BEFORE THE HEARINGS' COMMITTEE

IN THE MATTER of hearings on submissions concerning the proposed One Plan notified by the Manawatu-Wanganui Regional Council

STATEMENT OF EVIDENCE OF

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ON BEHALF OF:

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TAUMARUNUI FARMERS' GROUP 2008
PROPERTY RIGHTS, NEW ZEALAND

1.0 INTRODUCTION

1.1 I am a Principal Water Resources Scientist working for Opus International Consultants Ltd.

1.2 Prior to the start of 2008 I was an Associate Professor with the School of Earth Sciences at Victoria University of Wellington. I hold a Bachelor of Science degree with first class Honours, and a PhD. I am a member of the New Zealand Hydrological Society, the American Geophysical Union, the New Zealand Geographical Society, and the Australia-New Zealand Geomorphology Group. I taught undergraduate courses in geomorphology and hydrology, and a post-graduate course in hydrology and water resources. For more than 20 years my research focused on various aspects of geomorphology and hydrology including: landscape evolution, slope stability and erosion, geomechanics, soil-water interactions, hydraulic modelling, slope and surface water hydrology, slope and fluvial coupling, and natural hazards.

1.3 Within these fields I have edited one book, and written or co-authored 10 book chapters and over 40 internationally-refereed scientific publications.

1.4 Specific to this evidence, I have written two chapters for international texts. I have also had a number of papers on slope instability and multiple occurrence landslip events published in the peer-reviewed academic literature. I have presented numerous conference papers on the impact of extreme events throughout the lower North Island. I was an author of *Landforms and geological features: a case for preservation* published by the Nature Conservation Council in 1988.

1.5 I was the New Zealand Geographical Society representative on the Joint New Zealand Earth Science Societies' Working Group on Geopreservation. This group produced the first geopreservation inventory published in 1990 as the *New Zealand Landform Inventory.*

1.6 For three years I coordinated the investigation and field studies into the effect of hydro-electric operations on the fluvial and geomorphic processes of the Waikato River. This was part of the Assessment of Environmental Effects required as part of Mighty River Power Ltd's resource consent application to operate the Waikato hydro system.

1.7 I have read the Code of Conduct for Expert Witnesses in the Environment Court Practice Note (31 July 2006). I agree to comply with the Code of Conduct. Except where I state that I am relying upon the specified evidence of another person, my evidence in this statement 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.

2.0 EXECUTIVE SUMMARY

2.1 In this submission I would like to clear up a number of misunderstandings, misconceptions and errors that are inherent in the present draft of the One Plan. Given the inadequate scientific basis for the One Plan, I would also like to provide some basic information relating to the natural processes operating within the hill country. It is hoped that as a result of my evidence the present One Plan will be modified to reflect the actual conditions and processes operating within the Whanganui hillcountry. Inappropriate and ineffectual elements within the One Plan, based largely on emotion rather than reality, should be removed.

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

- That erosion is natural and to be expected at some level. The 'natural' level of erosion needs to be known and clearly defined. This is essential so that any discussion of acceleration, control, or minimization etc. can be placed in context.
- While considerable focus in the One Plan is on erosion control there is a complete lack of recognition that the major products of this erosion i.e., the flood plains, terraces and dunes are critical to the character, dynamics, wealth and economic viability of the Horizon's region.
- The reality is that the highly productive flood plains, terraces, and other low lying areas would not exist without erosion.
- Much of the motivation behind the policies and regulations within the One Plan appears to be to the control of flooding of natural flood plains. Floods will continue to occur on flood plains. During the 2004 event no areas were flooded that were not previously recognised flood plains. The full extent of the flood plains were not inundated indicating that more extreme events have occurred in the past and can therefore be expected in the future.
- The longer flood plains are occupied and used by humans, the bigger the floods and more severe the erosion events that will be encountered. This is a statistical reality that must be recognised and acknowledged within the One Plan.

- Just because humans occupy and exploit the assets of flood plains does not mean that the natural processes that led to their development will cease. Intermittent flood events must be regarded as a natural tax on the use of such environmental resources.
- Both erosion and deposition are natural. They will continue to occur despite human intervention.
- Multi-occurrence landslide events, such as that in February 2004, have occurred in the past and will occur in the future.
- Such events have been shown to increase the resistance of the slopes so that future events require greater triggering rainfalls. As a result, such events are less likely to occur in the future than in the past.
- 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.
- 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 highly misleading.
- The shallow soil slips, while appearing 'severe', are in fact responsible for little material entering rivers and streams.
- Therefore, defining erosion susceptibility from existing shallow soil slips is illogical and scientifically incorrrect. Therefore, the criteria and definition of HEL are wrong in fact. This probably explains the relatively low incidence of landslips in this terrain during 2004 found by Council studies.
- Likewise, it is largely irrelevant to treat or manage already failed slopes for erosion control. This is because once a slope has failed it has lost all the easily erodible material. Such sites are, as a result, likely to be some of the more stable areas within a catchment.
- Most of the material from these slips remains on the slope, or in higher order drainage channels. This prevents its movement down the fluvial system. This is confirmed by the Council's own studies, but is ignored in the One Plan.
- Of the 21,200km^2 studied by the Council 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.
- Of the land that was identified as 'susceptible to landsliding' only 26% experienced landslides. That is, 74% remained stable despite the extreme magnitude of the storm triggering rainfall. Therefore, the argument that such areas are susceptible to landsliding cannot be sustained.
- Much of the land classified as HEL is therefore some of the most resistant within the region rather than the most problematic. The most erodible lands are the flood plains and dunes not the Tertiary hillcountry in the upper Whanganui.
- The use of the term HEL is therefore emotive, wrong, highly misleading, and directs attention and resources into areas where the returns are likely to be minimal.
- 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.

- 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, losses in such situations may be very high.
- A 'model' farm at Tinui was devastated by an intense localized extreme rainfall event in 1987 despite all the very best and latest erosion control methods. The irony was that the 'rougher' areas of the farm were less affected than those with soil conservation works. This is likely because the soil had already been lost from these areas as discussed above.
- The problems of aggradation and reduced flood capacity of the Manawatu River are a response 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 but is ignored in the One Plan.
- 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.
- 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.
- The One Plan argues that a range of controls are necessary for the sustainable management of the HEL. 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.
- The policies and regulations in the One Plan, as they relate to hillcountry farm management, are therefore unfounded and unwarranted.

2.3 Relief sought:

- That the term *Highly Erodible Land* be changed to reflect the natural processes that are operating within this environment. It is suggested the *Inherently Unstable Terrain* more accurately reflects the natural dynamics of the landscape.
- Removal of the provisions relating to *Inherently Unstable Terrain* (i.e., HEL). They are restrictive, will achieve nothing in terms of sustainable land use, will alienate those who must work within them, will be difficult to enforce, and do not recognise the naturally dynamic nature of this landscape.
- That the One Plan be changed to recognise the benefits of ongoing research, and information as opposed to enforcement.
- That the One Plan recognises that the farmers' primary interest is the sustainable management of their land.
- That Horizons will work with the farmers to develop a code of practice to ensure that optimal land management is encouraged and adopted.
- That the One Plan be redrafted to reflect the actual processes operating, and the fact that these are largely natural.
- That the One Plan be redrafted in recognition of the fact that there is insufficient scientific evidence to provide justification for the current policies and regulations.

3.0 REGIONAL SITUATION

3.1 The conceptual model for the western side of the Horizon's region is often summarised as in Figure 1. Material is eroded from the mountains and then transported to the coast via the major rivers.

3.2 Such a model, however, fails to recognise is that rather than a continuous '*conveyor belt',* the system contains numerous stores. Sediment can remain in these stores for periods up to 1000s of years. Material can therefore 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.

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

3.4 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 flood plains, 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.

3.5 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 become, on occasion, liabilities. It is this apparent environmental contradiction that the One Plan appears to be trying to resolve – inappropriately.

3.6 There appears to be a belief that once humans exploit the assets of the physical environment e.g., the productive flood soils, then those processes that created the assets should cease.

3.7 Much of the One Plan appears to be developed from the perspective that we can control and manage 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.

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

3.9 Intermittent floods and erosion events must be regarded as nature's tax on our use of such environmental resources. While we may be able to delay payment of this tax, it must be paid at some stage; either through engineering works or damage.

4.0 PHILOSOPHICAL FRAMEWORK

4.1 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 appears to have been stimulated by the land's effect on human activities.

4.2 Resolving this misconception is fundamental to addressing potential problems. This indicates a lack of understanding of the natural physical processes operating within the One Plan. Given that the plan is supposedly based on 'science', this is of considerable concern. As will be discussed in the following sections, until a true understanding of the actual processes operating is gained, the One Plan is unlikely to achieve its stated goals.

4.3 There is a real risk that as long as the community goals that provide the rationale behind the One Plan are based on emotion and misunderstanding the plan is bound to fail.

4.4 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.

4.5 Long term conservation 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 costs.

4.6 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. 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.

4.7 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.

4.8 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. 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.

4.9 When carrying out the Land Use Capability Survey (as preparation of a Whole Farm Plan) 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!

4.10 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 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 revegetation 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)

4.11 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)

4.12 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.

5.0 CONTEXT TO SOIL SLIPPING

5.1 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.

5.2 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 rainfalls and floods. It is probable that previous erosion episodes have occurred during this type of climatic regime (Grant, 1983).

5.3 Many of the 0 and 1 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.

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

5.5 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.

5.6 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.

5.7 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.

5.8 Therefore, mass movement episodes similar to those taking place this century have occurred in earlier times. These earlier events occurred under forested slopes. Therefore, reafforestation 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.

5.9 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.

5.10 Sediment pulses during both historic and Holocene times suggest that sediment generation in New Zealand is particularly 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).

5.11 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.

5.12 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).

5.13 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 hill country, 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.

5.14 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).

5.15 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 more. This directly contradicts one of the fundamental premises behind the One Plan. The One Plan is therefore demonstrably wrong and the policies and regulations inappropriate.

5.16 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.

5.17 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.

5.18 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 if fact New Zealand, suggests that current rates of 'damage' are significantly less than they were in the past.

5.19 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' as suggested. Also, since the One Plan essentially proposes 'business as usual' with regard to erosion control, it is also likely to achieve limited success.

5.20 The 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.

5.21 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 locational potential. It is worth remembering that it was only the known floodplain that was flooded during the 2004 event, snd not even the entire floodplain. Therefore, bigger events have occurred in the past and will occur in the future.

5.22 Rather than addressing the dynamics of the flood plains themselves, there seems to be a completely unfounded, even illogical, premise in the One Plan that controlling hillcountry erosion will result in floodplains ceasing to flood.

5.23 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 flood plains 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. Again, this highlights a denial of reality and misplaced priorities.

6.0 HIGHLY ERODIBLE LAND (HEL)

6.1 I do not want to comment in detail on the sustainable nature of the hillcountry. However, the majority of the land classed as HEL, and therefore deemed by the One Plan to be unsustainable under pastoral land use, 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.

6.2 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 flood plains.

6.3 HEL 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.

6.4 Fundamentally, the categorisation of HEL is based on slope and an assessment of existing erosion. As already discussed, this is actually counter-intuitive since once the erosion has occurred, certainly with respect to shallow soil slip erosion, the area is actually significantly more stable than it was prior to the erosion.

6.5 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 oversteepening of slopes.'* This is an entirely natural process that would occur with or without human interaction with the environment.

6.6 This again highlights the confusion caused by attempting to define 'natural' as opposed to 'accelerated' erosion.

6.7 The categorisation of HEL 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 HEL it must have 5% erosion. This actually means that it 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 HEL.

6.8 Therefore, while HEL in hillcountry is 95% stable, the entire flood plains and dune areas are highly erodible without human intervention. The One Plan therefore seems to reflect a severe contradiction of reality.

6.9 The term HEL is therefore highly emotive and fundamentally incorrect. 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.

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

6.11 Although the definition of HEL is linked to the LUC, no calibration or validation is provided that this land is actually more highly erodible than other areas. As a result, the Section 32 reports can only be regarded as opinion. Moreover, when considered with the previous points relating to increasing resistance to erosion, the use of present erosion in the categorisation is demonstrably wrong. For example, if a slope is assessed one day and has no erosion one assumes that it can't be HEL. If for some reason there is a landslide during the night, and the same slope is assessed the next day, it will then be HEL. The reality is that it was actually more erodible the day before, when classified low than after the event when it was classified HEL. This highlights the inappropriate nature of the classification system that has been adopted.

6.12 As will be discussed in the next section, the inability of the HEL classification to identify accurately where the landslides in the 2004 event were located proves that it is an inappropriate index.

6.13 No-one has yet developed a model to accurately predict either the spatial or temporal occurrence of landslides with any degree of accuracy. 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 specific site scale, there is even less chance that potential instability can be resolved at the regional level.

6.14 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. This proves beyond doubt that these areas are anything but easily erodible!

7.0 2004 MULTI OCCURRENCE LANDSLIP EVENT

7.1 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.

7.2 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.

7.3 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 was probably more widespread (Hancox & Wright, 2005). This event was therefore an extremely large magnitude – low frequency event. Its impact on the landscape is therefore not ‘typical’.

7.4 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°.

7.5 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).

7.6 Differences in terrain characteristics were partially responsible for variations in 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 across the region. Variations in landslide types and characteristics were related to slope angle, slope height, and rock and soil type. The overall magnitude of the storm (amount and duration of rainfall) was also very important.

7.7 While the large number of shallow soil slips were perhaps one of the more dramatic results of the storm event this is misleading. The majority of geomorphic work (volume of material moved during the storm) was actually done by the few larger landslides. While the larger landslides (>1000 m^3) formed only about 3% of all landslides, they were responsible for about 48% of the volume of landslide debris eroded from hillslopes (Hancox & Wright, 2005).

7.8 The visual impact of the many small shallow landslides scarring large areas of hillcountry 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.

7.9 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).

7.10 The shallow scars and debris of smaller landslides also tend to regenerate grass cover relatively quickly. The larger slides in mudstone bedrock do not revegetate and therefore tend to be more permanent geomorphic features in the landscape (Hancox & Wright, 2005).

7.11 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.

7.12 While the debris deposited on top of pasture does have a very short term affect this material quickly re-vegetates and results in no overall loss of production. In fact, production off such areas may actually increase.

7.13 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.

7.14 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. The response via the One Plan is certainly not founded on geomorphic understanding, or the actual science, behind this multi occurrence landslide event.

7.15 It is important also to compare the effects of this event with Cyclone Alison which 'devastated' much of the southern Ruahine Range in 1965. This was a similar extreme event but under natural forest. The event mobilised millions of cubic metres of debris but even in that case over 80% of material is still where it was initially deposited.

8.0 CALIBRATION OF HEL CATEGORISATION

8.1 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 HEL; and the proposed management and regulatory instruments.

8.2 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. Not wishing to be facetious, Horizons should be congratulating the farmers and land managers that through their efforts 90% of potentially the most inherently unstable slopes in the region remained stable.

8.3 It is possible to criticise a number of aspects of the 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 are illuminating.

8.4 It is also important to recognise the inherent bias in the study. The authors state: *"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.

8.5 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. Even on this basis it is difficult to see the justification for the regulatory regime proposed.

8.6 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.

8.7 The authors themselves argue *"The proportion of landslide pixels that occurred in land susceptible to landsliding was 26%: a rather low accuracy."* It is worth reflecting on whether we would invest our own money in an enterprise with such a low level of confidence!

8.8 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 HEL, was wrong.

8.9 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! So just how riskier are the high risk areas?

8.10 Finally, the paper argues that forest would have ‘saved’ land from landsliding. In reality we can never know this. Given the stated bias in the paper discussed above, little credibility can be placed in this conclusion.

9.0 LINKAGE OF SLOPES TO RIVERS

9.1 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 in the material prepared by Horizons.

9.2 It is suggested that the aggradation in the rivers is a direct result of land management practices in the hillcountry. As will be explained below this is patently untrue and highly misleading. Data to support such an argument is simply not available.

9.3 As clearly reported by Hancox and Wright (2005) the majority of debris from the shallow landslides 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 down stream.

9.4 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.

9.5 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 downstream.

9.6 Therefore, within the upper Whanganui catchment the shallow soil slips contributed negligible amounts of sediment to the river systems. This is further discussed below.

9.7 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.

9.8 Such an effect is also not confined to just soil slips. Following Cyclone Alison's impact on the Ruahines 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.

9.9 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.

10.0 SOURCES OF AGGRADATION IN MANAWATU

10.1 One of the major misrepresentations within the Section 32 reports and the One Plan is the connection between slope processes (i.e., landslides) and aggradation of the lower river systems. Of particular concern is aggradation within the various flood control schemes, and the consequential reduction in flood capacity.

10.2 Aggradation within the flood control schemes is therefore one of the major justifications for regulatory and policy controls on hillcountry farmers. Despite this argument being promoted in the One Plan; the Council Officer's own reports counter to this argument.

10.3 For example Allan Cook's report clearly states that: "*River engineers are acutely aware that in designing flood protection schemes on flood plains 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 flood plains 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."

10.4 So, as stated by Cook, the problem of aggradation is natural. The logic of transferring the blame for this aggradation to hillcountry farmers is therefore not consistent. The costs associated with aggradation should be borne by those who reap the benefit from the protection works. The costs should certainly not be transferred to those hillcountry farmers in the upper catchment, by way of regulation and policy impositions.

10.5 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. It would appear that this knowledge has been 'lost' with staff changes over the past 30 years.

10.6 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 Southeastern 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."*

10.7 Aggradation had generally been attributed to increased erosion in the Range 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) concluded that *"It may be concluded that increased erosion in the Range has been of only secondary importance in influencing channel stability on the piedmont."*

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

1. 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.
2. Removal of forest cover from piedmont stream banks, permitting increased bank erosion and more extensive overbank flow and sediment deposition.
3. Channelisation on the fans, causing extensive scour of alluvial deposits.
4. An increase in erosion rates in the Range above the long term average caused primarily by changing weather patterns.

10.9 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.

10.10 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."* It would appear that this final comment has been used largely as the motivation for a number of the proposed strategies and policies within the One Plan.

10.11 Unfortunately floodplains will flood, naturally, and the extent of inundation is clearly dependent on the magnitude of the flood. The longer one occupies a floodplain the larger the magnitude flood one may have to confront.

10.12 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.

10.13 Channels adjust to accommodate the discharge and sediment supplied from the catchment; the higher the discharge, the bigger the channel (Figure 3). Where rivers flow across alluvial valley floors they are flowing between banks of alluvium (sediment) which was previously deposited by that river. This sediment is therefore readily eroded and transported by the river. As mentioned previously, this makes river banks HEL. Bank erosion should therefore come as no surprise, especially in 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).

10.14 The 2004 event was so large that it could not be contained. 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.

10.15 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).

10.16 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.

10.17 The quasi-natural morphology of many of these piedmont streams would be wide, shallow and more typically braided. However, this has been deemed not to be economically viable in this region. This means that rivers will continue to be constrained. Therefore, flooding of flood plains is natural and must be regarded as a tax we have to occasionally pay for their use.

10.18 The One Plan therefore aims to address aggradation within flood protection works. Horizons own evidence, and that of others, has clearly shown that the problem is NOT one originating in the hill and mountain country. It is caused largely by natural processes and management decisions on the rivers in piedmont areas and across the flood plains. These areas are not classed as HEL. Yet they are the source, and therefore also largely the solution, to the problem. It is here that any solution will be found. It will not be found in inappropriate management strategies and controls on hillcountry farmers.

11.0 WHANGANUI RIVER IS DISTINCTLY DIFFERENT TO THE MANAWATU

11.1 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.

11.2 The reality is that these have little relevance to the Whanganui catchment where the topography, lithology, and geomorphic and fluvial processes are all distinctly different.

11.3 Therefore, irrespective of the fact that the ‘solutions’ to these problems proposed in the One Plan are demonstrably wrong; they are definitely not transferable to the Whanganui catchment.

12.0 SEDIMENTATION/AGGRADATION IN THE WHANGANUI RIVER

12.1 Despite the fact that I have already shown that the loss of soil in the upper catchment has little affect on channel aggradation, an attempt was made to quantify the nature of any linkage in the Whanganui River.

12.2 Initially stream gauging data were requested from Horizons to see whether the channel cross sections at specific gauging sites were aggrading or degrading. Data exist for only one site within the upper catchment (i.e., Ohura @ Tokorima).

12.3 For this site, there are only five gaugings since 2001. However, two of these were on the 1 March 2004 and others were on 25 and 30th January 2008. These five gaugings were also undertaken at several different sites. While this is not an issue with regard to rating flows (the primary goal of undertaking a rating), it means that they cannot be used for assessing channel aggradation as the cross-sections are not comparable. As a result no changes in the channel cross section could be quantified.

12.4 Advice from Genesis Energy staff is that the bed of the Whanganui River at both Te Maire and Paetawa is degrading. Genesis staff are having to reposition their instrumentation at these sites to accommodate the lower bed levels. Therefore, rather than any sediment from the upper catchment causing the bed to build up, and reduce flood capacity, the opposite is actually happening.

12.5 An implicit link is also made in the One Plan between hillcountry management and water quality, specifically turbidity, of the rivers. Turbidity data were also sought from Horizons. While initially being told that I could have access to all the data; staff were directed to release only that up until 2004. That is, it is impossible to determine whether the 2004 event had any effect on turbidity levels over the later years, even though as argued above this is unlikely.

12.6 It would appear that data since 2004 has not been processed or audited.

12.7 It must be recognised that Horizons measure only turbidity and not suspended sediment concentrations. Turbidity is affected largely by the concentration of particles within the river but it tells little about the nature of those particles. If they are small they will be transported as wash load out of the catchment. If they are larger they may be deposited in low velocity flow BUT this is impossible to determine from the available data.

12.8 The data available shows a number of trends and relationships that clearly indicate that hillcountry management has little effect on sediment concentrations and turbidity in the lower catchments.

12.9 Figure 4 clearly shows an increase in turbidity with distance downstream along the Whanganui. Values are significantly less at Te Maire than they are at Te Rewa. This indicates that rather than material being dropped within the channel, the river is actually eroding more material. As a result, sediment from the hillcountry has a relatively minor impact on turbidity, and results in no bed aggradation.

12.10 Figure 5 provides additional support for the argument that sediment from the hillcountry has little effect on the channel dynamics of the Whanganui. This figure shows both the flow and turbidity at the Te Maire gauging site. If the supply of sediment was 'unlimited' – that is, if there was considerable material in storage waiting for transport downstream, as argued in the One Plan and Section 32 reports, one would expect to see a high correlation between the two variables. That is, peaks in flow should correspond with peaks in turbidity and *vice versa*.

12.11 It is immediately obvious that no such relationship exists. High turbidity does on occasion occur at high flow but it also occurs at low flows. What is more critical is that high flows are usually associated with relatively low turbidity levels. This clearly proves that the river is under-loaded. That is the river has the capacity to transport significantly more material than it does on most occasions. It does not carry more material because it is simply not available. This is in direct contradiction to the argument presented in the One Plan.

12.12 Land management of the hillcountry of the upper Whanganui therefore has a relatively minor impact on turbidity levels in the river.

12.13 Despite the above, the quality of the data on which Horizons have been basing their decision-making and policies must be questioned. Since no sediment data have been processed since 2004, it is impossible to support the contentions contained in the One Plan linking land use to turbidity and sediment transport.

12.14 Furthermore, as clearly shown in Figure 6 the quality of those data that do exist (at least for the Whanganui) must be questioned. This figure shows the continuous data relating to turbidity and laboratory determined turbidity values for a number of samples. One would expect to find a high degree of correlation between the two. That is, high field values should correlate with high laboratory values and *vice versa*. This is obviously not the case. In fact, it is impossible to detect any relationship at all.

12.15 Since one assumes that the laboratory values are 'correct', this suggests that the field data are of dubious quality. The data are certainly not robust enough on which to develop any policies or regulations.

13.0 SEDNET

13.1 Although not directly related to the One Plan, considerable emphasis is placed on the SedNet model when justifying the introduction of Whole Farm Plans under the SLUI.

13.2 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)

13.3 As has already been shown convincingly, these inherent assumptions are demonstrably incorrect. What this 'simple' model essentially did was to establish a self-fulfilling prophecy with limited credible scientific basis. Having assumed that land cover was a major control on sediment yield, without any calibration or validation, the model then 'proved' that more vegetation would reduce sediment yields!

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

13.5 The SedNet model therefore 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 then showed that increases in land cover would reduce sediment yields! This model, and the justification it provides for Whole Farm Plans, therefore has little credibility. It does not provide a scientific basis for the restrictive policies and regulations within the One Plan, and the SLUI.

13.6 While much of the One Plan focuses on the contribution of soil slips, this model 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 the active stream channels. The debris quickly stabilises and revegetates preventing the entry of sediment into the fluvial system.

13.7 As I have already shown, any increase in sediment load in waterways is not a response to landslip erosion in the hill country. Therefore, reductions in sediment load are unlikely won't follow restrictive practices on farmers.

14.0 CONCLUSIONS

14.1 There is a strong suggestion throughout the One Plan that its policies and objectives have been driven by 'science'. As has been shown in this submission this grossly over-states the reality of the situation. Much of the motivation behind the plan, as explained by Council officers, is the pursuit of community goals. These, however, must be realistic and practical. They cannot be based, as they would appear to be, on emotional and unrealistic expectations; or on inadequate science and information.

14.2 As has been illustrated throughout this submission there is no credible basis for:

- The definition of Highly Erodible Land (HEL)
- The assumption that erosion is accelerating
- The suggestion that the current land management of the hillcountry of the upper Whanganui River is not sustainable
- The linkage between land defined as Highly Erodible Land (HEL) and landslip occurrence
- The policies and regulations proposed for land management within areas defined as HEL.
- The benefits of the proposed land management controls within the upper Whanganui hillcountry on sustainability
- The benefits of the proposed land management controls within the upper Whanganui hillcountry on water quality
- And, although it is not directly related to the One Plan, the effectiveness of the SLUI.

14.3 Finally, aggradation and the flood risk to the lower Manawatu and Rangitikei would appear to be the motivation and stimulation for the proposed policies and regulations on farming activities within the upper Whanganui catchment. This is patently illogical since the catchments are distinctly different.

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John McConchie
30 June 2008

FIGURES

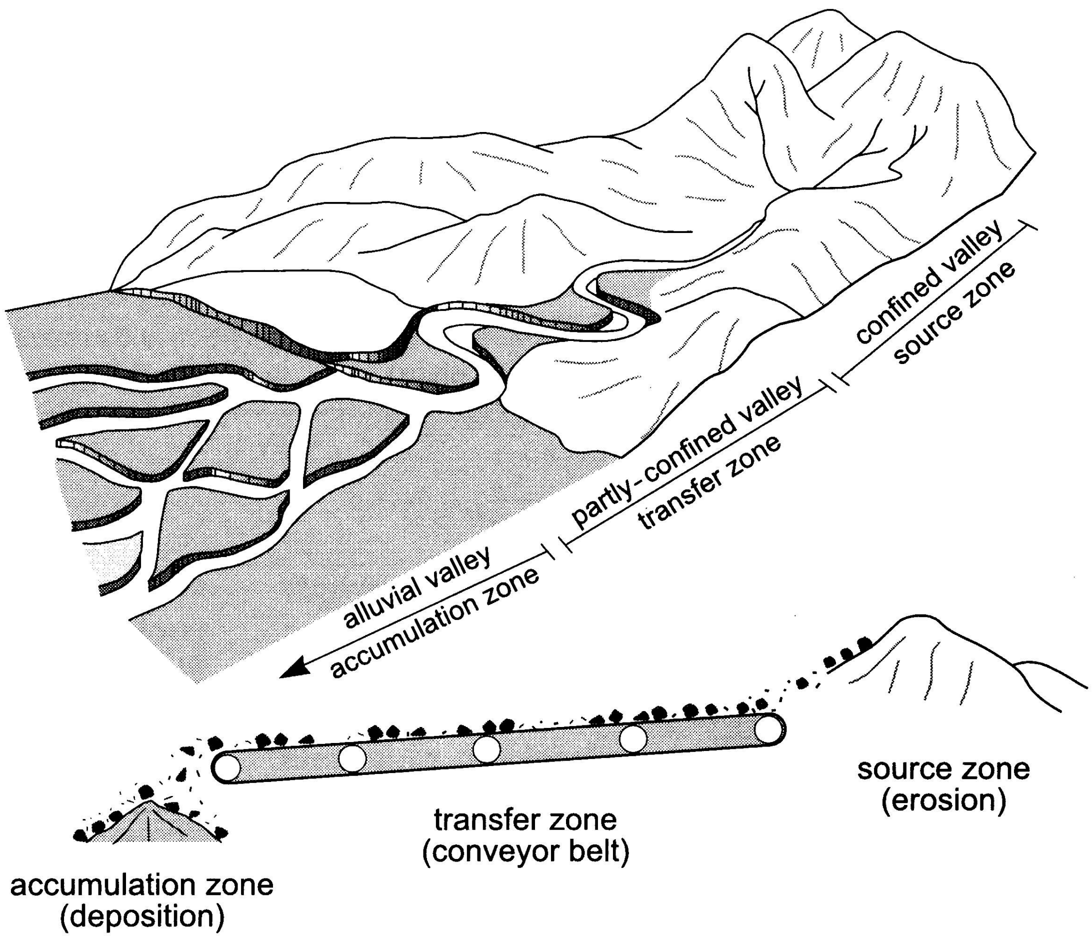

Figure 1: Basic concept model for sediment movement through a catchment.

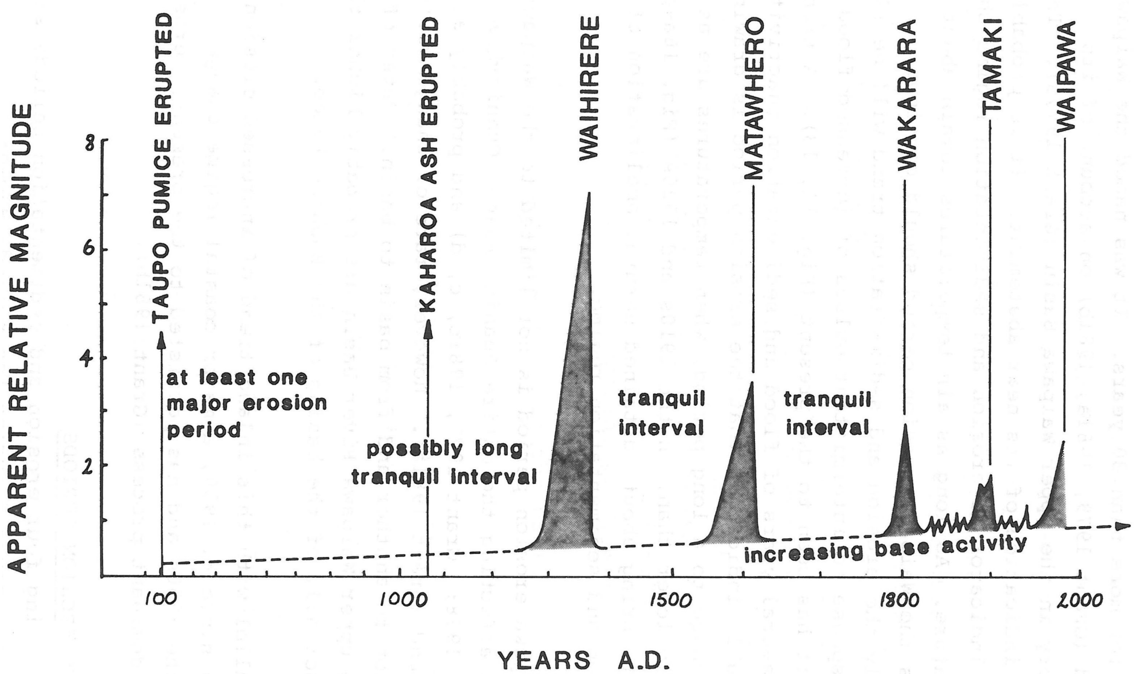

Figure 2: Erosion and sedimentation episodes since the 13th century (Grant, 1983).

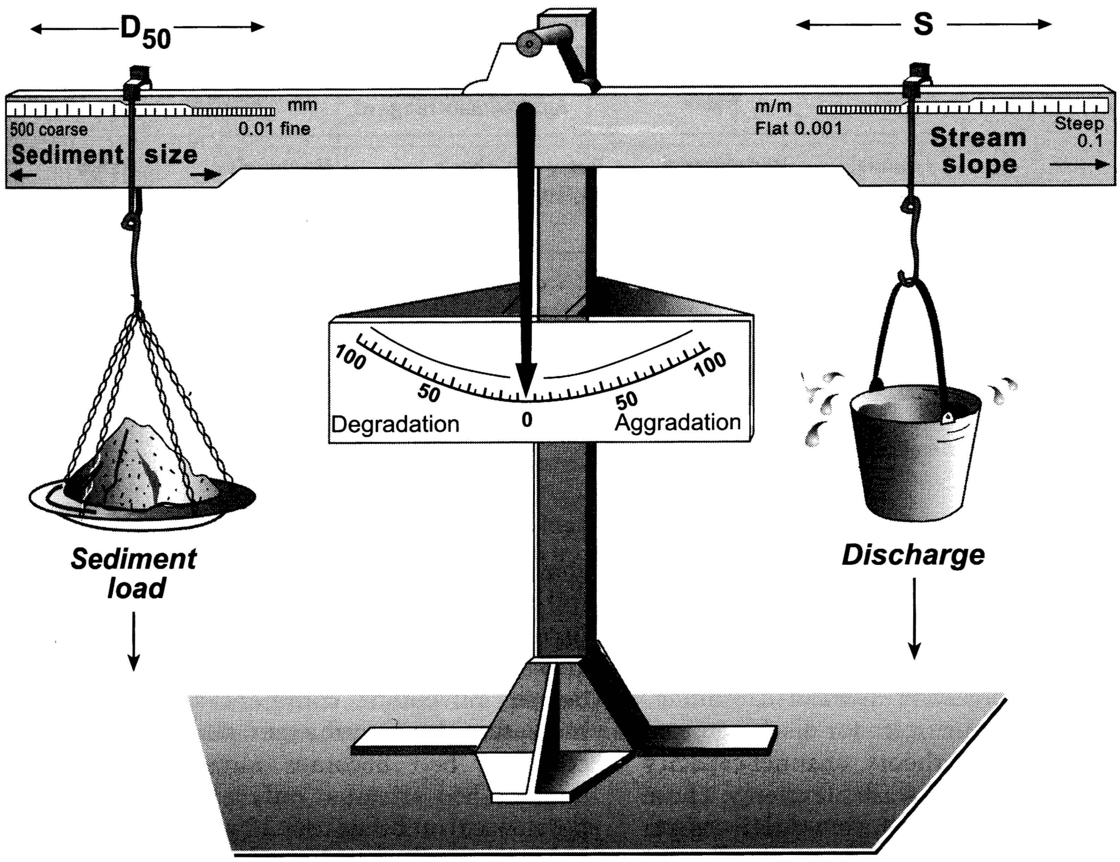

Figure 3: **River channels adjust by either aggrading or degrading in response to discharge and sediment supply.**

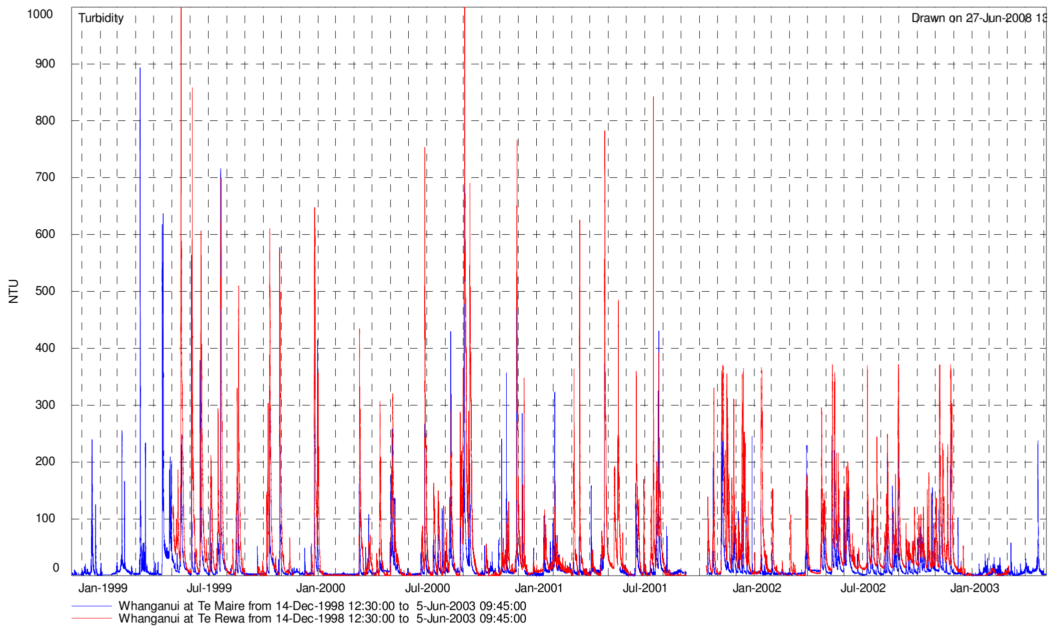

Figure 4: **Turbidity data from two sites on the Whanganui River.**

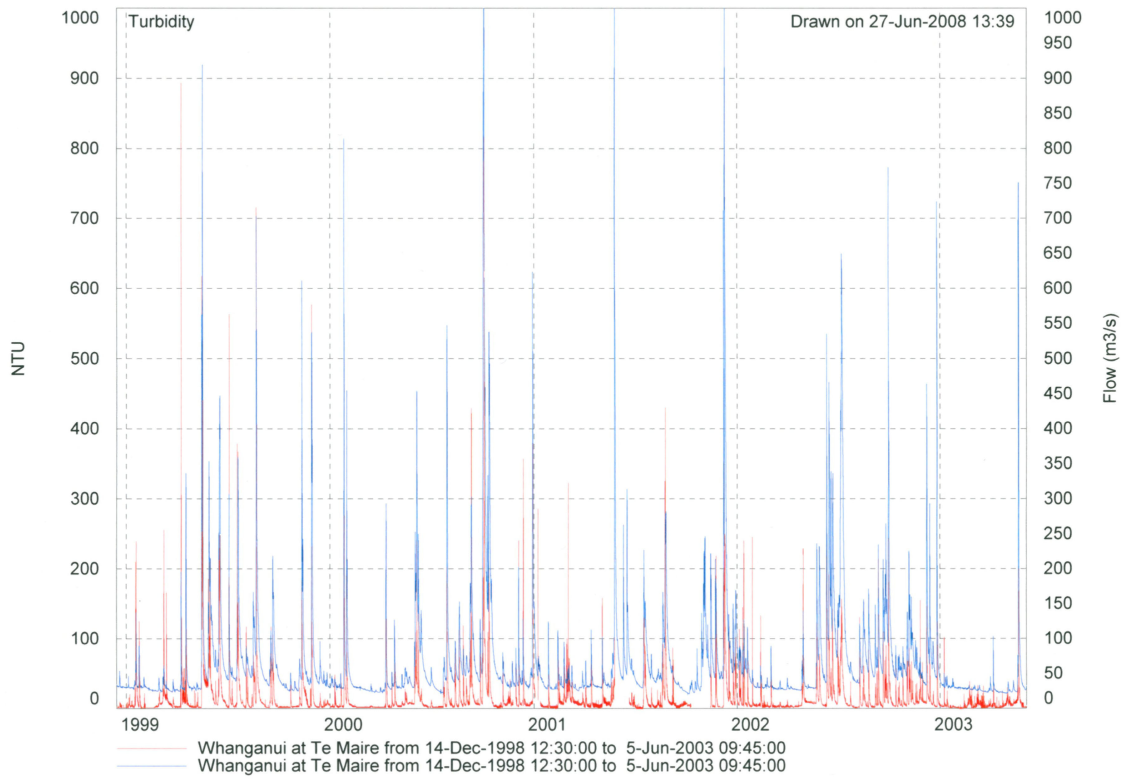

Figure 5: Relationship between turbidity and flow on the Whanganui River.

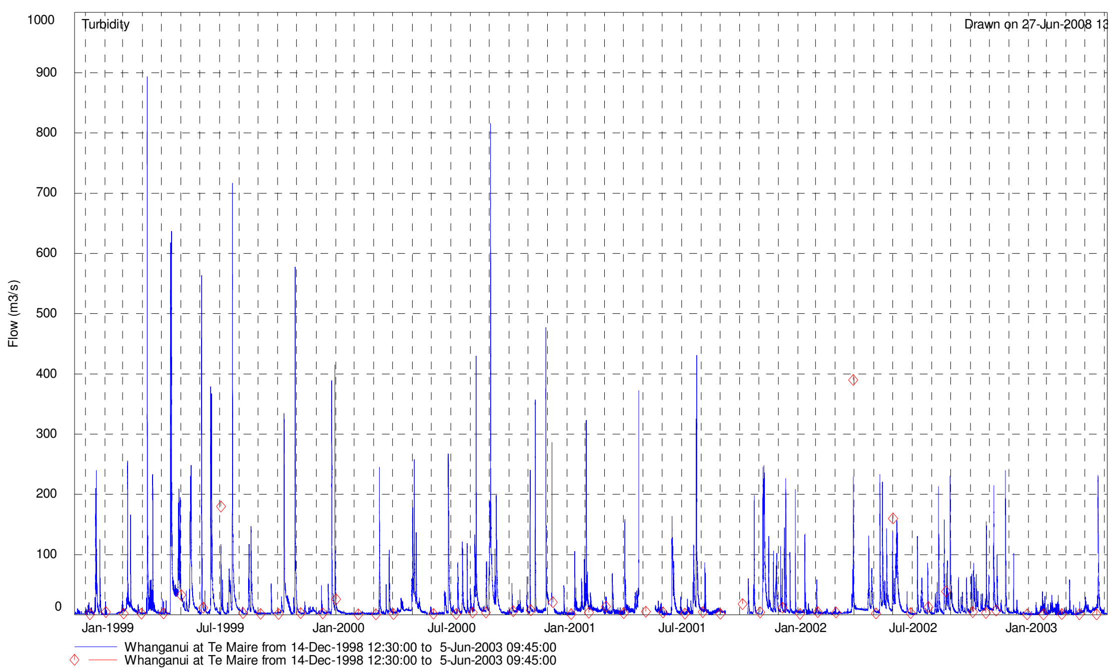

Figure 6: Relationship between field and laboratory turbidity data for the Whanganui River.