	168 Doesn't seem to chan
10.2	193
10.3	196
10.4	189
10.5	198
10.6	192
10.7	176
10.8	190
10.9	166
11	172
11.1	146
11.2	156
11.3	166
11.4	212
11.5	211
11.6	231
11.7	246
11.8	301
11.9	361
12	348
12.1	381
12.2	365
12.3	342
12.4	172
12.5	174
12.6	160
12.7	180
12.8	221
12.9	217
13	212
13.1	257
13.2	250
13.3	296
13.4	288
13.5	297
13.6	266
13.7	288
13.8	278
13.9	269
14	292
14.1	265
14.2	224
14.3	223
14.4	218
14.5	199
14.6	200
14.7	195
14.8	203
14.9	221
15	224
15	260
17	239
18	232
19	246
20	278

Row 2 no change

Horizontal	Height (m)
5	152 G2-1
6	95 9.75m to 10.30m
7	106
8	66 G2-2
9	81 10.70m to 12.65m
9.5	45
9.6	83 G2-3
9.7	78 12.90 to 16.28m.
9.8	124
9.9	134
10	160
10.1	131
10.2	131
10.3	122
10.4	45
10.5	15
10.6	9
10.7	8
10.8	181
10.9	189
11	183
11.1	208
11.2	252
11.3	259
11.4	228
11.5	399
11.6	418
11.7	513
11.8	583
11.9	619
12	595
12.1	486
12.2	478
12.3	409
12.4	402
12.5	264
12.6	16
12.7	78
12.8	78
12.9	79
13	267
13.1	264
13.2	234
13.3	240
13.4	334
13.5	266
13.6	342
13.7	219
13.8	277
13.9	199
14	120
14.1	161
14.2	146
14.3	124
14.4	113
14.5	171
14.6	210
14.7	232
14.8	263
14.9	278
15	365
15.1	348
15.2	228
15.3	258
15.4	224
15.5	314
15.6	364
15.7	355
15.8	419
15.9	409
16	409
16.1	392
16.2	317
16.3	300
16.4	305
16.5	318
16.6	290
16.7	291
17	295
18	278
19	237
20	229

Row 3 no change

Horizontal	Height (m)
5	229 G3-1
6	274 10.3 to 13.0m
7	201
8	197 G3-2
9	93 13.1m to 17.65m
10	86
10.1	69
10.2	49
10.3	167
10.4	214
10.5	287
10.6	307
10.7	329
10.8	371
10.9	360
11	366
11.1	321
11.2	329
11.3	354
11.4	347
11.5	348
11.6	345
11.7	313
11.8	289
11.9	291
12	237
12.1	240
12.2	228
12.3	179
12.4	125
12.5	95
12.6	142
12.7	247
12.8	225
12.9	278
13	359
13.1	391
13.2	511
13.3	519
13.4	407
13.5	409
13.6	395
13.7	460
13.8	447
13.9	398
14	311
14.1	315
14.2	312
14.3	333
14.4	235
14.5	238
14.6	248
14.7	178
14.8	179
14.9	189
15	127
15.1	86
15.2	108
15.3	281
15.4	222
15.5	237
15.6	212
15.7	249
15.8	319
15.9	347
16	332
16.1	362
16.2	403
16.3	387
16.4	391
16.5	366
16.6	412
16.7	408
16.8	437
16.9	407
17	409
17.1	352
17.2	340
17.3	377
17.4	357
17.5	311
17.6	352
17.7	333
17.8	339
17.9	364
18	352
18.1	343
18.2	364
18.3	348
18.4	316
18.5	329
18.6	326
18.7	270
18.8	269
19	275
20	171

Row 4 no change

Horizontal	Height (m)
5	242 G4-1
6	196 10.4m to 16.8m.
7	118
8	115 G4-2
9	152 17.1 to 19.6m.
10	232
10.3	113
10.4	115
10.5	89
10.6	94
10.7	132
10.8	147
10.9	154
11	178
11.1	480
11.2	435
11.3	263
11.4	343
11.5	239
11.6	206
11.7	178
11.8	198
11.9	209
12	227
12.1	234
12.2	354
12.3	371
12.4	452
12.5	436
12.6	327
12.7	351
12.8	313
13	373
13.1	400
13.2	548
13.3	493
13.4	341
13.5	426
13.6	348
13.7	345
13.8	234
13.9	224
14	183
14.1	133
14.2	294
14.3	317
14.4	293
14.5	339
14.6	340
14.7	377
14.8	382
14.9	335
15	337
15.1	333
15.2	281
15.3	240
15.4	332
15.5	334
15.6	283
15.7	258
15.8	356
15.9	319
16	285
16.1	286
16.2	274
16.3	326
16.4	323
16.5	310
16.6	327
16.7	360
16.8	364
16.9	380
17	484
17.1	462
17.2	557
17.3	557
17.4	744
17.5	737
17.6	753
17.7	680
17.8	557
17.9	541
18	542
18.1	503
18.2	476
18.3	472
18.4	457
18.5	432
18.6	417
18.7	329
18.8	417
18.9	434
19	466
19.1	574
19.2	508
19.3	492
19.4	467
19.5	456
19.6	351
19.7	306
19.8	352
19.9	370
20	394
21	402

Row 5 little change

Horizontal	Height (m)
5	307 G5-1
6	230 8.20 to 10.50m.
7	197
7.9	228 G5-2
8	67 11.15m to 15.10m.
8.1	78
8.2	113 G5-3
8.3	112 15.40m to 17.75m.
8.4	316
8.5	323
8.6	510
8.7	469
8.8	482
8.9	346
9	483
9.1	430
9.2	496
9.3	310
9.4	324
9.5	283
9.6	246
9.7	250
9.8	303
9.9	291
10	145
10.1	247
10.2	256
10.3	224
10.4	107
10.5	93
10.6	77
10.7	103
10.8	88
10.9	85
11	79
11.1	104
11.2	138
11.3	199
11.4	266
11.5	444
11.6	503
11.7	460
11.8	490
11.9	399
12	469
13.1	510
12.2	466
12.3	478
12.4	456
12.5	466
12.6	456
12.7	314
12.8	304
12.9	249
13	347
13.1	330
13.2	328
13.3	497
13.4	529
13.5	517
13.6	504
13.7	520
13.8	542
13.9	497
14	493
14.1	472
14.2	571
14.3	522
14.4	440
14.5	468
14.6	463
14.7	452
14.8	472
14.9	466
15	430
15.1	264
15.2	252
15.3	236
15.4	287
15.5	561
15.6	563
15.7	412
15.8	617
15.9	649
16	545
16.1	530
16.2	529
16.3	586
16.4	610
16.5	566
16.6	560
16.7	570
16.8	609
16.9	615
17	626
17.1	640
17.2	612
17.3	583
17.4	529
17.5	480
17.6	495
17.7	501
17.8	568
17.9	229
18	184
18.1	187
18.2	158
19	254
20	273

Row 6 no change

Horizontal	Height (m)
5	415 G6-1
6	387 6.50m to 9.90m.
6.3	382
6.4	349 G6-2
6.6	348 10.3 to 13.3m
6.7	350 G6-3
6.8	375 14.3 to 17.7m.
6.9	464
7	497
7.1	502
7.2	409
7.3	451
7.4	372
7.5	429
7.6	412
7.7	384
7.8	401
7.9	397
8	432
8.1	357
8.2	432
8.3	454
8.4	852
8.5	624
8.6	651
8.7	581
8.8	535
8.9	488
9	529
9.1	492
9.2	394
9.3	296
9.4	212
9.5	248
9.6	218
9.7	253
9.8	235
9.9	242
10	215
10.1	248
10.2	212
10.3	352
10.4	419
10.5	435
10.6	454
10.7	480
10.8	457
10.9	509
11	524
11.1	472
11.2	454
11.3	526
11.4	614
11.5	639
11.6	594
11.7	551
11.8	543
11.9	528
12	561
12.1	598
12.2	604
12.3	490
12.4	619
12.5	557
12.6	557
12.7	510
12.8	496
12.9	591
13	498
13.1	363
13.2	274
13.3	227
13.4	219
13.5	219
13.6	225
13.7	212
13.8	192
13.9	221
14	199
14.1	254
14.2	291
14.3	326
14.4	492
14.5	497
14.6	482
14.7	454
14.8	504
14.9	647
15	597
15.1	549
15.2	434
15.3	438
15.4	441
15.5	617
15.6	474
15.7	482
15.8	411
15.9	360
16	435
16.1	437
16.2	457
16.3	434
16.4	417
16.5	450
16.6	690
16.7	692
16.8	645
16.9	545
17	477
17.1	486
17.2	500
17.3	367
17.4	367
17.5	390
17.6	195
17.7	183
17.8	253
17.9	268
18	249
18.1	240
18.2	247
19	251
20	192

Row 7

Horizontal	Height (m)
3	264 G7-1
4	344 4.95 to 8.15m
4.5	222
4.7	185 G7-2
4.8	183 10.80s to 15.95m.
4.9	73
5	93
5.1	182
5.2	180
5.3	168
5.4	219
5.5	182
5.6	189
5.7	200
5.8	242
5.9	209
6	211
6.1	260
6.2	215
6.3	217
6.4	212
6.5	209
6.6	189
6.7	181
6.8	232
6.9	221
7	301
7.1	325
7.2	343
7.3	319
7.4	291
7.5	295
7.6	251
7.7	335
7.8	357
7.9	249
8	247
8.1	175
8.2	41
8.3	27
8.4	31
8.5	14
8.6	4
8.7	128
9	176
9.5	199
10	201
10.3	186
10.4	217
10.5	175
10.6	126
10.7	103
10.8	107
10.9	163
11	213
11.1	242
11.2	253
11.3	301
11.4	230
11.5	206
11.6	236
11.7	237
11.8	347
11.9	392
12	435
12.1	406
12.2	453
12.3	243
12.4	219
12.5	252
12.6	190
12.7	295
12.8	325
12.9	231
13	217
13.1	260
13.2	283
13.3	227
13.4	296
13.5	192
13.6	178
13.7	260
13.8	261
13.9	356
14	300
14.1	342
14.2	378
14.3	472
14.4	512
14.5	448
14.6	470
14.7	478
14.8	422
14.9	507
15	531
15.1	496
15.2	491
15.3	592
15.4	542
15.5	469
15.6	521
15.7	502
15.8	406
15.9	207
16	146
16.1	130
16.2	107
16.3	124
16.4	151
16.5	152
16.6	140
17	306
17.5	299
18	247
18.5	288
19	231
19.5	227
20	230

Row 8

Horizontal	Height (m)
2	282 G8-1
2.5	292 9.05m to 9.20m.
3	297
3.5	161 G8-2
4	203 9.35m to 12.00m.
4.5	153
5	117 G8-3
5.5	123 13.40m to 16.20m
6	107
6.5	116
6.6	10
6.7	121
6.8	141
6.9	142
7	135
7.1	142
7.2	173
7.3	239
7.4	215
7.5	251
7.6	209
7.7	191
7.8	196
7.9	206
8	220
8.1	209
8.2	200
8.3	206
8.4	220
8.5	236
8.6	230
8.7	215
8.8	277
8.9	232
9	218
9.1	211
9.2	246
9.3	191
9.4	201
9.5	261
9.6	288
10	326
10.5	343
10.6	373
10.7	347
10.8	408
10.9	343
11	312
11.1	321
11.2	358
11.3	317
11.4	321
11.5	349
11.6	382
11.7	371
11.8	325
11.9	307
12	310
12.1	300
12.2	286
12.5	289
13	274
13.1	256
13.2	229
13.3	248
13.4	236
13.5	272
13.6	269
13.7	442
13.8	469
13.9	503
14	526
14.1	533
14.2	503
14.3	458
14.4	476
14.5	467
14.6	422
14.7	424
14.8	363
14.9	339
15	342
15.1	325
15.2	290
15.3	336
15.4	376
15.5	336
15.6	332
15.7	352
15.8	311
15.9	390
16	343
16.1	342
16.2	268
16.3	252
16.4	263
16.5	271
16.6	322
17	400
17.5	371
18	490
18.5	359
19	327
19.5	291
20	293

Row 9

Horizontal	Height (m)
2	187 G9-1
2.5	241 11.40m to 13.30m
3	64
3.5	102 G9-2
4	65 13.6m to 17.2m
4.5	124
5	116
5.5	117
6	133
6.5	115
7	88
7.5	77
8	173
8.5	116
9	112
9.5	93
9.8	95
9.9	82
10	93
10.1	77
10.2	45
10.3	0
10.4	97
10.5	162
10.6	139
10.7	130
10.8	152
10.9	129
11	141
11.1	116
11.2	122
11.3	146
11.4	165
11.5	181
11.6	203
11.7	251
11.8	28
11.9	234
12	192
12.1	172
12.2	186
12.3	212
12.4	157
12.5	161
12.6	165
12.7	161
12.8	132
12.9	140
13	101
13.1	85
13.2	75
13.3	69
13.4	66
13.5	79
13.6	104
13.7	75
13.8	76
13.9	64
14	69
14.1	71
14.2	92
14.3	66
14.4	61
14.5	10
14.6	9
14.7	3
14.8	33
14.9	40
15	90
15.1	88
15.2	93
15.3	40
15.4	37
15.5	40
15.6	30
15.7	40
15.8	46
15.9	78
16	103
16.1	123
16.2	131
16.3	150
16.4	82
16.5	87
16.6	90
16.7	169
16.8	217
16.9	201
17	138
17.1	90
17.2	63
17.3	36
17.4	0
17.5	89
18	153
18.5	224
19	297

Row 10

Horizontal	Height (m)
2	227 G10-1
2.5	174 10.70m to 12.40m.
3	154 seat
3.5	272 G10-2
4	289 15.40m to 16.85m.
4.5	249 new gully
5	263
5.5	264
6	295
6.5	310
7	298
7.5	181
8	204
8.5	171
9	201
9.5	207
10	168
10.5	152
11	151
11.5	81
11.6	109
11.7	112
11.8	115
11.9	132
12	128
12.1	201
12.2	180
12.3	169
12.4	65
12.5	54
12.6	101
12.7	102
12.8	102
13	126
13.5	109
14	129
14.5	96
15	107
15	135
15.5	219
16	342
16.5	402
17	293
17.5	292
18	217
18.5	256
19	362
19.5	321
20	297

Filename: 020197.wb1

Tully Mine 1996.

Date 271296
This is transect information for gully plot.
Graphs drawn in GRAPHER, widths also collated here.

Row	*Width m(left)*	*Width m(right)*	*Comments*
R1-R2 (2.9m)			
1m	10.55	12.6	Width measurements from R1 at 1m and 2m.
	13.2	14.8	distance 2.9m apart.
2m	10.6	12.55	
	13.15	15.1	
R2-R3 (3.4m)			
1m	10	10.55	Width at 1m and 2m.
	11.35	13.72	distance 3.4m apart.
	15.3	16.6	
2m	10	10.35	
	10.9	12.3	
	12.7	13.7	
	15.2	17	
R3-R4 (2.6m)			
1m	10.55	15	Width at 1m.
	16.1	17.8	distance 2.6m.
R4-EP1(3m) ???			
1.5m	11.65	12.8	Width at 1.5m ??
	13.7	15.25	distance 3m ???
	15.65	17.4	
	18	20.7	
EP1-R5 (3.6)	8.75	10.6	Width measurements made at 2m from EPin 1, measmt taken from Row 5.
2m	11.2	12	Distance 3.6m.
	13.3	16.7	
R5-R6 (3.6m)			
2m	8	9.1	At 2m from R5, measure from R5.
	11.7	13	Distance 3.6m.
	13.3	15	
	15.4	17.6	
R6-EP2 (7.9m).			
3m	6.6	8	At 3m and 6m width measurments from R6.
	8.3	9	Distance 7.9m
	10.2	12.1	
6m	14.65	17.2	
	6.8	7.55	
	8.45	10.3	
	10.8	13	
	14.1	17.3	
EP2-R7 (3.6m)			
2m	5	6.1	Measuremt taken from R7, at 2m.
	7.2	8.65	
	14.1	15.2	
R7-R8 (5.7m)			
3m	7.35	8.5	Measured from R7 at 3m.
	11.6	13	
	14	16	
R8-EP3 (5.2m)			
3m	7.5	8.5	Measured from R8 at 3m
	9.2	10.9	
	11.7	14.3	
EP3-R9 (7.8m)			
			No significant deposits from below.
R9-EP4 (6.9m)			
EP4-R10(5.7m).			
R10-EP5 (9.2m).			

Filename: 281296.wk1

2.12.26

Row 1 281296

Horizontal	Height (m)	
5	196	G1-1
6	157	10.65 to 12.70
7	143	
8	147	G1-2
9	112	13.00 to 14.30
10	144	
10.1	160	
10.2	193	
10.3	158	
10.4	190	
10.5	190	
10.6	192	
10.7	194	
10.8	195	
10.9	224	
11	210	
11.1	210	
11.2	176	
11.3	224	
11.4	201	
11.5	206	
11.6	207	
11.7	202	
11.8	219	
11.9	201	
12	246	
12.1	201	
12.2	205	
12.3	247	
12.4	172	
12.5	174	
12.6	160	
12.7	180	
12.8	221	
12.9	217	
13	193	
13.1	256	
13.2	299	
13.3	353	
13.4	362	
13.5	371	
13.6	364	
13.7	299	
13.8	276	
13.9	269	
14	292	
14.1	265	
14.2	224	
14.3	223	
14.4	218	
14.5	199	
14.6	200	
14.7	193	
14.8	203	
14.9	221	
15	224	
15.1	200	
15.2	278	
15.3	232	
15.4	246	
15.5	276	

Row 2

Horizontal	Height (m)	
5	152	G2-1
6	95	9.75m to 10.30m
7	106	
8	66	G2-2
9	61	10.70m to 12.45m
9.5	45	
9.6	52	G2-3
9.7	78	12.90 to 14.20m
9.8	124	
9.9	136	
10	160	
10.1	131	
10.2	131	
10.3	122	
10.4	45	
10.5	19	
10.6	9	
10.7	8	
10.8	101	
10.9	169	
11	163	
11.1	240	
11.2	252	
11.3	259	
11.4	229	
11.5	259	
11.6	410	
11.7	512	
11.8	585	
11.9	619	
12	535	
12.1	486	
12.2	425	
12.3	409	
12.4	402	
12.5	264	
12.6	16	
12.7	78	
12.8	78	
12.9	78	
13	267	
13.1	264	
13.2	334	
13.3	340	
13.4	334	
13.5	266	
13.6	242	
13.7	219	
13.8	227	
13.9	197	
14	125	
14.1	161	
14.2	146	
14.3	124	
14.4	113	
14.5	171	
14.6	210	
14.7	232	
14.8	262	
14.9	278	
15	365	
15.1	349	
15.2	278	
15.3	258	
15.4	224	
15.5	314	
15.6	364	
15.7	355	
15.8	419	
15.9	409	
16	409	
16.1	392	
16.2	317	
16.3	300	
16.4	305	
16.5	315	
16.6	290	
16.7	291	
17	265	
18	276	
19	237	
20	229	

Row 3

Horizontal	Height (m)	
5	229	G3-1
6	274	10.2 to 15.6m.
7	201	
8	197	G3-2
9	95	15.1m to 17.85m.
10	56	
10.1	69	
10.2	49	
10.3	167	
10.4	214	
10.5	287	
10.6	307	
10.7	329	
10.8	321	
10.9	360	
11	366	
11.1	321	
11.2	329	
11.3	354	
11.4	347	
11.5	346	
11.6	345	
11.7	219	
11.8	189	
11.9	251	
12	237	
12.1	240	
12.2	299	
12.3	129	
12.4	129	
12.5	99	
12.6	162	
12.7	247	
12.8	225	
12.9	378	
13	359	
13.1	391	
13.2	511	
13.3	519	
13.4	407	
13.5	409	
13.6	395	
13.7	460	
13.8	447	
13.9	390	
14	311	
14.1	315	
14.2	312	
14.3	333	
14.4	235	
14.5	233	
14.6	248	
14.7	179	
14.8	179	
14.9	189	
15	127	
15.1	86	
15.2	188	
15.3	291	
15.4	272	
15.5	237	
15.6	212	
15.7	249	
15.8	319	
15.9	347	
16	333	
16.1	362	
16.2	403	
16.3	387	
16.4	387	
16.5	360	
16.6	412	
16.7	408	
16.8	437	
16.9	407	
17	409	
17.1	352	
17.2	348	
17.3	377	
17.4	351	
17.5	311	
17.6	352	
17.7	353	
17.8	399	
17.9	384	
18	352	
18.1	343	
18.2	364	
18.3	348	
18.4	316	
18.5	329	
18.6	326	
18.7	270	
18.8	269	
19	279	
20	177	

Row 4

Horizontal	Height (m)	
5	242	G4-1
6	196	10.4m to 16.0m.
7	118	
8	119	G4-2
9	152	17.1 to 19.6m
10	232	
10.3	113	
10.4	115	
10.5	89	
10.6	94	
10.7	132	
10.8	147	
10.9	194	
11	176	
11.1	400	
11.2	433	
11.3	263	
11.4	342	
11.5	236	
11.6	208	
11.7	179	
11.8	198	
11.9	209	
12	227	
12.1	214	
12.2	254	
12.3	371	
12.4	452	
12.5	438	
12.6	327	
12.7	351	
12.8	313	
12.9	373	
13	409	
13.1	549	
13.2	493	
13.3	341	
13.4	426	
13.5	349	
13.6	246	
13.7	389	
13.8	234	
13.9	224	
14	183	
14.1	132	
14.2	294	
14.3	317	
14.4	299	
14.5	339	
14.6	360	
14.7	377	
14.8	362	
14.9	335	
15	227	
15.1	337	
15.2	281	
15.3	240	
15.4	286	
15.5	264	
15.6	334	
15.7	283	
15.8	259	
15.9	256	
16	319	
16.1	385	
16.2	286	
16.3	274	
16.4	328	
16.5	323	
16.6	318	
16.7	327	
16.8	360	
16.9	364	
17	380	
17.1	404	
17.2	402	
17.3	357	
17.4	314	
17.5	237	
17.6	293	
17.7	386	
17.8	357	
17.9	361	
18	342	
18.1	303	
18.2	476	
18.3	472	
18.4	457	
18.5	432	
18.6	317	
18.7	523	
18.8	417	
18.9	434	
19	466	
19.1	524	
19.2	508	
19.3	497	
19.4	457	
19.5	456	
19.6	391	
19.7	306	
19.8	352	
19.9	370	
20	394	
21	402	

Row 5

Horizontal	Height (m)	
5	307	G5-1
6	230	9.20 to 10.90m.
7	197	
7.9	229	G5-2
8	87	11.10m to 14.90m.
8.1	70	
8.2	119	G5-3
8.3	119	15.40m to 17.75m.
8.4	516	
8.5	523	
8.6	510	
8.7	485	
8.8	482	
8.9	346	
9	483	
9.1	430	
9.2	495	
9.3	510	
9.4	334	
9.5	269	
9.6	248	
9.7	290	
9.8	303	
9.9	251	
10	145	
10.1	247	
10.2	230	
10.3	224	
10.4	107	
10.5	93	
10.6	77	
10.7	102	
10.8	86	
10.9	85	
11	79	
11.1	104	
11.2	138	
11.3	199	
11.4	266	
11.5	444	
11.6	503	
11.7	480	
11.8	490	
11.9	399	
12	483	
12.1	510	
12.2	486	
12.3	470	
12.4	466	
12.5	458	
12.6	456	
12.7	314	
12.8	304	
12.9	249	
13	342	
13.1	330	
13.2	328	
13.3	497	
13.4	523	
13.5	517	
13.6	504	
13.7	520	
13.8	542	
13.9	487	
14	453	
14.1	472	
14.2	571	
14.3	595	
14.4	572	
14.5	631	
14.6	583	
14.7	525	
14.8	504	
14.9	561	
15	617	
15.1	648	
15.2	543	
15.3	536	
15.4	529	
15.5	586	
15.6	610	
15.7	566	
15.8	560	
15.9	570	
16	605	
16.1	615	
16.2	626	
16.3	645	
16.4	612	
16.5	553	
16.6	528	
16.7	486	
16.8	495	
16.9	501	
17	268	
17.1	220	
17.2	184	
17.3	197	
17.4	158	
17.5	256	
17.6	273	

Row 6

Horizontal	Height (m)	
5	415	G6-1
6	387	8.50m to 9.30m.
6.3	382	
6.4	348	G6-2
6.5	349	10.3 to 13.3m
6.6	348	
6.7	350	G6-3
6.8	375	14.3 to 17.7m.
6.9	494	
7	497	
7.1	502	
7.2	409	
7.3	451	
7.4	372	
7.5	429	
7.6	417	
7.7	384	
7.8	401	
7.9	397	
8	432	
8.1	397	
8.2	432	
8.3	454	
8.4	352	
8.5	624	
8.6	681	
8.7	593	
8.8	535	
8.9	496	
9	529	
9.1	492	
9.2	354	
9.3	298	
9.4	312	
9.5	348	
9.6	218	
9.7	253	
9.8	235	
9.9	242	
10	215	
10.1	248	
10.2	272	
10.3	357	
10.4	419	
10.5	415	
10.6	454	
10.7	480	
10.8	497	
10.9	509	
11	534	
11.1	412	
11.2	484	
11.3	526	
11.4	544	
11.5	539	
11.6	504	
11.7	551	
11.8	543	
11.9	529	
12	561	
12.1	518	
12.2	504	
12.3	490	
12.4	519	
12.5	557	
12.6	547	
12.7	510	
12.8	486	
12.9	591	
13	499	
13.1	562	
13.2	574	
13.3	537	
13.4	519	
13.5	517	
13.6	519	
13.7	517	
13.8	197	
13.9	221	
14	196	
14.1	234	
14.2	291	
14.3	320	
14.4	492	
14.5	487	
14.6	482	
14.7	454	
14.8	504	
14.9	547	
15	557	
15.1	518	
15.2	434	
15.3	439	
15.4	441	
15.5	517	
15.6	474	
15.7	482	
15.8	481	
15.9	360	
16	435	
16.1	432	
16.2	457	
16.3	434	
16.4	417	
16.5	450	
16.6	660	
16.7	692	
16.8	645	
16.9	548	
17	477	
17.1	488	
17.2	500	
17.3	367	
17.4	362	
17.5	390	
17.6	395	
17.7	183	
17.8	233	
17.9	268	
18	349	
18.1	240	
18.2	247	
19	251	
20	192	

Row 7

Horizontal	Height (m)	
3	264	G7-1
4	251	4.9 to 8.18m
4.6	230	
4.7	86	G7-2
4.8	111	10.65 to 13.85m.
4.9	86	
5	146	
5.1	248	
5.2	253	
5.3	259	
5.4	192	
5.5	190	
5.6	185	
5.7	237	
5.8	266	
5.9	229	
6	248	
6.1	207	
6.2	244	
6.3	209	
6.4	200	
6.5	166	
6.6	182	
6.7	226	
6.8	274	
6.9	290	
7	333	
7.1	352	
7.2	321	
7.3	224	
7.4	300	
7.5	247	
7.6	305	
7.7	369	
7.8	222	
7.9	367	
8	63	
8.1	41	
8.2	55	
8.3	27	
8.4	36	
8.5	42	
8.6	4	
9	178	
9.5	266	
10	183	
10.3	180	
10.4	186	
10.5	211	
10.6	187	
10.7	125	
10.8	169	
10.9	221	
11	287	
11.1	321	
11.2	300	
11.3	332	
11.4	228	
11.5	197	
11.6	248	
11.7	235	
11.8	339	
11.9	334	
12	452	
12.1	309	
12.2	248	
12.3	248	
12.4	242	
12.5	317	
12.6	327	
12.7	284	
12.8	259	
12.9	214	
13	272	
13.1	222	
13.2	204	
13.3	284	
13.4	269	
13.5	294	
13.6	305	
13.7	267	
13.8	342	
13.9	397	
14	299	
14.1	318	
14.2	329	
14.3	587	
14.4	515	
14.5	515	
14.6	515	
14.7	479	
14.8	546	
14.9	525	
15	551	
15.1	532	
15.2	539	
15.3	540	
15.4	482	
15.5	490	
15.6	492	
15.7	504	
15.8	224	
15.9	127	
16	154	
16.1	151	
16.2	185	
16.3	198	
17	347	
18	247	
19	247	
20	227	

Row 8

Horizontal	Height (m)	
2	282	G8-1
2.5	257	4.95m to 9.10m
3	222	
3.5	272	G8-2
4	217	10.9m to 11.7m.
4.5	251	
5	222	G8-3
5.5	235	13.3m to 15.15m.
6	217	
6.5	92	
6.6	18	
6.7	121	
6.8	124	
6.9	129	
7	138	
7.1	148	
7.2	214	
7.3	230	
7.4	253	
7.5	254	
7.6	207	
7.7	165	
7.8	221	
7.9	217	
8	227	
8.1	237	
8.2	223	
8.3	221	
8.4	250	
8.5	263	
8.6	214	
8.7	197	
8.8	211	
8.9	225	
9	195	
9.1	156	
9.2	197	
9.3	237	
9.4	272	
9.5	349	
9.6	315	
10	378	
10.5	367	
10.6	377	
10.7	378	
10.8	329	
10.9	397	
11	330	
11.1	462	
11.2	532	
11.3	533	
11.4	526	
11.5	483	
11.6	369	
11.7	341	
11.8	309	
11.9	312	
12	297	
12.5	337	
13	263	
13.1	216	
13.2	229	
13.3	236	
13.4	264	
13.5	367	
13.6	415	
13.7	464	
13.8	511	
13.9	553	
14	577	
14.1	578	
14.2	508	
14.3	548	
14.4	542	
14.5	536	
14.6	457	
14.7	482	
14.8	420	
14.9	408	
15	399	
15.1	319	
15.2	332	
15.3	223	
15.4	241	
15.5	274	
16	229	
16.5	297	
17	287	
17.5	378	
18	464	
18.5	364	
19	309	
19.5	302	
20	294	

Row 9

Horizontal	Height (m)	
2	182	G9-1
2.5	241	9.90m to 12.70m
3	61	
3.5	102	
4	93	
4.5	124	
5	101	
5.5	108	
6	109	
6.5	93	
7	85	
7.5	47	
8	95	
8.5	103	
9	92	
9.5	86	
9.8	95	
9.8	82	
10	76	
10.1	17	
10.2	45	
10.3	0	
10.4	87	
10.5	156	
10.6	130	
10.7	130	
10.8	152	
10.9	128	
11	131	
11.1	96	
11.2	211	
11.3	197	
11.4	142	
11.5	180	
11.6	230	
11.7	224	
11.8	219	
11.9	222	
12	241	
12.1	195	
12.2	167	
12.3	182	
12.4	184	
12.5	137	
12.6	100	
12.7	104	
12.8	105	
12.9	99	
13	89	
13.1	86	
13.2	52	
13.5	82	
14	49	
14.5	71	
15	82	
15.5	61	
16	54	
16.5	95	
17	124	
17.5	90	
18	171	
18.5	234	
19	297	

Row 10

Horizontal	Height (m)	
2	247	no gullies.
2.5	185	
3	148	
3.5	291	
4	307	
4.5	349	
5	289	
5.5	290	
6	310	
6.5	339	
7	249	
7.5	208	
8	225	
8.5	209	
9	217	
9.5	205	
10	242	
10.5	271	
11	235	
11.5	201	
12	233	
12.5	121	
13	168	
13.5	124	
14	147	
14.5	193	
15	135	
15.5	219	
16	342	
16.5	402	
17	293	
17.5	282	
18	247	
18.5	256	
19	362	
19.5	321	
20	257	

191296. *Little DATA*

Row 1 Horizontal	Height (m)
12.25	30
12.3	130
12.35	100
12.4	90
13.2	120
13.3	145
13.4	204
13.5	210
13.6	205
13.7	154
13.8	175
13.9	172
14	158
14.1	155
14.2	128
14.3	116
14.4	111

Gully G1-2 13.20m to 14.4

Row 2 Horizontal	Height (m)
11.1	105
11.2	105
11.3	150
11.4	175
11.5	70
11.6	105
11.7	150
11.8	11
12	95
13	70
13.1	110
13.2	220
13.3	250
13.4	170
13.5	230
13.6	205
13.7	200
13.8	190
13.9	80
14	80
14.7	85
14.8	200
14.9	290
15	310
15.1	220
15.2	250
15.3	270
15.4	245
15.5	210
15.6	160

G2-1 11.20m to 12.00m

G2-2 13.00m to 13.90m

G2-3 14.70m to 15.60m

Row ? Horiz	t (m)
11	150
11.1	130
11.2	140
11.3	40
11.4	110
11.5	120
11.6	70
11.7	20
11.8	25
11.9	50
12	0
12.1	20
12.2	5
12.3	50
12.4	40
12.5	115
12.6	120
12.7	25
12.8	80
12.9	10
13	15
13.1	55
13.2	70
13.3	80
13.4	110
13.5	100
13.6	100
13.7	130
13.8	230
13.9	190
14	180
14.1	170
14.2	170
14.3	210
14.4	200
14.5	175
14.6	140
14.7	100
14.8	100
14.9	50
15	20
15.1	20
15.2	20
15.3	160
15.4	160
15.5	50
15.6	70
15.7	50
15.8	10
15.9	20
16	80
16.1	80
16.2	140
16.3	170
16.4	180
16.5	220
16.6	260
16.7	230
16.8	130

Row Horizontal	Height (m)
13.1	154
13.2	168
13.3	120
13.4	81
13.5	89
13.6	54
13.7	75
13.8	130
13.9	158
14	145
14.1	198
14.2	285
14.3	390
14.4	360
14.5	300
14.6	278
14.7	233
14.8	155
14.9	176
15	145
16.3	270
16.4	345
16.5	355
16.6	393
16.7	378
16.8	314
16.9	310
17	305
17.1	318
17.2	308
17.3	321
17.4	371
17.5	317
17.6	345
17.7	345

G4-1 13.10m to 15.00m

G4-2 16.40m to 17.80m

NO Row 5.

Ro Horizontal	Height (m)
10.3	320
10.4	320
10.5	370
10.6	370
10.7	350
10.8	390
10.9	400
11	260
11.1	250
11.2	260
11.3	250
11.4	230
11.5	230
11.6	230
11.7	180
11.8	180
11.9	210
12	190
12.1	260
12.2	260
12.3	230
12.4	240
12.5	200
12.6	200
12.7	220
12.8	220
12.9	180
13	170
13.1	170
13.2	240
13.3	230
13.4	200
13.5	200
13.6	190
13.7	280
13.8	195
13.9	260
14	270
14.1	340
14.2	280
14.3	280
14.4	320
14.5	340
14.6	320
14.7	250
14.8	250
14.9	340
15	300
15.1	270
15.2	580
15.3	350
15.4	350
15.5	420
15.6	400
15.7	230
15.8	120
15.9	250
16	295
16.1	350

Row ? Horizontal Height (m)

Row 8 Horizontal Height (m)

Row 9 Horizontal Height (m)

Row 10 Horizontal Height (m)

Rows 5,7,8,9 and 10 were installed on Christmas EVE.

Date 191296.
This is transect information for gully plot.
Graphs drawn in GRAPHER, widths also collated here.

Row	*Width m(left)*	*Width m(right)*	*Comments*

no width measurements taken before the 281296.

Appendix C

VOLUME COMPUTATIONS

UPPER SURFACE
Grid File: C:/SURFER6/FINAL 1310/GREUWN11-60.GRD
Grid size as read: 148 cols by 448 rows
Delta X: 0.129252
Delta Y: 0.154362
X-Range: 1 to 20
Y-Range: 1 to 70
Z-Range: 0.0742561 to 13.2

LOWER SURFACE
Grid File: C:/SURFER6/FINAL 1310/GREUWN12-60.GRD
Grid size as read: 148 cols by 448 rows
Delta X: 0.129252
Delta Y: 0.154362
X-Range: 1 to 20
Y-Range: 1 to 70
Z-Range: 0.0741444 to 13.2

VOLUMES
Approximated Volume by
Trapezoidal Rule: 5.0696
Simpson's Rule: 5.06872
Simpson's 3/8 Rule: 5.06876

CUT & FILL VOLUMES
Positive Volume [Cut]: 7.36498
Negative Volume [Fill]: 2.29538
Cut minus Fill: 5.0696

AREAS
Positive Planar Area (Upper above Lower): 683.027
Negative Planar Area (Lower above Upper): 627.973
Blanked Planar Area: 0
Total Planar Area: 1311

Positive Surface Area (Upper above Lower): 683.421
Negative Surface Area (Lower above Upper): 628.061

VOLUME COMPUTATIONS

UPPER SURFACE
Grid File: C:/SURFER6/FINAL 1310/GREUWN1-60.GRD
Grid size as read: 148 cols by 448 rows
Delta X: 0.129252
Delta Y: 0.154362
X-Range: 1 to 20
Y-Range: 1 to 70
Z-Range: 0.0744283 to 13.2

LOWER SURFACE
Grid File: C:/SURFER6/FINAL 1310/GREUWN11-60.GRD
Grid size as read: 148 cols by 448 rows
Delta X: 0.129252
Delta Y: 0.154362
X-Range: 1 to 20
Y-Range: 1 to 70
Z-Range: 0.0742561 to 13.2

VOLUMES
Approximated Volume by
Trapezoidal Rule: 1.28752
Simpson's Rule: 1.28733
Simpson's 3/8 Rule: 1.28735

CUT & FILL VOLUMES
Positive Volume [Cut]: 4.33231
Negative Volume [Fill]: 3.04472
Cut minus Fill: 1.28759

AREAS
Positive Planar Area
(Upper above Lower): 583.369
Negative Planar Area
(Lower above Upper): 727.631
Blanked Planar Area: 0
Total Planar Area: 1311

Positive Surface Area
(Upper above Lower): 583.584
Negative Surface Area
(Lower above Upper): 727.729

VOLUME COMPUTATIONS

UPPER SURFACE
Grid File: C:/SURFER6/FINAL 1310/GULLYUP.GRD
Grid size as read: 148 cols by 448 rows
Delta X: 0.129252
Delta Y: 0.154362
X-Range: 1 to 20
Y-Range: 1 to 70
Z-Range: -0.00718905 to 13.1849

LOWER SURFACE
Grid File: C:/SURFER6/FINAL 1310/GREUWN1-60.GRD
Grid size as read: 148 cols by 448 rows
Delta X: 0.129252
Delta Y: 0.154362
X-Range: 1 to 20
Y-Range: 1 to 70
Z-Range: 0.0744283 to 13.2

VOLUMES
Approximated Volume by
Trapezoidal Rule: 1.1089
Simpson's Rule: 1.1123
Simpson's 3/8 Rule: 1.1125

CUT & FILL VOLUMES
Positive Volume [Cut]: 16.6359
Negative Volume [Fill]: 15.5266
Cut minus Fill: 1.10924

AREAS
Positive Planar Area
(Upper above Lower): 710.62
Negative Planar Area
(Lower above Upper): 600.38
Blanked Planar Area: 0
Total Planar Area: 1311

Positive Surface Area
(Upper above Lower): 712.77
Negative Surface Area
(Lower above Upper): 602.112

VOLUME COMPUTATIONS

UPPER SURFACE
Grid File: C:/SURFER6/FINAL 1310/GREWN11-60.GRD
Grid size as read: 148 cols by 448 rows
Delta X: 0.129252
Delta Y: 0.131991
X-Range: 1 to 20
Y-Range: 1 to 60
Z-Range: 0.072109 to 13.1

LOWER SURFACE
Grid File: C:/SURFER6/FINAL 1310/GREWN12-60.GRD
Grid size as read: 148 cols by 448 rows
Delta X: 0.129252
Delta Y: 0.131991
X-Range: 1 to 20
Y-Range: 1 to 60
Z-Range: 0.0727892 to 13.1

VOLUMES
Approximated Volume by
Trapezoidal Rule: 1.59113
Simpson's Rule: 1.59089
Simpson's 3/8 Rule: 1.59094

CUT & FILL VOLUMES
Positive Volume [Cut]: 5.11929
Negative Volume [Fill]: 3.52803
Cut minus Fill: 1.59127

AREAS
Positive Planar Area
(Upper above Lower): 617.891
Negative Planar Area
(Lower above Upper): 503.109
Blanked Planar Area: 0
Total Planar Area: 1121

Positive Surface Area
(Upper above Lower): 618.092
Negative Surface Area
(Lower above Upper): 503.274

VOLUME COMPUTATIONS

UPPER SURFACE
Grid File: C:/SURFER6/FINAL 1310/GREWN1-60.GRD
Grid size as read: 148 cols by 448 rows
Delta X: 0.129252
Delta Y: 0.131991
X-Range: 1 to 20
Y-Range: 1 to 60
Z-Range: -0.0053389 to 13.1

LOWER SURFACE
Grid File: C:/SURFER6/FINAL 1310/GREWN11-60.GRD
Grid size as read: 148 cols by 448 rows
Delta X: 0.129252
Delta Y: 0.131991
X-Range: 1 to 20
Y-Range: 1 to 60
Z-Range: 0.072109 to 13.1

VOLUMES
Approximated Volume by
Trapezoidal Rule: -2.93096
Simpson's Rule: -2.93613
Simpson's 3/8 Rule: -2.93599

CUT & FILL VOLUMES
Positive Volume [Cut]: 10.3875
Negative Volume [Fill]: 13.3183
Cut minus Fill: -2.93076

AREAS
Positive Planar Area
(Upper above Lower): 562.34
Negative Planar Area
(Lower above Upper): 558.66
Blanked Planar Area: 0
Total Planar Area: 1121

Positive Surface Area
(Upper above Lower): 565.196
Negative Surface Area
(Lower above Upper): 562.677

VOLUME COMPUTATIONS

UPPER SURFACE
Grid File: C:/SURFER6/FINAL 1310/GULLY.GRD
Grid size as read: 148 cols by 448 rows
Delta X: 0.129252
Delta Y: 0.131991
X-Range: 1 to 20
Y-Range: 1 to 60
Z-Range: -0.00718805 to 13.091

LOWER SURFACE
Grid File: C:/SURFER6/FINAL 1310/GREWN1-60.GRD
Grid size as read: 148 cols by 448 rows
Delta X: 0.129252
Delta Y: 0.131991
X-Range: 1 to 20
Y-Range: 1 to 60
Z-Range: -0.0053389 to 13.1

VOLUMES
Approximated Volume by
Trapezoidal Rule: -25.7291
Simpson's Rule: -25.7336
Simpson's 3/8 Rule: -25.7344

CUT & FILL VOLUMES
Positive Volume [Cut]: 49.0484
Negative Volume [Fill]: 74.7779
Cut minus Fill: -25.7295

AREAS
Positive Planar Area
(Upper above Lower): 434.924
Negative Planar Area
(Lower above Upper): 686.076
Blanked Planar Area: 0
Total Planar Area: 1121

Positive Surface Area
(Upper above Lower): 471.65
Negative Surface Area
(Lower above Upper): 695.702

VOLUME COMPUTATIONS

UPPER SURFACE
Grid File: C:/SURFER6/FINAL 1310/GREUPW1-60.GRD
Grid size as read: 148 cols by 448 rows
Delta X: 0.129252
Delta Y: 0.154362
X-Range: 1 to 20
Y-Range: 1 to 70
Z-Range: 0.0725886 to 13.2

LOWER SURFACE
Grid File: C:/SURFER6/FINAL 1310/GREUPW2-60.GRD
Grid size as read: 148 cols by 448 rows
Delta X: 0.129252
Delta Y: 0.154362
X-Range: 1 to 20
Y-Range: 1 to 70
Z-Range: 0.071882 to 13.2

VOLUMES
Approximated Volume by
Trapezoidal Rule: 9.04404
Simpson's Rule: 9.04275
Simpson's 3/8 Rule: 9.04265

CUT & FILL VOLUMES
Positive Volume [Cut]: 20.6759
Negative Volume [Fill]: 11.632
Cut minus Fill: 9.04393

AREAS
Positive Planar Area
(Upper above Lower): 504.476
Negative Planar Area
(Lower above Upper): 806.524
Blanked Planar Area: 0
Total Planar Area: 1311

Positive Surface Area
(Upper above Lower): 511.321
Negative Surface Area
(Lower above Upper): 806.854

VOLUME COMPUTATIONS

UPPER SURFACE
Grid File: C:/SURFER6/FINAL 1310/GREUPW-60.GRD
Grid size as read: 148 cols by 448 rows
Delta X: 0.129252
Delta Y: 0.154362
X-Range: 1 to 20
Y-Range: 1 to 70
Z-Range: 0.073895 to 13.2

LOWER SURFACE
Grid File: C:/SURFER6/FINAL 1310/GREUPW1-60.GRD
Grid size as read: 148 cols by 448 rows
Delta X: 0.129252
Delta Y: 0.154362
X-Range: 1 to 20
Y-Range: 1 to 70
Z-Range: 0.0725886 to 13.2

VOLUMES
Approximated Volume by
Trapezoidal Rule: 1.04362
Simpson's Rule: 1.04256
Simpson's 3/8 Rule: 1.04237

CUT & FILL VOLUMES
Positive Volume [Cut]: 12.1965
Negative Volume [Fill]: 11.1532
Cut minus Fill: 1.04326

AREAS
Positive Planar Area
(Upper above Lower): 467.003
Negative Planar Area
(Lower above Upper): 843.997
Blanked Planar Area: 0
Total Planar Area: 1311

Positive Surface Area
(Upper above Lower): 469.957
Negative Surface Area
(Lower above Upper): 844.313

VOLUME COMPUTATIONS

UPPER SURFACE
Grid File: C:/SURFER6/FINAL 1310/GULLYUP.GRD
Grid size as read: 148 cols by 448 rows
Delta X: 0.129252
Delta Y: 0.154362
X-Range: 1 to 20
Y-Range: 1 to 70
Z-Range: -0.00718905 to 13.1849

LOWER SURFACE
Grid File: C:/SURFER6/FINAL 1310/GREUPW-60.GRD
Grid size as read: 148 cols by 448 rows
Delta X: 0.129252
Delta Y: 0.154362
X-Range: 1 to 20
Y-Range: 1 to 70
Z-Range: 0.073895 to 13.2

VOLUMES
Approximated Volume by
Trapezoidal Rule: -0.582538
Simpson's Rule: -0.578776
Simpson's 3/8 Rule: -0.578766

CUT & FILL VOLUMES
Positive Volume [Cut]: 15.4438
Negative Volume [Fill]: 16.0265
Cut minus Fill: -0.582666

AREAS
Positive Planar Area
(Upper above Lower): 638.639
Negative Planar Area
(Lower above Upper): 672.361
Blanked Planar Area: 0
Total Planar Area: 1311

Positive Surface Area
(Upper above Lower): 641.556
Negative Surface Area
(Lower above Upper): 673.715

VOLUME COMPUTATIONS

UPPER SURFACE
Grid File: C:/SURFER6/FINAL 1310/GRERODW1-60.GRD
Grid size as read: 148 cols by 448 rows
Delta X: 0.129252
Delta Y: 0.131991
X-Range: 1 to 20
Y-Range: 1 to 60
Z-Range: 0.0386643 to 13.1

LOWER SURFACE
Grid File: C:/SURFER6/FINAL 1310/GRERODW2-60.GRD
Grid size as read: 148 cols by 448 rows
Delta X: 0.129252
Delta Y: 0.131991
X-Range: 1 to 20
Y-Range: 1 to 60
Z-Range: 0.0391576 to 13.1

VOLUMES
Approximated Volume by
Trapezoidal Rule: 9.41993
Simpson's Rule: 9.41612
Simpson's 3/8 Rule: 9.41618

CUT & FILL VOLUMES
Positive Volume [Cut]: 17.0696
Negative Volume [Fill]: 7.65
Cut minus Fill: 9.41964

AREAS
Positive Planar Area
(Upper above Lower): 491.6
Negative Planar Area
(Lower above Upper): 629.4
Blanked Planar Area: 0
Total Planar Area: 1121

Positive Surface Area
(Upper above Lower): 497.12
Negative Surface Area
(Lower above Upper): 629.652

VOLUME COMPUTATIONS

UPPER SURFACE
Grid File: C:/SURFER6/FINAL 1310/GRERODW-60.GRD
Grid size as read: 148 cols by 448 rows
Delta X: 0.129252
Delta Y: 0.131991
X-Range: 1 to 20
Y-Range: 1 to 60
Z-Range: 0.0387761 to 13.1

LOWER SURFACE
Grid File: C:/SURFER6/FINAL 1310/GRERODW1-60.GRD
Grid size as read: 148 cols by 448 rows
Delta X: 0.129252
Delta Y: 0.131991
X-Range: 1 to 20
Y-Range: 1 to 60
Z-Range: 0.0386643 to 13.1

VOLUMES
Approximated Volume by
Trapezoidal Rule: 5.17578
Simpson's Rule: 5.17419
Simpson's 3/8 Rule: 5.17424

CUT & FILL VOLUMES
Positive Volume [Cut]: 12.263
Negative Volume [Fill]: 7.08735
Cut minus Fill: 5.17563

AREAS
Positive Planar Area
(Upper above Lower): 481.085
Negative Planar Area
(Lower above Upper): 639.915
Blanked Planar Area: 0
Total Planar Area: 1121

Positive Surface Area
(Upper above Lower): 483.911
Negative Surface Area
(Lower above Upper): 640.104

VOLUME COMPUTATIONS

UPPER SURFACE
Grid File: C:/SURFER6/FINAL 1310/GULLY.GRD
Grid size as read: 148 cols by 448 rows
Delta X: 0.129252
Delta Y: 0.131991
X-Range: 1 to 20
Y-Range: 1 to 60
Z-Range: -0.00718805 to 13.091

LOWER SURFACE
Grid File: C:/SURFER6/FINAL 1310/GRERODW-60.GRD
Grid size as read: 148 cols by 448 rows
Delta X: 0.129252
Delta Y: 0.131991
X-Range: 1 to 20
Y-Range: 1 to 60
Z-Range: 0.0387761 to 13.1

VOLUMES
Approximated Volume by
Trapezoidal Rule: 6.04445
Simpson's Rule: 6.04578
Simpson's 3/8 Rule: 6.04592

CUT & FILL VOLUMES
Positive Volume [Cut]: 21.8192
Negative Volume [Fill]: 15.775
Cut minus Fill: 6.04417

AREAS
Positive Planar Area
(Upper above Lower): 524.06
Negative Planar Area
(Lower above Upper): 596.94
Blanked Planar Area: 0
Total Planar Area: 1121

Positive Surface Area
(Upper above Lower): 530.518
Negative Surface Area
(Lower above Upper): 598.255

Appendix D

Consequently to the cessation of monitoring period, during the dry season (June), field samples were taken to gauge some of the characteristics of waste rock material from the batter site.

Three sites were investigated by the geomorphology group at ***eriss***, and moisture content and bulk density determined.

Bulk density defined as weight of rock smaple divided by total volume, including porosity. Moisture content for this purpose refers to a difference between dry and wet weight of the sample.

The total weight of wet soil sample and the volume occupied as determined using standard techniques.

On each of the 3 sites, 3 samples were taken and examined.

Average bulk Density was determined to be 1.93 g/cm^3.

Table D-1: Bulk Density determination series 3 samples taken at 3 locations.

Sample	Soil Mass (Wet)	Soil Mass (Dry)	Volume (cc)	Bulk Density	Moisture Content (%)
1A	481.55	479.94	286.67	1.67	0.38
1B	678.44	674.37	377.65	1.79	0.60
1C	536.05	533.09	294.83	1.81	0.55
2A	484.99	482.43	226.51	2.13	0.53
2B	526.94	524.77	275.73	1.90	0.41
2C	513.70	512.10	273.91	1.87	0.31
3A	345.32	342.50	180.61	1.89	0.82
3B	299.21	296.84	140.43	2.11	0.79
3C	249.96	247.98	111.25	2.23	0.79