BEFORE THE ENVIRONMENT COURT | ENV-2010-WLG-00148

UNDER	the Resource Management Act 1991
IN THE MATTER	of an appeal under clause 14 of the First Schedule of the Act
BETWEEN	**FEDERATED FARMERS OF NEW ZEALAND** **ENV-2010-WLG-000148** **Appellant**
AND	**MANAWATU-WANGANUI REGIONAL COUNCIL** **Respondent**

STATEMENT OF TECHNICAL EVIDENCE BY
DR JOHN (JACK) ALLEN McCONCHIE

on behalf of

FEDERATED FARMERS
MICHAEL PETERSEN &
TAUMARANUI FARMERS' GROUP 2008

INTRODUCTION

Qualifications and experience

1. My full name is Dr John (Jack) Allen McConchie. I am the Principal Water Resources Scientist working for Opus International Consultants Ltd (**Opus**).

2. I hold the following academic qualifications:

    - BSc (with First Class Honours); and a
    - PhD.

3. My experience that is relevant to the evidence I am about to provide includes that, prior to the start of 2008, I was an Associate Professor with the School of Earth Sciences at Victoria University of Wellington. I taught undergraduate courses in geomorphology and hydrology, and a post-graduate course in hydrology and water resources. For more than 30 years my research focused on various aspects of hydrology and geomorphology, including slope and surface water hydrology, hydrometric analysis, flood hazard assessments and hydraulic modelling, landscape evolution, slope stability and erosion, natural hazards, slope and fluvial coupling, soil-water interactions, fluvial geomorphology including sediment transport, bank erosion and sedimentation, and the impact of 'extreme' events. The majority of this research has been undertaken throughout the Wellington Region, in Wairarapa, and in Hawkes Bay; although I have worked extensively throughout the lower North Island.

4. Within these fields I have edited one book. I have written or co-authored 10 book chapters, and over 40 internationally-refereed scientific publications. A number of these publications relate to detailed research of slope instability in rural Wairarapa and Hawkes Bay.

5. I am a member of the Australia-New Zealand Geomorphology Group, the New Zealand Geographical Society, the American Geophysical Union, the New Zealand Hydrological Society, and the Environment Institute of Australia and New Zealand.

6. I was the New Zealand Geographical Society representative on the Joint New Zealand Earth Science Societies' Working Group on Geopreservation. This group produced a discussion paper *'Landforms and geological features: a case for preservation'* published by the Nature Conservation Council in 1988. It also developed the first geopreservation inventory for the country, published in 1990 as the New Zealand Landform Inventory.

7. Of particular relevance to this hearing, I:

a) Published a paper in the international literature on the distribution of landslips in the Wairarapa hill country following the 1977 district-wide event;

b) Completed my PhD thesis on the soil-water interactions, characteristics and dynamics of deep-seated seasonal earthflows. This resulted in a number of peer-reviewed international publications;

c) Have presented numerous conference publications on the controls, triggering and mechanics of landslips within Wairarapa and Hawkes Bay;

d) Visited the Pottinger farm at Tinui immediately following the 1988 'weather bomb';

e) Organised and ran numerous field trips over many years throughout the lower North Island hill country investigating slope and hydrological processes; including the impact of shallow soil slips, soil loss, and slope and fluvial coupling; and

f) Am an 'Independent technical advisor' for the New Zealand Transport Agency (**NZTA**) on hydrology, stormwater management, and climate change.

8. As a result of this experience, I have extensive and detailed knowledge of the physical environmental processes, including hill country erosion and hydrology in areas such as found throughout Horizon's region.

Code of Conduct for Expert Witnesses

9. I confirm that I have read, and am familiar with, the Code of Conduct for Expert Witnesses in the Environment Court Consolidated Practice Note (2006). I agree to comply with that Code. Other than where I state that I am relying on the evidence of another person, my evidence is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

EXECUTIVE SUMMARY

10. In this evidence I would like to clear up a number of misunderstandings, misconceptions and errors concerning mass movement erosion, landscape evolution, and the impact of human activities in hillcountry terrain.

11. In particular, I would like to illustrate that the current level of understanding of mass movement processes restricts our ability to accurately identify future erosion sites in a robust and reliable manner. Determining whether these potential erosion sites will contribute sediment to the stream network is even more problematic.

12. I would also like to provide some basic information relating to the natural processes operating within hillcountry terrain. It is hoped that as a result of my evidence decisions will be able to be made based on fact and reality rather than supposition and emotion.

13. There are a number of specific issues on which I will present evidence:

a) No area of sloping ground can be regarded as being completely free from the risk of instability: assessments of slope stability are therefore assessments of the probabilities of failure. These probabilities change over time.

b) Erosion within hillcountry terrain is natural and to be expected at some level. This erosion explains largely the form and character of the landscape. The 'natural' level of erosion needs to be known and clearly defined if human impacts are to be placed in context. The fact that mass movement erosion is variable in both time and space makes the definition of 'natural' erosion, either at a place or through time, extremely difficult. However, without such a context any discussion of acceleration, control, or minimization etc. has no foundation.

c) Realistic predictive mathematical analyses of slope stability cannot be carried out for natural slopes. This is because stability is controlled by the presence of 'imperfections' in slope materials. Predictive models are usually only relevant for artificial slopes where the material properties are known and can be engineered to behave in a particular manner.

d) Research undertaken in Wairarapa, Hawkes Bay, Wellington and other places has identified a clear link between weather patterns, storminess, and hillcountry slope instability. A valid assumption is that adverse weather patterns will arrive at irregular intervals in the future as they have in the past. The frequency and magnitude of erosion is, however, also strongly linked to slope, geology, vegetation, roading, and land use.

e) These investigations have confirmed that mass movement activity in New Zealand has been discontinuous and variable in its intensity for many thousands of years. This makes it increasingly difficult (if it was ever possible) to distinguish between 'natural' and 'accelerated' (human initiated) erosion. There are many occasions in which landslides have occurred in mature forest (presumably close to its natural state) alongside landslides occurring on pasture land during the same event.

f) Sediment cores taken from a valley floor in Wairarapa showed the presence of five separate mass movement deposits of material similar to that from 1977 landslip event. The 1977 and 1961 erosion episodes were easily identified. There were three earlier deposits which were assumed to be younger than 100-130 years i.e., since forest clearance and European land use. However the radiocarbon dates of these deposits were 533±59, 1580±90 and 3290±190.

g) The earlier events identified in these cores therefore occurred on forested slopes. Reforestation and erosion control measures therefore cannot be considered a 'guarantee' against future landslide activity. Furthermore, current land use practices cannot be considered a causative factor in all landslide episodes.

h) It is therefore neither appropriate, nor possible, to designate the common rural forms of mass movement as 'natural' or 'accelerated' by field observation.

i) It must also be recognised that the major products of this erosion are the floodplains, terraces and dunes which are critical to the character, dynamics, wealth and economic viability of the Horizon's region.

j) The reality is that the highly productive floodplains, terraces, and other low lying areas would not exist without erosion in the headwaters.

k) Much of the motivation behind the policies and regulations within the One Plan appears to be to control flooding of floodplains. Floods will continue to occur on floodplains. During the 2004 event no areas were flooded that were not previously recognised as floodplains. It is significant that the full extents of these floodplains were not inundated. Therefore more extreme events have occurred in the past and can therefore be expected in the future.

l) The longer floodplains are occupied and used by humans, the bigger the floods and more severe the erosion events that will be encountered. This is a statistical and environmental reality.

m) Just because humans occupy and exploit the assets of floodplains does not mean that the natural processes that led to their formation will cease. Intermittent flood events must be regarded as a natural 'tax' on the use of such environmental resources.

n) Therefore both erosion and deposition are natural processes. They will continue to occur despite human intervention.

o) Multi-occurrence landslide events, such as that in February 2004, have occurred in the past and will occur again in the future.

p) Such events, however, have been shown to increase the resistance of the slopes. Future landslip events therefore require greater triggering rainfalls, and by definition must be less frequent. Consequently future events are less likely than in the past.

q) Erosion scars from shallow soil slips are some of the most stable elements of the landscape as all the loose unconsolidated material has been removed. Therefore, measuring erosion scars is not a measure of potential instability. In reality it only measures past instability, and as a consequence improved stability. All studies have shown that repeated failure of shallow soil slips does not occur. The location of future soil slips is related to the distribution of undisturbed slope material rather than past slope failures.

r) Therefore, while a slope stability assessment prior to such a major triggering event may have had some validity, using the slips that occurred to indicate future instability is misleading and actually inappropriate.

s) Studies have also shown that while numerous shallow soil slips might appear 'severe', such slope failures are in fact responsible for little of the material entering rivers and streams.

t) Therefore, defining erosion susceptibility from some forms of mass movement e.g. debris flows, landslides and shallow soil slips on the basis of erosion scars is illogical and incorrrect. Therefore, the criteria and definition of Hillcountry Erosion Management Areas (HEMA) in the One Plan are wrong in fact. This probably explains the relatively low incidence of landslips in this terrain during 2004 found by Council studies.

u) Likewise, it is largely irrelevant and ineffective to treat or manage erosion on many types of already failed slopes. This is because once a slope has failed it has lost all the easily erodible material. Such sites are likely to be some of the more stable areas within a catchment without any erosion control.

v) Most of the material from soil slips also remains on the slope, or in higher order drainage channels. This prevents its movement down the fluvial system. This has been confirmed by various studies commissioned by the Horizon's Regional Council.

w) Of the 21,200km^2 surveyed by Horizons after the 2004 event, 0.9% was affected by landslides. That is, 99.1% was not affected and was therefore stable despite the extreme nature of the 2004 triggering event.

x) Of the land that was identified as 'susceptible to landsliding' only 26% experienced landslides. That is, 74% of the so called high risk land remained stable despite the extreme magnitude of the storm triggering rainfall. The argument that such areas are generally susceptible to land sliding therefore cannot be sustained.

y) Much of the land classified as HEMA is therefore some of the more resistant within the region, rather than the most problematic. The most erodible lands are actually likely to be the floodplains, dunes, gullies, and deep-seated earthflows and not the Tertiary hillcountry.

z) The use of the term HEMA is therefore emotive, wrong, highly misleading. It potentially directs attention and resources into areas where the returns are likely to be minimal.

aa) Landslides do and will continue to occur even under forest. Such landslides, while of lower frequency, are generally bigger and more problematic as they include significant volumes of woody debris. This acts as a 'rasp', incorporating more material from the channel and increases the risk of debris torrents. It is generally acknowledged that much of the damage to infrastructure during the 2004 event was caused by woody debris in the river channels, not sediment.

bb) Even properties with the best soil conservation measures can be affected catastrophically should the triggering rainfalls be large enough. Because of the loss of the conservation works, as well as the soil, the actual losses in such situations may be extremely high.

cc) In 1988 a 'weather bomb exploded' over Tinui in Wairarapa. This had dramatic consequences in terms of slope instability, soil erosion, flooding, and sedimentation. Immediately after the event I visited the Pottinger property behind Tinui. Jim Pottinger had been the Deputy Chair of the Wairarapa Catchment Board for a number of years prior to the weather bomb. His property was a 'show piece' of all the latest soil conservation and erosion control techniques. The property was often used for field days, and visited by international experts to view New Zealand's approach to soil conservation.

dd) During this weather bomb many of the better producing and well managed slopes failed, bringing down with them all the various erosion control measures which had been implemented. When talking to Jim Pottinger I can quite clearly remember him looking at the scarred hill sides and saying *"I had done everything possible to improve stability and still look at what happened. What more could I have done."* The truth is probably nothing.

ee) Slope failures are not triggered by slope angle but by intense or prolonged rainfall. Consideration of the hydraulic conditions within the slope is therefore essential for any valid and robust regional slope instability model.

ff) An erosion management model based on a single slope angle, or the land unit approach of the Land Use Classification (LUC), for the entire region is inappropriate. It casts an unreasonable, overly conservative, and unjustifiable 'net' over the landscape. Many persons would need to apply for resource consents when on investigation they will be found to be unnecessary. This will impose considerable financial cost, cause significant delays in implementing management decisions, and place a major burden on Council staff.

gg) To ensure sound and informed decisions regarding erosion it is necessary to create a realistic, and accurate, model of actual and possibly potential erosion sites. This model requires consideration of all the major factors that influence erosion. These include lithology, soil cohesion, internal angle of friction, slope angle, slope form, weight of soil, slope hydrology - which in turn is controlled by the drainage characteristics of the soil, vegetation type, and the incidence of previous landslips.

hh) It is possible to develop a robust regional slope stability model using existing data sources. Such a model does not rely on the availability of LiDAR data (high resolution topographic data obtained from an airborne laser survey); although this would improve the resolution and reliability of the model. Assuming that the accuracy of slope measures derived from existing topographic data is accepted the same information could be used to derive slope form indices. Regional soil and geologic data likewise already exist.

ii) The location of previous failures, such as those that occurred in 2004, is not a good indication of possible future failures. Once the weak material has been removed, as happens with shallow slope failures, sites actually increase in resistance. This has been shown in all areas affected by shallow soil slips in New Zealand and overseas. As a result, catchments tend to have become more resistant over time.

jj) The use of very extreme events to establish slope instability thresholds biases the results by producing artificially low values. The effect of this is to establish significantly higher thresholds for risk mitigation than for other environmental hazards. To use the 2004 events to establish minimum stability thresholds is to apply a risk of less than 1 in 150 years. For most other hazards mapped at the regional scale e.g., floods, a 1:50 year or 1:100 year risk level is usually adopted. A threshold based on a 1:150 year event therefore places much higher standards on farmers than for any other persons living within the region. This is inequitable.

kk) Having set an equitable level of acceptable risk for all persons the design storm can be defined. This will allow the regional slope instability model to be tuned to particular hydrologic conditions based on slope form and position. The appropriate threshold values for different combinations of factors could then be defined and quantified. Such an approach would ensure that all persons, and activities, within the Horizon's region are treated equitably and fairly.

ll) Once a model of potentially unstable areas has been developed it is unnecessary to further delineate, or designate, these areas as HEMA. All areas within the region potentially prone to slope failures must be treated in the same manner. That is, any model should not just consider land under pastoral land use. This is the current situation with respect to the 'Dymond map of Highly Erodible Land (HEL)'. To treat erosion irrespective of vegetation cover ensures equity throughout the community. To treat farmers in particular areas differently from those in other areas with the same potential problem is not reasonable. It is the problem that must be addressed, not particular land uses. The erosion 'problem' must then be managed consistently throughout the entire region. The designation of particular land as HEL or HEMA is therefore unnecessary, misleading, and inequitable.

mm) Once a threshold is established for a particular set of criteria it is inappropriate to extrapolate this out to the limit of a LUC class or the property boundary such as recommended at present. If sufficient evidence exists that certain slopes are potentially unstable, the same evidence must also confirm the stability of the remaining land on the property. To extrapolate higher risk areas onto stable areas seriously questions the approach and methodology adopted to assess the risk.

nn) Data collected following the 2004 storm event indicate that vegetation must be older than approximately 10 years to provide significant improvement in slope stability. Vegetation affects the hydraulic conditions of the slope, and increases the effective cohesion of the regolith. It is the size and extent of the root system that largely determines the effect of vegetation. While the root network is often related to age, it is actually controlled by the species, soil, climate, and growing conditions. It is therefore suggested that rather than using an essentially arbitrary age criterion for vegetation clearance, this should be based on stem diameter or canopy cover. Both stem diameter and canopy cover are relatively easy to assess in the field. They do not require coring of the main stem to determine age.

oo) The problems of aggradation and reduced flood capacity of the Manawatu River are a response largely to human interference on the piedmont slopes, and via flood protection works, not hillcountry land management. This is acknowledged in the Council's own reports.

pp) The Whanganui catchment is distinctly different to both the Manawatu and Rangitikei catchments. The problems of one system therefore cannot be transferred to the others.

qq) The limited data that are available for the Whanganui suggests that the bed is degrading. The river is under-loaded with sediment. That is, any sediment removal in the upper catchment is not adversely affecting the river's flood capacity. The argument for controlling hillcountry land use to control aggradation is therefore unfounded.

rr) The One Plan argues that a range of controls are necessary for the sustainable management of the HEMA. Farm production across these areas has risen significantly despite limited erosion. The farms are still profitable. This would suggest that current land management and decision-making by the farmers are sustainable.

ss) The current mapping of HEL/HEMA fails to recognise the dynamic nature of mass movement processes, and in particular whether a specific site is relict or continues to provide sediment to a catchment. The mapping process also over-estimates the potential erosion problem by extrapolating site-specific erosion features across a wider area.

tt) Mapping erosion areas should focus specifically on those areas currently providing sediment to the stream and channel network. To direct attention to other areas, which may or may not potentially provide sediment, will dissipate and therefore significantly reduce the potential benefits to the community from erosion control practices.

14. On balance, it is my professional opinion that the decisions of the hearing panel are essentially sound. These decisions recognise the inherent uncertainty of physical environmental processes, and the role of human activities. While there are a number of practical issues which would need to be resolved e.g. the determination of appropriate slope angles, these could be addressed through workshops and information booklets. Many of the practical issues at a site-specific level could be addressed through the recognition of 'best practice' and industry codes of practice. The employment of recognised experienced contractors for specific projects would be an efficient and effective way of achieving the various policy objectives.

COMMENT ON PROPOSED RULES

15. *Rule 12-1A Small scale land disturbance including earthworks.* On balance I would support this rule but believe that the limit of 2500m² per property should relate to a contiguous area rather than the total area of disturbance across the entire property. For example, on a larger property five areas of 500m² would breach this rule, but the potential for adverse environmental effects would be extremely low. It should also be recognised that work of this scale would take a bulldozer less than 30mins.

a) The standard conditions should provide for the adoption of industry codes of practice by contractors and endorsed by Horizon's Regional Council. Contractors operating to accepted 'best practice' standards will ensure that all works are undertaken to minimise any potential adverse effects.

b) The condition regarding the discharge of sediment should recognise the 'field application' of such a standard. I would propose that the condition refer to a 'noticeable change in colour and clarity' rather than referring to a precise 'technical standard' derived from either laboratory or field analysis.

c) The recognition of a threshold slope angle, while not ideal, would be simple to implement if guidance was provided as to how and where the slope was to be measured.

d) The conditions regarding distance of the activity from a river bed and lake indicates that a 'prioritising' of potential effects is recognised for areas with different attributes. This is reasonable; however, this hierarchy could be stated explicitly. A clearer link of those habitats, wetlands, and trout spawning areas which must be considered to Schedule AB should also be made. At present, condition (d) and (h) in particular do state that these features are contained in Schedule AB. This leaves interpretation as to what is a wetland etc. extremely broad. This would not appear to be the intention of this condition.

e) With respect to controlling sediment transfer to a river or stream the effects of riparian vegetation decrease exponentially with increasing distance from the channel or water body i.e. the greatest benefits are achieved from vegetation close to the channel. A 5m threshold would maximise the potential benefits of trapping any sediment while minimising loss of potential production.

16. *Rule 12-1 Large scale land disturbance including earthworks.* On balance I would support this rule for the reasons stated earlier. However, I believe that a permitted activity status would be more appropriate for such works.

a) The threshold of 2500m² per property should again relate to a contiguous area rather than the total area across the entire property for the reasons as discussed earlier.

b) I certainly endorse the need for an Erosion and Sediment Control plan as defined in the glossary for such an activity. Any plan should apply best practice to minimise erosion and the runoff of sediment.

c) The recognition of a threshold slope angle, while not ideal, would be simple to implement if guidance was provided as to how and where the slope was to be measured.

d) Condition (c) relating to water quality is too complicated and technical for practical application. More simple criteria such as a 'noticeable change in colour and clarity' would be easier to assess in the field, and to enforce should this be necessary.

e) The conditions regarding distance of the activity from a river bed and lake indicates that a 'prioritising' of potential effects is recognised for areas with different attributes. This is reasonable, however, this hierarchy could be stated explicitly. A clearer link of those habitats, wetlands, and trout spawning areas which must be considered to Schedule AB should also be made. At present, condition (d) and (h) in particular do state that these features are contained in Schedule AB. This leaves interpretation as to what is a wetland etc. extremely broad. This would not appear to be the intention of this condition.

f) Contractors should be encouraged to apply 'best practice' through and industry Code of Practice which has been endorsed by Horizon's Regional Council.

17. *Rule 12-3 Cultivation.* Again, I would support this rule but with the suggested changes to conditions discussed previously regarding the assessment of water quality, and distance from water bodies and distinctive habitats. It is particularly pleasing to see the recognition of the value of industry Codes of Practice.

a) With regard to the distance of cultivation from rivers etc. it should be recognised that a range of active soil erosion control practices exist control sediment movement. These practices are significantly more effective than passive land management. This rule should therefore provide scope for the implementation of these practices rather than relying solely on distance of the activity from a water body.

18. *Rule 12-4A Vegetation clearance.* I would generally support this rule. It is pleasing that this rule recognises the '*contiguous nature*' of the vegetation to be cleared. This is consistent with what I have suggested for *Rules 12-1A and 12-1*. I would suggest that the various minor modifications to the general conditions discussed above relating to distance from the beds of rivers, water quality, and habitats be also adopted for *Rule 12-4A*.

19. I would support *Rules 12-4, 12-5, and 12-5A*.

REGIONAL SITUATION

20. The conceptual model of erosion and sediment transport within the Horizon's region is often summarised as in Figure 1. Material is eroded from the mountains and hillcountry and then transported to the coast via rivers and streams.

21. Such a model, however, fails to recognise that rather than a continuous 'conveyor belt', the system is episodic and contains numerous sediment stores. Sediment can remain in these stores for periods up to 1000s of years. Material can be eroded from one portion of the landscape but then be stored, and essentially become stable, in another. This material may then be remobilised at some later time without any change to the original source.

22. At the current time approximately 30% of the Horizon's region is lowland (essentially floodplains, terraces, and dunes), 12% mountain lands, and 58% hillcountry.

23. The erosion of material from the headwaters of the various streams and rivers has created the extensive and productive terraces and floodplains. Without these deposits of eroded debris, the region would be at least 30% smaller. The region would also have no floodplains, terraces and dunes which are critical to the character, dynamics, wealth and economic viability of the region. The locations for most of the urban centres would also not exist.

24. Exploitation of such areas, however, means that considerable investment is currently at risk from the same natural processes that created these environmental assets. These assets consequently become, on occasion, liabilities. It is this apparent environmental contradiction that the One Plan is trying to address.

25. Much of the One Plan appears to be developed in the belief that we can control the natural physical processes operating within our dynamic landscape. While on occasion we can interrupt or modify the natural environmental processes, eventually these processes change or break free from their human 'shackles' e.g., the 2004 flood events.

26. The landscape is not static, and just because we utilise the resources does not mean that natural processes will stop.

PHILOSOPHICAL FRAMEWORK

27. Section 32 reports with regard to land state that *"Land management issues stem mainly from the effects of human activities on land."* While some land management issues relate to human activity, those aimed to be addressed in the Land Section of the One Plan actually appear to have been stimulated by the land's effect on human activities. This misconception indicates a lack of understanding of the actual natural physical processes operating within the Horizon's region.

28. Statements on slope instability, magnitude of erosion, and costs and benefits of associated soil conservation programmes have little meaning unless they are placed in some clearly defined time frame. Neither the erosion 'problem', nor the effectiveness of its solution, can be properly judged without such a reference.

29. Long term soil conservation and land management programmes instigated in response to inevitable outcries from one event (such as 2004) may have little more than political or psychological benefits to offset the cost if not targeted effectively.

30. Even the terms used to describe erosion need to be defined within the same context. The 'mass movement regime' for example, consists of all those processes from the imperceptibly slow to the catastrophically rapid which continually act to lower relief. It also includes both active and relict erosional features which no longer contribute sediment. The term 'instability' (or 'inherent instability') is used to denote a hillslope condition in which known or foreseen variation in forces may overcome resistance within the hillslope to produce landslides. It follows that although the occurrence of landslides denotes instability, the absence of landslides does not necessarily denote stability.

31. Much of New Zealand's and Horizon's hillcountry and mountain terrain is in a state of instability. Recent fluctuations in triggering conditions have produced a hierarchy of landslide activity. For convenience this can be divided, in decreasing order of magnitude, into: episodes, events, and associated occurrences. In general, critical triggering conditions which produce episodes occur every few years, events are separated by days or weeks, and occurrences by minutes or hours.

32. Investigations indicate that in inherently unstable areas like New Zealand, mass movement activity has been discontinuous and variable in its intensity for many thousands of years. This makes it increasingly difficult (if it was ever possible) to distinguish between 'natural' and 'accelerated' (or human-initiated) erosion, particularly in rural areas. Even in the last ten years there have been a number of occasions in which landslides have occurred in mature forest (presumably close to its natural state), alongside landslides occurring on pasture land during the same event.

33. When carrying out the LUC survey does the soil conservator, in an attempt to follow instructions, classify those landslides in forest as 'n' (natural erosion) and those on farmland as 'accelerated'? And, what if a similar triggering storm fell instead solely on highly stocked farmland? Would all the landslides then be mapped as accelerated erosion? Most likely yes!

34. Apart from the distinction applied in this way being beyond the capabilities of even the experts (a Commission of Inquiry could not resolve the question for Abbotsford), the enshrinement of this concept of accelerated erosion leads to many misconceptions. If the dichotomy of 'natural' versus 'accelerated' and 'initiated' is accepted categorically; the maxims *'what humans have initiated humans can stop'* and *'what humans have accelerated humans can control'* tend to promote compelling and perhaps unattainable objectives. These in turn can put a degree of unjustified faith

in catchment re-vegetation and restoration as a means of obtaining slope stability. It is not uncommon to read statements such as *'A tree covered landscape is required if stability is to be achieved on North Island mudstone hills'.* (Crozier *et al.*, 1982)

35. That carefully selected vegetation applied in the appropriate places is one of the most important tools in soil conservation is not in question. Neither are the well known deleterious effects of human activities on vegetation and soil resources. The concern here is that an inapplicable distinction between natural and accelerated erosion, perpetuated by standard procedures, not only obscures the real causes of erosion but over-emphasises the importance of humans and over-simplifies the solution. It has been stated that *"I wonder to what extent our hard-won distinction between natural erosion and accelerated erosion "conceals more than it reveals"* (Crozier *et al.*, 1982).

36. The One Plan perpetuates these myths and confusion with the same potential consequences. The Plan states *"Accelerated erosion contributes to: a significant reduction in productive capability of land; high sediment loads in waterways; land stability hazard etc."* In the upper Whanganui catchment at least, all these assertions are demonstrably incorrect.

CONTEXT OF SOIL SLIPPING

37. It is generally accepted that there have been five erosion and sedimentation periods since the 13th Century (Figure 2). The relative magnitude of each of these has decreased through time. All periods, except the Tamaki, exceeded the magnitude of the present Waipawa period which started in the 1950s.

38. Four of these erosion periods occurred in the absence of introduced animals. The first three took place before the influence of European settlement, but with the presence of Polynesians. However, because of their lengthy durations, and their extent in New Zealand, the erosion periods are not likely to have been chance, or culturally induced occurrences. Furthermore, each erosion period ended regardless of human presence or absence. The Waipawa erosion period has been linked to a climatic regime of warmer temperatures and increased activity of heavy rainfall events and floods. It is probable that previous erosion episodes have occurred during this type of climatic regime (Grant, 1983).

39. Many of the zero and 1st order valleys in hillcountry areas are flat-floored. This indicates a change from a fluvial to a mass movement dominated regime. It also indicates that the majority of material being eroded from the slopes is deposited close to the source. The material does not make its way to the lower catchment. This is contrary to one of the arguments promoted in the One Plan.

40. Drilling through these flat valley floors therefore provides a record of landslip incidence on the upper catchment slopes.

41. Cores taken through the valley floors in the Wairarapa indicated the presence of five separate mass movement deposits. The depositional surfaces of the 1977 landslip episode, and what is assumed to be the 1961 episode, were easily identified by the presence of recognisable grass reed and sedge remains. However, three earlier deposits, which were originally assumed to be younger than 10-130 years, yielded radiometric dates of 533 ± 59; 1580 ± 90; and 3290 ±190 years before 1980. These earlier episodes involved the deposition of significantly greater volumes of material than is occurring at present.

42. That is, landslip events prior to the arrival of humans to New Zealand, and occurring under a full forest vegetation cover, were more extreme but less frequent than under pastoral land use.

43. Erosion under 'natural' vegetation continues to occur. For example, in the upper Waipawa catchment in 1975; and at Raparaparikiki on the East Cape during Cyclone Bola in 1988.

44. Therefore, mass movement episodes similar to those taking place this century have occurred in earlier times. These earlier events occurred under forested slopes. Therefore, reforestation cannot be considered a 'guarantee' against landslide activity. European land use practices cannot be considered a causative factor in all landslide episodes. It is neither appropriate, nor possible, to designate the common rural forms of mass movement as natural or accelerated by field observation. Such an approach should be abandoned.

45. Shallow regolith slope failures are a widespread and recurrent problem in New Zealand. While most slope failures are triggered by the interaction of water with the slope material, many failure sites are predisposed to instability as a result of New Zealand's dynamic tectonic and climatic history. The length of time it takes the landscape to adjust to changes in conditions has led to many slopes being out of equilibrium with the present topographic and climatic setting. Many slopes are thus preconditioned for landsliding, and require only a small change in one factor to trigger failure. Failure can be caused by either an increase in the shearing force (the force tending to make the material slide down slope) or a decrease in the material's shear strength (the properties holding the material onto the slope). Water content, because it varies rapidly, is the most common trigger of these slope failures.

46. Sediment pulses during both historic and Holocene times suggest that sediment generation in New Zealand is strongly related to landslide erosion. However, most recent studies suggest the need to differentiate between low-magnitude/high frequency and high-magnitude/low frequency events. The high magnitude/low frequency events are less important for total sediment yield than the cumulative influence of low-magnitude/high frequency events. Although landslides contribute to the high-magnitude events, lower magnitude storms generate more sediment through erosion processes such as gully and stream bank erosion (Glade, 2003).

47. There is little doubt that the conversion of forest to pasture about 150 years ago decreased the size of the rainfall event required to trigger slope failure. This resulted in greater landslide activity. Research indicates that shallow landslides caused progressive regolith stripping and redeposition of the debris at the slope base. The exposed bedrock is less permeable than the pre-existing regolith cover, and the redeposited soil has a higher unit weight. Hence, alterations in both hydrological and geotechnical conditions result, changing the triggering thresholds for further failure.

48. Over time, as the regolith is stripped progressively upslope, the threshold for slope failure also changes. The landscape becomes more stable. This has also been described overseas as the 'exhaustion model'. Landslide deposits increase in bulk density and cohesion as a result of remoulding further increasing resistance to failure (Brooks *et al.*, 2002).

49. The erosional response to a triggering agent such as rainfall is commonly modelled (as implicit in the One Plan and various Section 32 reports) on the assumption that instability thresholds for a given response are constant through time. In the actively unstable New Zealand hillcountry, however, the process of erosion itself influences subsequent stability for the reasons discussed above. The response to a given level of a triggering agent (e.g., amount of rainfall) therefore changes through time, and as a result stability thresholds must be considered unstable.

50. Specifically, there is evidence from throughout New Zealand that the initially most susceptible sites tend to become more stable, presumably as a result of failure. Therefore, the catchment as a whole, exhibits a greater degree of stability. The decrease in susceptibility to landslips is interpreted as an increase in the triggering threshold needed to generate a given catchment-wide erosional response (Preston, 1999).

51. Significantly larger, more extreme, and therefore rarer events are now required to trigger landslips than in the past. As a result, rates of landslips are now significantly less than they were 100 years ago; not greater or even constant (Preston, 1999). This directly contradicts one of the fundamental premises behind the One Plan.

52. These facts relating to shallow soil slips have been confirmed with data from the Hawke's Bay, Taranaki, and the Wairarapa. This is now the accepted model of stability and hillslope evolution for the hillcountry of the lower North Island.

53. This process-response pattern is seen throughout the hillcountry of the lower North Island where landslip susceptibility is controlled dominantly by the amount of undisturbed material remaining in the catchment. This is why assessing landslip erosion after an event to indicate future susceptibility is completely misleading and lacks scientific foundation.

54. The Section 32 reports state that *"Future agricultural practices have the potential to increase the rate of damage if they do not take the natural limitations of the land into account."* All the evidence from the Horizon's region, and in fact New Zealand (Preston, 1999; Glade, 2003), suggests that current rates of 'damage' are significantly less than they were in the past.

55. The present extent of erosion has occurred despite the work by Catchment Boards and other individuals and organisations to manage soil erosion since the 1940s. This indicates that much of the erosion is in fact natural, and not 'accelerated'.

56. The Section 32 reports go on to say *"The Region has substantial areas of highly productive alluvial plains and terraces. The most versatile of these areas are the Class I and II soils, which are highly sought after for intensive agricultural uses such as dairying, cropping, and horticulture."* This ignores the fact that these areas are largely floodplains. They are formed in debris eroded from the mountains, and then transported downslope towards the sea.

57. Floodplains are some of the most dynamic elements of our landscape. Although we recognise them as floodplains, and accept that they have flooded in the past, there is a reluctance to accept that they will continue to flood once they are occupied and humans start to exploit their productive or location potential. It is worth remembering that it was only the known floodplain that was flooded during the 2004 event, and not even the entire floodplain. Therefore, bigger events have occurred in the past and will occur in the future.

58. Rather than addressing the dynamics of the flood plains themselves, there seems to be a belief that controlling hillcountry erosion will result in floodplains ceasing to flood.

59. The One Plan argues that the mountain lands and hillcountry have a high potential for erosion. In fact, the floodplains have a significantly higher susceptibility to erosion. The material forming floodplains was deposited

by the rivers, and as a result it can be readily re-entrained if not protected in some manner. This is why the Council spends millions of dollars a year on river channel works.

HILLCOUNTRY EROSION MANAGEMENT AREAS (HEMAs)

60. I do not want to comment in detail on the sustainable nature of pastoral farming on hillcountry. However, the majority of the land currently classed as HEMA has been farmed for at least 100 years. This land is currently carrying more stock per hectare; and is producing more meat and wool, as well as timber on much shorter rotations, than 100 years ago. If such land use was in fact unsustainable, one would expect to see a reduction in productivity. Such a response is not apparent in any of the data available.

61. The One Plan identifies unsustainable land use of hillcountry as a major factor contributing to environmental damage. In fact, the cost of hillcountry erosion during the 2004 event was relatively minor when compared to roading, infrastructure, flooding and other damage on the floodplains. Much of this resulting damage was actually caused by woody debris from forest covered lands being eroded and carried by the rivers in flood.

62. HEMA is defined by the Council as hillcountry with a potential for 'severe erosion', or hillcountry with a potential for 'moderate erosion' but where erosion debris will enter directly into waterways.

63. The categorisation of HEMA is based on slope and an assessment of the erosion observed when mapped, often over 30 years ago, and extrapolated to the boundary of the LUC unit. As already discussed, this is actually counter-intuitive since once the erosion has occurred, certainly with respect to many forms of mass movement, the area is actually significantly more stable than it was prior to the erosion.

64. The categorisation also increases the 'risk' where riparian landslides are present. The report, however, goes on to say that these are *'failures contiguous with, and deliver all sediment to, water courses and usually result from associated undercutting and over-steepening of slopes'.* This is an entirely natural process that would occur with or without human interaction with the environment.

65. The categorisation of HEMA is also related to the percent of erosion in each LUC unit. This raises a number of issues. The first, and most fundamental, is that to be classed as HEMA the unit must have 5% erosion. This actually means that land within an HMEA is 95% stable. The second is that all the LUC units are of a different size, and therefore the amount of erosion is not a constant. It is much easier to have higher percentages of erosion within smaller units than in larger units. Since the units are invariably smaller in hillcountry this tends to bias the definition of HEMA.

66. Therefore, while HEMA in hillcountry is 95% stable, the entire floodplains and dune areas are highly erodible without human intervention.

67. The term HEMA is therefore highly emotive and misleading. While the land is inherently unstable, it is not highly erodible. That is why major, and increasing, triggering events are necessary to generate landslips in this terrain.

68. The term HEMA should be changed to reflect the reality of the situation. It is suggested that Inherently Unstable Terrain would be a more scientifically correct term.

69. Although the definition of HEMA is linked to the LUC, no calibration or validation is provided that much of this land is actually more highly erodible than other areas. As previously explained many forms of mass movement lead to increasing resistance to future erosion. The use of the erosion when the area is mapped is therefore often overly simplistic and conservative. For example, if a slope is assessed one day and has no erosion one assumes that it can't be HEMA. If for some reason there is a landslide during the night, and the same slope is assessed the next day, it will then be HEMA. The reality is that it was actually more erodible the day before, when classified low than after the event when it was classified HEMA. This highlights the inappropriate nature of the classification system that has been adopted.

70. As will be discussed later, the inability of the HEMA classification to identify accurately the location of landslides resulting from the 2004 event highlights the uncertainty of the mapping methodology.

71. No-one has yet developed a model to predict accurately either the spatial or temporal occurrence of landslides. Therefore, there is no methodology that can be incorporated into any planning framework. So far, the search for an appropriate model has been akin to the search for the Holy Grail. Since such a model has proved to be impossible, even at the site-specific scale, there is even less chance that potential instability can be resolved at the regional level.

72. Being highly erodible would imply that the landscape is easily eroded. However, it took an extremely high magnitude low frequency event – something that only occurs only once every 100-150 years - to cause the landslides during the 2004 event. These areas were certainly not easily erodible.

THE 2004 MULTI OCCURRENCE LANDSLIP EVENT

73. The 2004 multi occurrence landslip event has been used as the justification, and basis for many of the policies proposed within the One Plan. It is therefore important to review exactly what can be learned from that event.

74. As already stated, landslides triggered by rainstorms are a well recognised problem in New Zealand. There are on average two or three economically significant landslip episodes in the country each year.

75. The February 2004 storm was possibly the most widespread rainfall-induced landslide episode in the last 35 years. Landslides were triggered over 16000km^2 of the southern North Island. Landslide damage in the Wanganui-Manawatu hillcountry during the storm was probably as severe as that in the Gisborne and Hawke's Bay areas during Cyclone Bola in March 1988, but more widespread (Hancox & Wright, 2005).

76. While the frequency of the 2004 event is likely to have varied throughout the region, it is generally accepted that this event was both extreme and rare. Estimates suggest that its return period was in excess of 150 years. This event, and the response of the landscape to the stress it imposed, was therefore extreme but atypical.

77. The landslides that were triggered during this event have been intensively studied, and subsequently reported, by Hancox and Wright (2005). Their findings can be summarised as follows:

    a) Bedrock in the bush-clad and less affected Tararua and Ruahine ranges and greater Wellington area is mainly hard greywacke and argillite of Triassic/Jurassic age (~150-200 million years). The more landslide-affected steep hill country north of Wanganui and Palmerston North is underlain by younger (Pliocene-early Quaternary, ~5-2 million years) soft mudstone, sandstone, and conglomerate. Widely-affected areas of northern and southern Wairarapa are also underlain by similar weak sedimentary rocks (sandstone, siltstone, claystone) of Cretaceous to Miocene age (~100-15 million years), with less landslide damage apparent in bush-covered hills and ranges of harder Jurassic-Cretaceous sandstone. That is, lithology had a critical control on landslide density and incidence, and the susceptibility of slopes to instability.

    b) Of the New Zealand Tertiary rocks, mudstone is the most fertile soil parent material (with pasture producing the highest stock-carrying capacities), but it also exhibits the most severe erosion hazards. This makes this unit both desirable and undesirable for pasture.

c) There were many thousands of small to medium (<100-1000m^3) shallow (1-2m deep) soil and debris slides and flows. There were also some larger (~1000-200,000m^3) deep-seated landslides in Tertiary mudstone.

d) Landslides occurred on natural slopes ranging from between 15° and 40°. There were very few landslides on gentle slopes (<15°) and also very few on very steep natural slopes (>36°). There was a clear preference for landslides on slopes with a northerly (NE-NW) aspect, compared with generally wetter southerly (SE-SW) slopes, even though rainfall mainly came from the south during the storm. Regolith stripping by previous slope failures reduced the landslide susceptibility of south-facing slopes. North facing slopes appear to be more vulnerable to rainfall-induced landsliding because of thicker, weaker, and more porous soils.

e) Most of the landslides occurred on steeper grass-covered hillslopes, gullies, and steep terrace edges. There was an average landslide density of ~5.2 landslides per km^2, with landslides occurring on grassed slopes steeper than ~20°, but especially on slopes steeper than 35°.

f) None of the many pre-existing, deep-seated very large bedrock slides in Tertiary hill country – such as the Otoko Lakes (~100 million m^3) and Ohorea (~175 million m^3) landslides in the upper Mangawero Valley were affected by the storm. No new landslides of this type and size were formed.

g) The distribution of landslide damage shows that topography, geology (rock and soil types), and vegetation cover all had a strong influence on landslide occurrence during the February 2004 storms. That is, slope angle was not the only control on slope instability.

h) A high level of landslide damage occurred in some areas, while damage was low in other areas of similar terrain. Differences in terrain characteristics were partially responsible for variations in the landslide distribution and density throughout the storm-affected area. However, in areas of similar terrain and vegetation cover differences in landslide distribution are inferred to have been caused by local variations in rainfall intensity. Areas of higher intensity rainfall may explain zones of greater landslide damage. Variations in landslide types and characteristics are related to slope angle, slope height, and rock and soil type;

although the overall magnitude of the storm (amount and duration of rainfall) is also very important. Differences in landslide size are related to the nature of the terrain in which they occur, particularly the height of the slope on which the landslide occurs.

i) Although forest provided good protection against landsliding on some hillslopes, trees close to river banks collapsed into the channel when undercut by the rivers in flood. Collapse of pine trees into the Pohangina River contributed to the vegetation and tree debris that caused the collapse of the road bridge at Ashhurst. Trees planted close to the river channel do little to prevent river bank erosion, and in this situation the trees are a potential (man-made) hazard.

j) Young trees less than about 10 years old offer little protection against landsliding. They have insufficient canopy cover for effective interception of rainfall to reduce rapid runoff and soil saturation during severe rainstorms. Root strength effects are also less in younger trees.

k) The majority of geomorphic work (volume of material moved during the storm) was done by the larger landslides. These were numerically only a very small proportion of the total number of landslides. Larger landslides (>1000m^3) were only about 3% of all landslides but were responsible for about 48% of the volume of landslide debris eroded from hillslopes. However, the visual impact of many small shallow landslides scarring hill country pasture was more striking than a few larger slides that eroded deeper into bedrock. Larger landslides generally had longer debris tails, and significantly more were connected to stream channels when compared to the shallow soil slips. In terms of sediment budget therefore, larger landslides were more important as they delivered much more sediment to streams and rivers than the smaller slides where much of the debris remained on the slopes. The shallow scars and debris of smaller landslides also tend to regenerate grass cover more quickly than larger slides in mudstone bedrock, which therefore tend to be more permanent geomorphic features in the landscape.

l) In the case of the February 2004 storm, the trigger of instability was the intense and prolonged rainfall over a three-day period producing saturated slopes. Saturation reduces the shear strength of the soil. When the shear stress exceeds the shear strength landslides occur. Saturation of slopes is a major cause of landslide initiation in the New Zealand hill country. Data show that concave slopes produced approximately half of all the landslides during the 2004 storm.

m) Soil characteristics affect landslide likelihood. The ability of a soil to drain freely or to hold large amounts of moisture influences hillslope hydrology. The strength of a soil is a function of its parent material; and is determined by porosity, cohesiveness, compaction, and Atterburg limits (i.e. cohesive behaviour).

n) The magnitude of a landsliding event (landslide volumes, density, and areal extent) is determined not only by the magnitude of the triggering force, but also by the nature of the terrain in which the event occurs. Terrain characteristics that are known to affect the geomorphic landslide response to triggering events include:

i. Geology/lithology

ii. Thickness and type of soil and regolith

iii. Slope angle

iv. Hydrology; determined by soil, bedrock, slope angle, slope aspect, topography, and climate

v. Topography; elevation, slope form (concave/convex), changes in slope form

vi. Vegetation

vii. The processes acting on and within the slope, weathering, mass wasting, soil creep, surface wash, subsurface piping

viii. Whether a slope is undergoing denudation, accumulation, or transportation

ix. The magnitude of the triggering event

x. Previous slope failures removing transportable material

xi. Antecedent moisture conditions; saturated slopes are more likely to fail because of reduced shear strength and increased shear stress

xii. Position on the slope profile – upper, mid, or lower profile

78. The average landslide density was approximately 5.2 landslides per km^2, with landslides occurring on slopes steeper than ~20°, but especially on slopes steeper than 35°.

79. While much of the focus was on the shallow soil slips under pasture, in some areas there was also significant landsliding on scrub and bush-covered river banks, or on slopes planted with pine trees that had been destabilised by fluvial undercutting. Loading of fluvial systems with tree debris from riverbank collapses contributed to the destruction of several bridges during the flood. Therefore, the cost and impact of landslides is not solely related to the degree of disturbance (Hancox & Wright, 2005).

80. The visual impact of the many small shallow landslides scarring hill country pasture land is often more striking than a few larger slides that erode deeper into bedrock. As a result, the tendency is to focus attention and resources at the smaller landslips while their geomorphic effect is relatively minor, and in most cases over immediately following failure.

81. The larger landslides also had a higher degree of connectivity to the fluvial system. Therefore, in terms of the sediment budget (where the debris ended up), these larger landslides were also more important. They delivered much more sediment to the streams and rivers than did smaller slides where much of the debris remained on the slopes (Hancox & Wright, 2005).

82. In the mapping exercise undertaken by Hancox & Wright (2005), both the scars and debris were mapped. As a result, the calculations of areal disturbance are affected by double accounting. That is, the reported land disturbance by landslips is at least twice the actual amount.

83. While the debris deposited on top of pasture has a short term affect, this material quickly re-vegetates and generally results in little overall loss of production.

84. However, even given this over-estimation of effect, the affected area of landslipping averaged only 5%. That is, 95% of the area remained stable even during this extreme event. Even in the small areas that were worst affected, only 20-35% of the ground was disturbed. Therefore, even in these areas 65-80% of the ground remained unaffected.

85. It is generally acknowledged that this was an extreme event, with a Return Period of at least 100-150 years. It therefore does not reflect typical conditions. While the response to the visual impact of this event is understandable, much of the response has been based on emotion.

86. It is important also to compare the effects of this event with Cyclone Alison which 'devastated' much of the southern Ruahine Range in 1975. This was a similar extreme event but affected land under natural forest. The event mobilised millions of cubic metres of debris. However, even in that case over 80% of material is still where it was initially deposited.

TRIGGERING OF SLOPE FAILURE

87. The mechanism of slope failures during extreme rainstorm events has been studied by myself and others in detail; both within New Zealand and overseas. It is generally accepted that the triggering of slope failure is a function of changes in soil-water conditions.

88. While slope angle is an important pre-condition for instability, it is never the actual trigger. A pre-occupation with slope angle ignores the fundamental processes leading to slope instability.

89. Shallow landslides, such as the majority of those that occurred during the 2004 event, are usually modelled as infinite equilibrium slopes where the shear strength of the material is balanced against the shear stress acting on the slope[1].

90. This relationship stresses the importance of the type of material, its thickness, variation in material properties, and the hydraulic condition of the slope. While slope angle is important, it is neither the critical control, nor trigger of instability. The focus on slope angle therefore ignores the processes controlling the stability of slopes.

91. The critical slope angle for any material can also be determined. Note that the critical slope angle is controlled solely by the frictional strength of the material and the hydraulic conditions within the slope. It is these factors that therefore control slope instability and that should be used as the basis for any regional slope instability (management) model.

92. Data already exist, or could be easily derived, that allow the development of a robust slope stability model for the Horizon's region. This model would allow an accurate erosion hazard map to be produced.

PREVIOUS WORK ON CRITICAL SLOPE ANGLES

93. DeRose (1995) provides a review of the available information and data relating to critical slope angles as they affect slope instability in New Zealand. However, he also states that these results cannot be applied without quantification to other regions.

94. Landslides tend not to be evenly distributed within regions, and are often clustered into 'families' related to specific triggering events. These are usually high intensity storms producing rainfall depths above certain critical threshold values that vary according to local pre-conditions to failure. Landslide densities tend to be higher in storms with higher rainfall totals.

---

[1] $F = \dfrac{c' + (\gamma - M\gamma_w).z.\cos^2\beta.\tan\varphi'}{\gamma.z.\sin\beta.\cos\beta}$

c' effective cohesion; tanφ'; effective internal friction; β slope angle; M relative thickness of saturated zone; γ weight of material; γ_w weight of water; z material thickness

95. Within areas that have had the same total rainfall, there is usually a great deal of variation in landslide densities; with intact hillsides interspersed among those that have eroded. This variability can be attributed to the different susceptibility of individual hillslopes to failure. Controlling factors are likely to be those that influence slope stability by altering the balance between shear strength (resistance) and shear stress (shearing forces promoting failure).

96. Most landslides occur where the soils are: 'weakest'; prone to frequent soil saturation; on steep hillslopes with convergent drainage; lacking a forest cover; deep, and underlain by rocks with a lower permeability (leading to saturation of the soil); and underlain by rocks that weather to produce regolith with low frictional and cohesive strength when saturated.

97. There is usually a well-defined limiting slope for a given set of lithologic, soil, hydrologic, and climatic conditions below which landslides do not occur. The limiting slope for landslide occurrence is between 18 and 24° for most areas of hill country in the North Island. Above this limiting slope there is an increase in the frequency of landslides; reaching a maximum between 26 and 40°. The frequency distribution of the slopes of landslides is similar to that for the hillslopes on which the landslides occur. There is usually an upper limit of slope failure of between 50 and 60°. The mean slope of landslide distributions is typically between 29 and 39°. There are usually few landslides at, or immediately above, the limiting slopes.

98. The results of these studies suggest that differences in slope distributions relate to lithology. Landslides occur on the gentlest slopes where hillslopes are underlain by soft Tertiary mudstone and sandstone lithologies.

99. The lowest overall slope angles that have been measured were for landslides triggered during Cyclone Bola. This is because of the higher rainfall, and therefore critical moisture conditions, experienced within much lower angled slopes. The mean slopes that failed were between 27.4 and 30.6°.

100. This same relationship was confirmed when the landslides triggered during the 2004 storm event are analysed.

101. For less intense, more frequent storms, the mean slope for landsliding ranges from 33-36°. Clearly therefore, the slope distributions for landslides relate to rainfall conditions. The larger magnitude the event, the greater number of landslides and lower threshold slope angles. Extreme events therefore have exceptionally low slope failure thresholds. The use of such large events therefore biases any delineation of thresholds for slope failure and produces overly conservative critical slope angles.

102. The results summarised by DeRose (1995) show that landslide erosion is confined to hillslopes above certain slope angles. Hillslopes steeper than 30° are particularly prone to landslide erosion in most areas of hillcountry. Hillslopes gentler than 20° remain largely unaffected. Hillslopes between 20 and 30° have different landslide susceptibility, and resultant landslide densities, depending on the local soil and hydrological conditions that affect slope stability.

103. In particular, threshold slopes for landsliding vary according to lithology as follows: above 20° on hillslopes underlain by soft Tertiary mudstone and sandstone, Miocene andesite, and deeply weathered greywacke; above 27-28° on hillslopes underlain by hard sandstone; and above about 33° on hillslopes underlain by hard greywacke. On hillslopes underlain by hard Jurassic greywacke mean slopes were 44.5° in Eastbourne and 49° in and around Wellington City.

WHAT DO WE KNOW?

104. Slope failures are not triggered by slope angle.

105. The majority of slope failures are triggered by intense or prolonged rainfall. Consideration of the hydraulic conditions within the slope is therefore essential for any valid and robust regional slope instability model.

106. Critical angles for slope instability are strongly related to the underlying lithology. This affects the nature of the weathered regolith, hydraulic conditions within the slope, and it usually controls the nature of the shear plane, hence angle of the failure surface. Slope form also has a major control on the critical angle.

107. There are significant differences between the inherent strength of the various lithologic units found within the Horizon's region. It is generally accepted that the average slope of terrain in a particular lithology reflects the strength of that geologic unit. Using topographic and geologic data for the Horizon's region, significant differences in the strength of the various units is apparent (Table 1). Some units are at least 8 times 'stronger' than others.

Table 1: **Average slope angles for landscapes formed in different geologic units within the Horizon's region.**

Area (km^2)	Mean slope (°)	Lithology
855	1	Sand
1120	3	Gravel/silt
38	4	Tuff
966	5	Volcanic agglomerate
2	7	Greensand, siliceous claystone, limestone, coal
4119	8	Sand/silt
3	8	Mudstone, chert, volcanics, limestone, conglomerate schist
417	10	Ignimbrite
174	11	Sandstone, siltstone
390	12	Agglomerate breccia
4	13	Peat
180	14	Calcareous siltstone, sandstone, siltstone
55	14	Conglomerate
164	14	Mudstone, conglomerate tuff
1	14	Siltstone, greensand, shale, conglomerate
951	15	Siltstone conglomerate
461	15	Siltstone, claystone
2864	17	Calcareous siltstone
5355	17	Siltstone, conglomerate limestone
2522	22	Mudstone, spilitic tuff
1560	23	Siltstone, limestone

108. The use of a single threshold slope angle for the entire Horizon's region is therefore overly simplistic.

109. It is possible to develop a robust slope stability model, including the effects of geology, drainage conditions, and previous slope failures using existing data sources. Such a model does not rely on the availability of LiDAR data. Assuming that the accuracy of slope measures derived from existing topographic data is accepted, the same information could be used to derive slope form indices. Regional soil and geologic data likewise already exist.

110. The use of extreme events to establish slope instability thresholds biases the results and produces artificially low threshold values. The effect of this is to establish significantly higher levels for risk mitigation than for other environmental hazards. To use the 2004 events to establish minimum stability thresholds is to use a risk of less than 1 in 150 years. For most other hazards mapped at the regional scale e.g., floods, a 1:50 year or 1:100 year risk level is usually adopted. A threshold based on a 1:150 year event therefore places restrictions from much higher standards on some members of the community.

IMPLICATIONS

111. An erosion management model based on a single slope angle, or the land unit approach of the LUC, for the entire region is inappropriate. It casts an unreasonable, overly conservative, and unjustifiable 'net' over the landscape.

112. To ensure sound and informed decisions regarding erosion it is necessary to create a realistic, and accurate, model of actual and possibly potential erosion sites. This model requires consideration of all the major factors that influence erosion. These include lithology, soil cohesion, internal angle of friction, slope angle, slope form, weight of soil, slope hydrology - which in turn is controlled by the drainage characteristics of the soil, vegetation type, and the incidence of previous landslips.

113. Once a model of potentially unstable areas has been developed it is unnecessary to further delineate, or designate, these areas as HEMA. All areas within the region potentially prone to slope failures must be treated in the same manner. That is, any model should not just consider land under pastoral land use. This is the current situation with respect to the 'Dymond map of HEL'. To treat erosion irrespective of vegetation cover ensures equity throughout the community. To treat farmers in particular areas differently from those in other areas or the wider community with the same potential problem is not reasonable. It is the erosion problem that must be addressed, not particular land uses.

114. Once a threshold is established for a particular set of criteria it is inappropriate to extrapolate this out to a property or LUC unit boundary. If sufficient evidence exists that certain slopes are potentially unstable, the same evidence must also confirm the stability of the remaining land on the property. To extrapolate higher risk areas to the entire property seriously questions the approach and methodology adopted to assess the risk.

115. The use of extreme events to define erosion thresholds imposes a significantly higher standard of risk mitigation on some members of the community than the rest of society. The current slope threshold is based on experience during storm events with a return period of at least 1:150 years.

116. Having set an equitable level of acceptable risk for all persons the design storm can be defined. This will allow the regional slope instability model to be

tuned to particular hydrologic conditions based on slope form and position, soils, lithology etc. The appropriate threshold values for different combinations of factors could then be defined and quantified. Such an approach would ensure that all persons, and activities, within the Horizon's region are treated equitably.

117. Data collected following the 2004 storm event indicate that vegetation must be older than approximately 10 years to provide significant improvement in slope stability. Vegetation affects the hydraulic conditions of the slope, and increases the effective cohesion of the regolith. It is the size and extent of the root system that largely determines the effect of vegetation. While the root network is often related to age, it is actually controlled by the species, soil, climate, and growing conditions. It is therefore suggested that rather than using an essentially arbitrary age criterion for vegetation clearance, this should be based on stem diameter or canopy cover. Both stem diameter and canopy cover are relatively easy to assess in the field. They do not require coring of the main stem to determine age.

CALIBRATION OF HEL CATEGORISATION

118. Considerable emphasis in the One Plan has been placed on the work of Dymond *et al.* (2006) with regard to defining and justifying the classification of HEMA; and as a result the proposed management and regulatory instruments.

119. In the introduction to Dymond *et al.* (2006) it states that up to 10% of some slopes slipped and as a result something has to be done to improve the stability. This ignores the fact that 90% of these supposedly unstable slopes actually remained intact.

120. It is possible to criticise a number of aspects of the methodology used in Dymond *et al.* (2006). These include: the failure to include any drainage conditions, which are critical to triggering slope instability during intense rainstorms; the quantification of runout zones; and the difficulty of using unsupervised classifications in forest and scrub as opposed to pasture. The conclusions of the study are however interesting.

121. It is also important to recognise the inherent bias in the study. The authors state: that *"the main purpose of the landslide susceptibility model is to identify where land cover needs to be changed."* Given that this was the stated aim of the study, it cannot be argued that it provides unbiased justification to support land use change, and the imposition of policy and regulatory controls to achieve that aim.

122. Of the 21,200km^2 studied, 190km^2 were affected by landslides i.e., 0.9%. Therefore of the entire study area 99.1% was stable and suffered no landslide damage.

123. However, the paper also argues that their model predicted that 1240km^2 of the region is susceptible to landsliding. Therefore, even of this 'most susceptible area' only 15% (which is likely to be an over-estimate because of pixel size etc,) was affected by landslides. That is, even on this most at risk area over 85% was stable during the 2004 extreme event. The authors themselves argue that *"The proportion of landslide pixels that occurred in land susceptible to landsliding was 26%: a rather low accuracy."*

124. Because of the failure of the model to predict the occurrence of landslides the authors then broadened their criteria to include the 'whole hillside approach'. Essentially, they increased the 'window' to increase the chance of picking up landslides. Widening the 'search area' certainly increased the likelihood of detecting landslides BUT it also confirmed that the original model, and therefore the justification and basis of HEMA, was wrong.

125. Even with this widened search criterion the 'most susceptible areas' still only contained 58% of the landslides. That is, 42% of the landslides actually occurred in lower risk areas.

126. Finally, the paper argues that forest would have 'saved' land from landsliding. In reality we can never know this.

LINKAGE OF SLOPES TO RIVERS

127. There is considerable emphasis in the One Plan and Section 32 reports that what happens on the slopes affects the fluvial system. While this is true in some situations, it is not always the case. It is certainly not the case to the level and degree argued.

128. It is suggested that the aggradation in the rivers is a direct result of land management practices in the hillcountry. The presence of floodplains, terraces and other depositional areas which pre-date pastoral farming clearly show that this is not the case.

129. As clearly reported by Hancox and Wright (2005), the majority of debris from the shallow landslides in pastoral hillcountry remained either on the slope or at least very close to the failure surface. That is, this material did not load the streams and result in aggradation further downstream.

130. Likewise, *Dymond et al.* (2006) showed that even on susceptible land classified as contributing sediment directly to the fluvial system only 1 in 10

debris-tails reached first order streams. On non-contributing land fewer than 1 in 100 debris-tails reached first order streams during the 2004 event.

131. As a result, almost none of the debris from shallow soil slips entered the stream channels. In those cases where it did, the first order streams have so little flow that they have no capacity to transport this material further downstream.

132. These results are not unique to the Horizon's region. The same effect has been found in with regard to shallow soil slips in Hawke's Bay and the Wairarapa.

133. Such an effect is also not confined to just soil slips. Following Cyclone Alison's impact on the Ruahine Ranges in 1975; 80 cross-sections were established, in a series of characteristic reaches along the river so that future changes could be monitored and quantified. These cross-sections were re-surveyed in 1996-97, and provide a record of channel changes over 20 years.

134. Since 1977 there has been a significant reduction in the Active Bed Widths within each reach: up to 80% but an average of about 40%. The reduced activity of the streams over the once extensive "floodplain" has allowed the revegetation and stabilisation of the 'Alison' sediment. In fact over 60% of this sediment is still in storage where it was deposited during the event.

CAUSES OF AGGRADATION IN MANAWATU

135. A major assumption in the Section 32 reports and the One Plan is the supposed connection between slope processes (i.e., landslides and erosion) and aggradation of the lower river systems. Of particular concern to the Horizon's Council is aggradation within the various flood control schemes, and the consequential reduction in flood capacity.

136. Aggradation within the flood control schemes is one of the major justifications for regulatory and policy controls on hillcountry land management. Despite this argument being promoted in the One Plan; the Council Officer's own reports provide contradictory evidence.

137. For example Allan Cook's report clearly states that: *"River engineers are acutely aware that in designing flood protection schemes on floodplains they are interfering with the natural erosion/deposition processes that have created those floodplains. Those natural processes were occurring long before land development created a need for flood protection schemes and will continue indefinitely irrespective of any human intervention.*

The containment of flood flows within narrow flood channels will obviously result in a more rapid aggradation of land between the flood defences than occurred on the previously unconstrained flood plain. Accordingly, the designers of flood protection schemes have always understood that the service level of their works would either progressively decline with time, or alternatively, the defences would need to be progressively upgraded to maintain original design standards.

However, the construction of the flood protection schemes within New Zealand has followed reasonably closely upon the clearance and intensive development of the respective upper catchments, and the effect of that development on the rate of upper catchment erosion and resulting flood plain building may not in all cases have been fully understood.

Optimally, communities should not have developed on floodplains to the extent that major flood protection works have become necessary. The reality is, however, that many major communities in New Zealand have developed in highly flood-prone areas and there is now no practicable option other than to provide a level of protection for them."

138. So, as stated by Cook, the problem of aggradation is natural. The logic of transferring the blame for this aggradation to hillcountry land management practices is inconsistent with the understanding of the natural processes operating. The costs associated with aggradation should be borne by those who reap the benefit from the protection works.

139. The source of material resulting in aggradation within the flood control works was clearly, and unequivocally answered by the Councils' own staff back in the late 1970s. For example, Mosley (1977) stated that *"There has recently been growing concern that stream channel instability, and hence river control problems, are growing in the South-eastern Ruahine piedmont (mountain foot) area. Possible effects vary from deposition of gravel on paddocks at the foot of the range, to increased siltation on the berms of the Lower Manawatu River. Consideration of the factors that control channel stability suggest that the stream channels at the foot of the Range are inherently unstable. Streambed gradient, the 'flashy' nature of runoff, the quantity of sediment transported, the proportion of course sediment in the streams and the non-cohesive nature of the stream banks all lead to potential instability. This situation has been considerably worsened by removal of forest from the stream banks which has accelerated bank erosion, and construction of road and rail embankment which constrict flows and exacerbate flooding when streams flow overbank."*

140. Aggradation had generally been attributed to increased erosion in the ranges causing an increase in sediment transport rates in the streams (only one of the factors involved in channel instability). The increased erosion has been attributed in turn to a collapse of the forest canopy as a result of browsing animals. After considering longer term erosion rates Mosley (1977) wrote that *"It may be concluded that increased erosion in the Range has been of only secondary importance in influencing channel stability on the piedmont."*

141. Mosley (1977) went on to list the four major causes of stream channel instability, in order of priority, to be:

a) Removal of forest cover from the valley throats of the upper catchments, permitting rapid transmission of water and sediment from upper catchments to piedmont channels.

b) Removal of forest cover from piedmont stream banks, permitting increased bank erosion and more extensive overbank flow and sediment deposition.

c) Channelisation on the fans, causing extensive scour of alluvial deposits.

d) An increase in erosion rates in the Range above the long term average caused primarily by changing weather patterns.

142. These findings are still relevant and were confirmed during the 2004 flood event. Flooding caused catastrophic channel change in a number of small to medium-sized channel systems in the upland fringes. These were a major source of sediment to the lower parts of the fluvial system i.e., resulting in aggradation within the river control works.

143. Following the 2004 floods Fuller (2005) wrote that: *"Hydrologically flooding is a natural occurrence – in fact trying to keep floodwaters from a floodplain is most unnatural, depriving areas of replenishment by fertile silts. Furthermore, floodplains act as sponges soaking up floodwaters which serves to attenuate the flood peak at it travels downstream. By keeping all the floodwaters within the channel not only are problems of erosion likely to occur, but pressure on flood protection schemes downstream area also increased. However, society demands that economic activity on the floodplain is acceptable, and therefore in need of protection."*

144. Unfortunately for human activities floodplains will continue to flood. The extent of inundation is clearly dependent on the magnitude of the flood. The longer one occupies a floodplain the larger the flood one is likely to encounter.

145. During the 2004 event some of the worst affected rivers were the Pohangina, Oroua, Kiwitea and Turakina; in other words, the smaller/medium sized rivers at the margins of the hillcountry. These rivers occupy the 'piedmont' setting described by Mosley (1977). Their location at this upland fringe places them in a dynamic context, with steep gradients and gravel-beds.

146. Channels adjust to accommodate variations in discharge and sediment supplied from the catchment; the higher the discharge, the bigger the channel (Figure 3). Where rivers flow across valley floors they are flowing between banks of alluvium (sediment) which was previously eroded, transported, and deposited by that river. This sediment can therefore be readily eroded and transported by the river. Bank erosion during floods is therefore no surprise; especially within the dynamic setting of piedmont rivers. What was a surprise was the scale of bank erosion observed on some of these rivers during the floods of 2004; over 50m in places along the Kiwitea River at Fielding (Fuller, 2005).

147. The 2004 flood event was so large that all the water could not be contained within the channel. Part of the problem associated with confining a river within stopbanks is that flows that may have dispersed down side channels, or across the floodplain, are now confined between the banks. The banks are therefore the focus of excess stream power, and are increasingly susceptible to erosion.

148. Research elsewhere in New Zealand has suggested that channel constriction increases the frequency of sediment transport. The outcome in both the Pohangina and Oroua rivers has been slight bed degradation, which in turn has led to undercutting of the banks. The pre-scheme channel patterns of the Pohangina and Oroua rivers were also wider than today, and more braided. This has been heralded as evidence for the success of the scheme, which sought to stabilise the river, narrow the channel, and close off abandoned river channels that still carried flood waters (Fuller, 2005).

149. Narrowing of the channel worsened the channel erosion that occurred during the February 2004 floods. Lining the channels with trees also substantially added to the woody debris transported during the flood. This put so much pressure on bridges, that it arguably caused the failure of some.

150. The *quasi-natural* morphology of many of these piedmont streams would have been wide, shallow and typically braided. However, such a form restricts land management and economic options. It does not 'suit human requirements'. Consequently rivers will continue to be artificially constrained.

151. The One Plan aims to address aggradation within flood protection works through a focus on hillcountry erosion. Horizons own evidence, and that of others, clearly shows that this problem does not originate in the mountains and hillcountry. It is caused largely by natural processes and management decisions on the rivers in piedmont areas and across the flood plains.

152. Much of the One Plan, and the Section 32 reports, would appear to be based on the perceived problems and processes within the Manawatu and Rangitikei Rivers. These problems and processes have little relevance to the Whanganui catchment where the topography, lithology, and geomorphic and fluvial processes are all distinctly different.

SEDNET

153. Although not directly related to the One Plan, considerable emphasis is placed on the SedNet model when justifying hillcountry land use management decisions.

154. As stated in the Section 32 report by Dymond: *"To evaluate the implementation of Whole Farm Plans, a simplified version of SedNet is applied. If we assume bank erosion is approximately equal to floodplain deposition we can focus exclusively on hillside erosion (including gully erosion). We also assume that mean hillside erosion is controlled by three factors: geology, annual rainfall, and land cover."* Schierlitz et al. (2006)

155. I have already shown that these inherent assumptions are incorrect. What this 'simple' model essentially does is establish a *self-fulfilling prophecy*. Having assumed that land cover is a major control on sediment yield, without any calibration or validation, the model then 'proves' that more vegetation will reduce sediment yields.

156. The basic premise that 'bank erosion is equal to flood plain deposition' also ignores the work of the Council's own staff which clearly identifies both the sources and volume of sediment supplied to the rivers. Certainly bank erosion does not equal flood plain deposition.

157. The SedNet model provides no data relating to the sources and controls on sediment yields. It also provides no calibration or validation. Having assumed that land cover affects sediment yields it shows that increases in land cover would reduce sediment yields.

158. While much of the One Plan focuses on the contribution of soil slips, SedNet focuses on average sediment yields. As has been shown, there is little linkage between the shallow soil slips and subsequent erosion and deposition. In most instances, the debris from the soil slips remains on the slope, or at least out of active stream channels. The sediment essentially goes into storage at some lower level within the catchment. The debris quickly stabilises and re-vegetates preventing the entry of sediment into the fluvial system.

159. As I have already shown, landslip erosion in the hillcountry is generally not the cause of increases in the sediment load of waterways. Therefore, significant reductions in sediment load are unlikely to result from changes in land use management practices in the hillcountry terrain of Horizon's region.

SUMMARY

160. My professional opinion is that the decisions reached by the hearing panel are in essence sound. They afford a level of appropriate protection to ensure sustainable management of land resources in the Horizons region.

161. There is still a requirement for resolution of some of the practical issues such as the appropriateness or not of slope angles to determine activity status. However, many of these could be further refined through workshops with landowners and information and guidance offered by both land management officers and printed material provided by the Council.

162. It is critical that rules developed for use by landowners are straightforward to interpret, and practical to implement. Generally people are more likely to adhere to less complex standards and conditions. An example being the use of a visual change in colour or clarity of receiving waters (condition (c) rule 12-1) rather than reference to another schedule in the plan.

REFERENCES

Brooks, S.M.; Crozier, M.J.; Preston, N.J.; Anderson, M.G. 2002: Regolith stripping and the control of shallow translational hillslope failure: application of a two-dimensional couple soil hydrology-slope stability model, Hawke's Bay, New Zealand. Geomorphology 45: 165-179.

Crozier, M.J.; Eyles, R.J.; Marx, S.L.; McConchie, J.A.; Owen, R.C. 1980: Distribution of landslips in the Wairarapa hill country. *New Zealand journal of geology and geophysics 23:* 575-586.

DeRose, R. 1995: Slope limitations to sustainable land use in hill country prone to landslide erosion. Unpublished report, Landcare Research, Palmerston North, New Zealand. (This article was later published in the New Zealand Resource Management Association broadsheet).

Crozier, M.J.; McConchie, J.A.; Owen, R.C.; Eyles, R.J. 1982: Mass movement erosion Wairarapa. Research Report, Department of Geography, Victoria University, Wellington, New Zealand.

Dymond, J.R.; Ausseil, A.; Shepherd, J.D.; Buettner, L. 2006: Validation of a region-wide model of landslide susceptibility in the Manawatu-Wanganui region of New Zealand. Geomorphology 74: 70-79.

Fuller, I.C. 2005: February floods in the lower North Island, 2004: catastrophe – causes and consequences. New Zealand Geographer 61, 40-50.

Glade, T. 2003: Landslide occurrence as a response to land use change. Catena 51: 297-314.

Grant, P.J. 1983: Recently increased erosion and sediment transport rates in the upper Waipawa River Basin, Ruahine Range, New Zealand. Soil Conservation Centre Aokautere Publication No. 5.

Hancox, G.T.; Wright, K. 2005: Landslides caused by the February 2004 rainstorms and floods in southern North Island, New Zealand. Geological and Nuclear Sciences Science Report 2005/10.

Hancox, G.T.; Wright, K. 2005: Analysis of landsliding caused by the 15-17 February 2004 rainstorm in the Wanganui-Manawatu hill country, southern North Island, New Zealand. Geological and Nuclear Sciences Science Report 2005/11. 64p.

Mosley, M.P. 1977: Southeastern Ruahine investigation report on erosion and sedimentation. Manawatu Catchment Board and Regional Water Board, Palmerston North, New Zealand.

Page, M.; Shepherd, J.; Dymond, J.; Jessen, M. 2005: Defining highly erodible land for Horizons Regional Council. Landcare Research Ltd, Contract report LC0506/050.

Preston, N.J. 1999: Event-induced changes in landsurface condition – implications for subsequent slope stability. Zeitschrift für Geomorphologie. Supplementband 115, 157-173.

Schierlitz, C.; Dymond, J.; Shepherd, J. 2006: Erosion/sedimentation in the Manawatu catchment associated with scenarios of Whole Farm Plans. Landcare Research Ltd., Contract report 0607/028.

John (Jack) McConchie
Principal Water Resources Scientist
17 February 2012

FIGURES

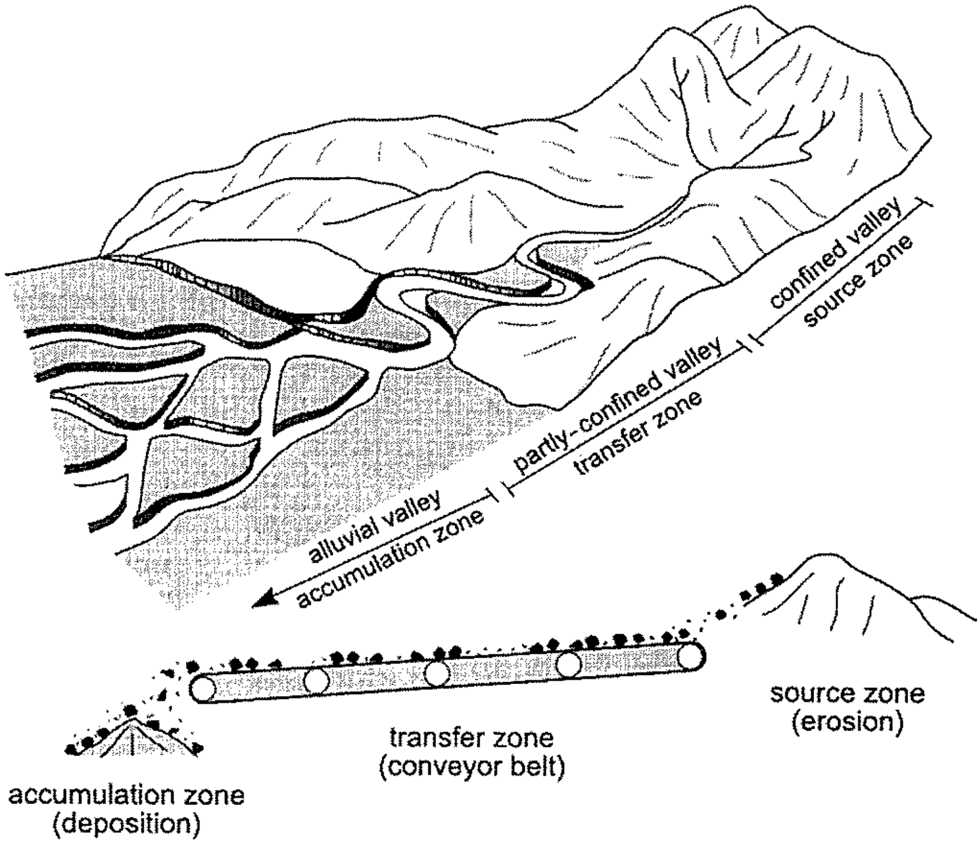

Figure 1: Basic concept model for sediment movement through a catchment.

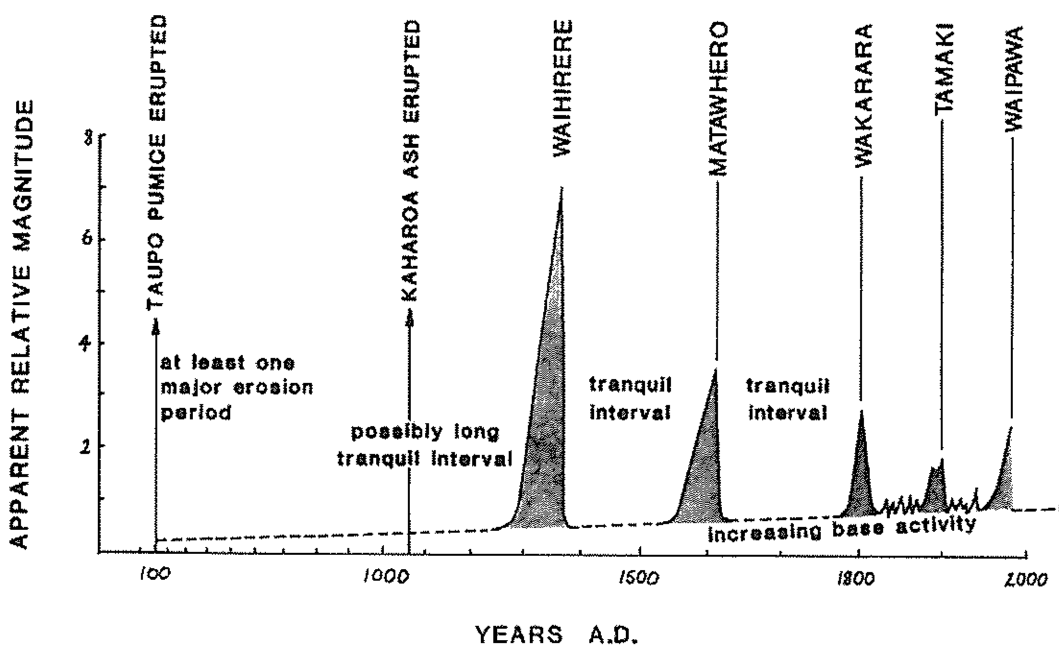

Figure 2: Erosion and sedimentation episodes since the 13th century (Grant, 1983).

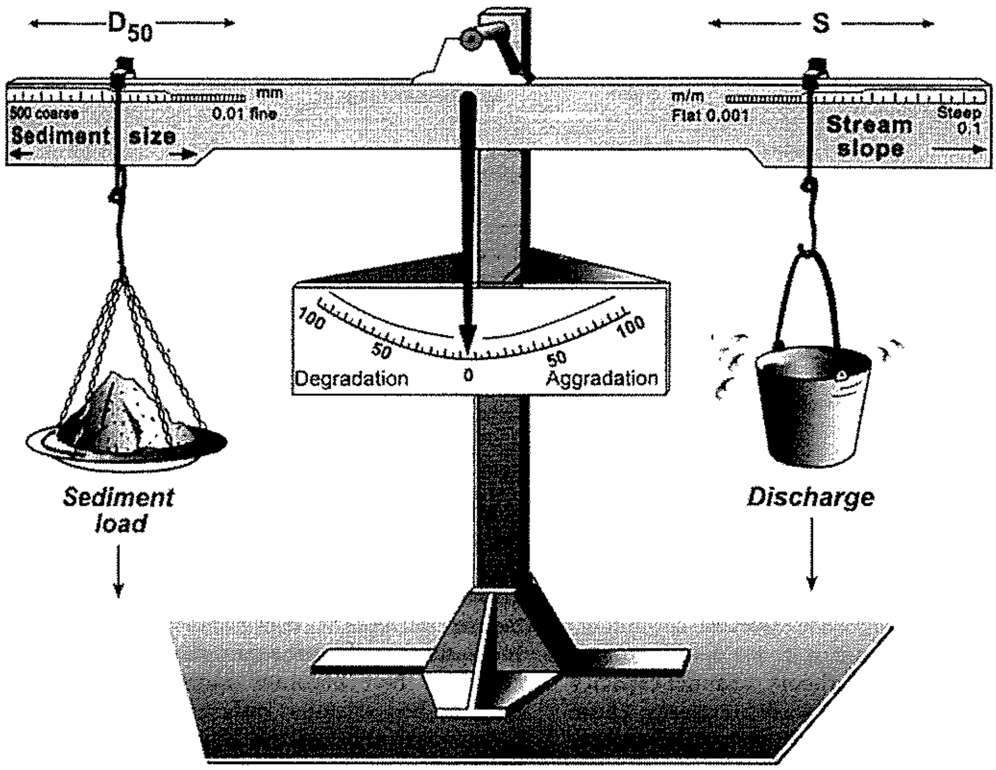

Figure 3: **River channels adjust by either aggrading or degrading in response to changes in discharge and sediment supply.**