MAJOR REGIME CHANGES OF THE TUKITUKI RIVER, HAWKE'S BAY, SINCE ABOUT 1650 A.D.*

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SUMMARY

The Tukituki River catchment is simply described. The river system is treated in three sections—upper, middle and lower.

Evidence for an important erosion interval c. 1650 A.D., based on a study of depositional terraces, is outlined and adopted as a time basis.

Present channel geometry and flood levels are related to the 1650 A.D. depositional surfaces (Matawhero). Since 1650, five broad periods of river history based on the rate of change are recognised, and it is deduced that the Modern erosion phase was initiated prior to the European settlement and probably a little before 1800.

Several changes in the precipitation regime since 1650 A.D. are implied and, in particular, it is postulated that small-area rain storms have increased in intensity in the last 20–30 years.

Some implications in the fields of hydrology, climatology and geomorphology are discussed.

INTRODUCTION

An important natural event in one tributary catchment frequently does not correspond with that in another; whether it is fire, damage from wind, snow, or frost, or the occurrence of damaging rain storms. Therefore, the larger is the area studied the better will be the perspective gained; and to obtain a good understanding of river behaviour, the entire system must be studied. It is not sufficient to make broad regional surveys of, say, the montane protection forests of the upper section of river systems or the overflow patterns in the lower, for each system has its own complexities and peculiarities. Furthermore, where a general trend may be in operation, both the stage reached and the current rate, in each section of each river system, are liable to marked differences; therefore each must be assessed separately.

This presentation gives no more than a sketch of the history of the Tukituki River; but it introduces, and broadly exemplifies, a method of unravelling river history and determining present river trends, by the study and utilisation of river depositional surfaces and their ages.

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THE CATCHMENT

The Tukituki River rises on the eastern side of the Ruahine Range (c. 5,000ft) and enters the sea in Hawke Bay, about seven miles south of Napier. The channel distance is almost 80 miles and the drainage area about 940 sq. miles (Fig. 1). The river system is referred to in three sections—upper, middle, and lower (Figs. 2 and 3).

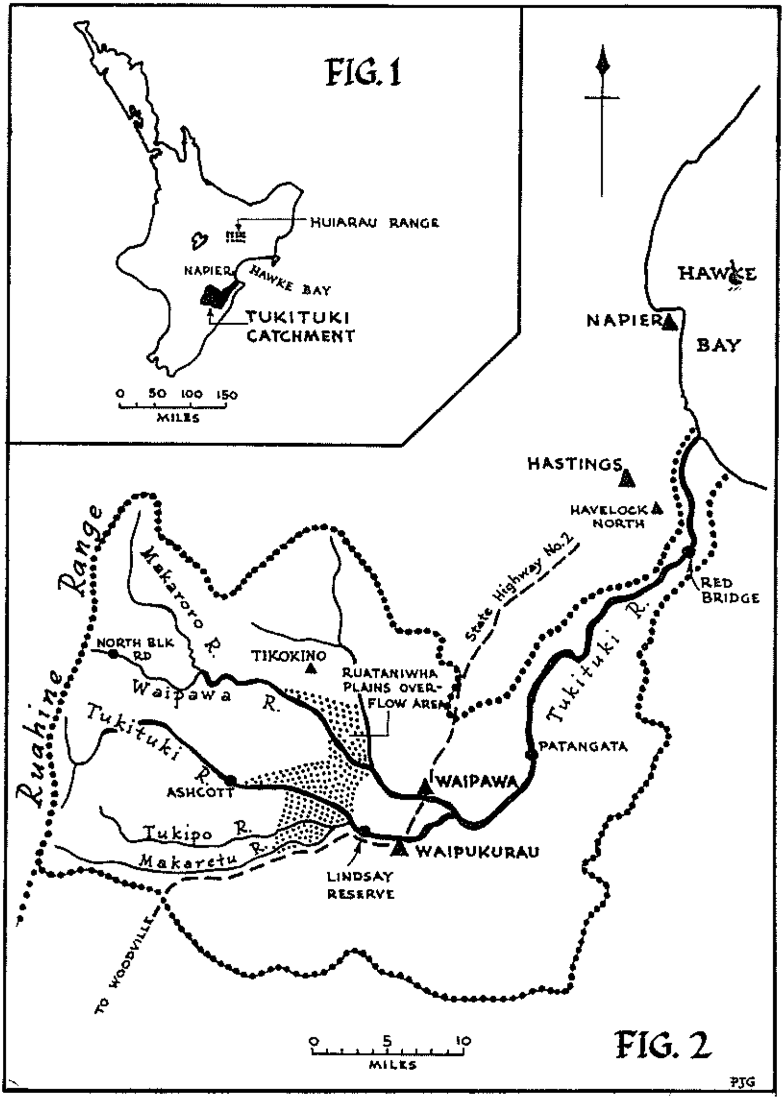


Fig. 1—LOCATION of Tukituki Catchment.
Fig. 2—OUTLINE of Tukituki Catchment.

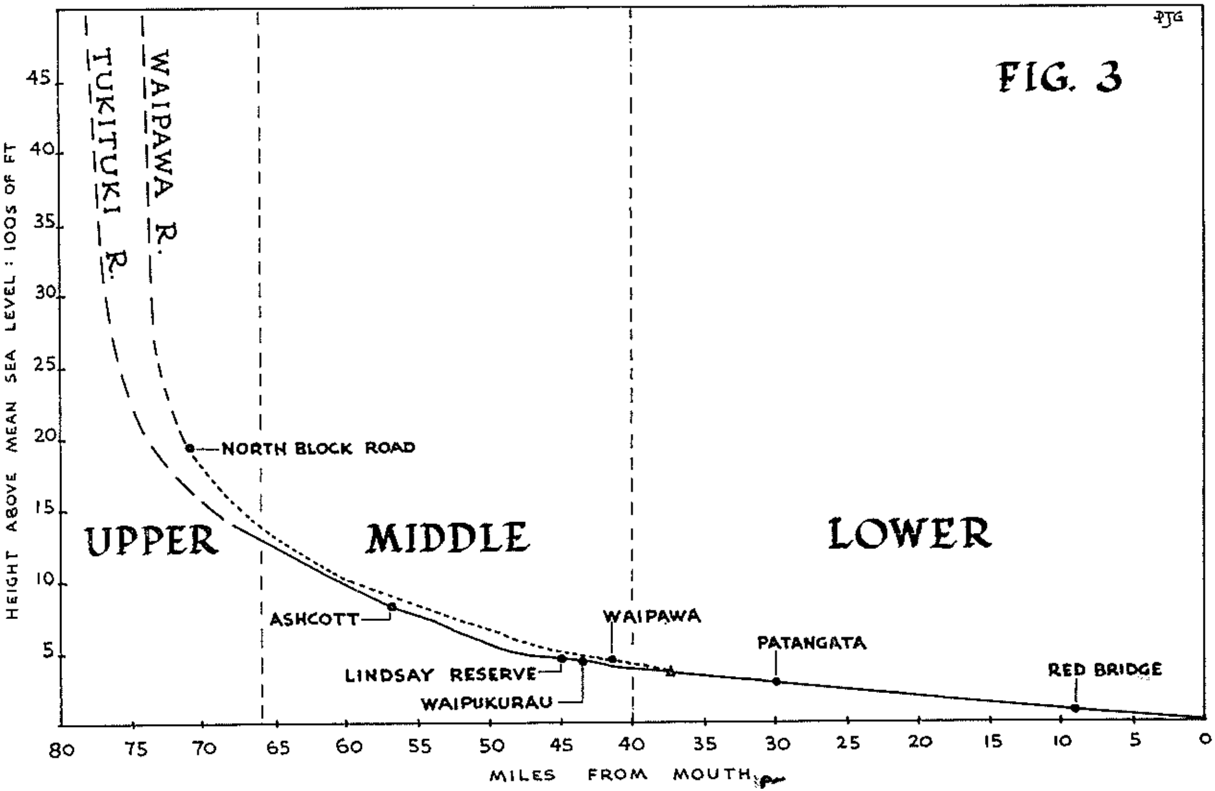


Fig. 3—LONGITUDINAL PROFILES of Tukituki and Waipawa rivers.

The upper section lies on and just east of the Ruahine Range composed of Jurassic greywackes and argillites. The middle section traverses firstly wide gravel plains and high terraces (Holocene and Upper Pleistocene), and then, in the vicinity of Waipawa and Waipukurau, a complex hilly belt of highly faulted limestones, conglomerates, argillites, siltstones, sandstones, and mudstones ranging in age from Pleistocene to Cretaceous. Both the upper and middle sections fall in a general ESE direction across the structural land "grain".

The lower section, however, falls NNE parallel with the "grain" and traverses a complex hilly belt of high gravel terraces, limestones, conglomerates, siltstones, sandstones, and mudstones of Pleistocene to Oligocene age. For the last five miles to the coast, the land is easy-rolling and flat, comprising alluvial gravels, sands and silts of Holocene age (Kingma, 1962). It is clear that geological structure has moulded the course of the Tukituki River in its lower section and, perhaps, recent tectonic movements have been responsible for some apparent anomalies in the river regime.

Mean annual rainfalls range from 32in. at the coast to about 150in. on the Ruahine Range. On higher parts of the lower section, and on the upper section, daily rainfalls may exceed 10in., and this amount may fall in as many hours.

Near the river mouth, summer flows are of the order of 200 cusecs, the annual flood is about 40,000 cusecs, and the estimated maximum probable flood flow is about 170,000 cusecs.

EROSION INTERVAL ABOUT 1650 A.D.

From investigations in the forested Urewera region the author (Grant, 1963: 158, 166) postulated that forests of the Huiarau Range (Fig. 1) were greatly modified, probably by gale force winds, around 1650 A.D. This event was accompanied, or immediately followed, by a short erosion interval. Confirmation of this event was afforded by the existence in waterways of low, recent-looking depositional terraces. Maximum tree (podocarp) ages on these deposits were of the order of 300 years, while the immature character of the forest soils proclaimed these trees to be the primary colonisers. In short, the erosion interval took place, or at least terminated, not long before 1650.

Support for this postulated catastrophic event comes from Pullar (1965a), who made a detailed study of stages of infilling of the Gisborne Plains where significant sedimentation occurred well after the Kaharoa eruption of c. 1000 A.D. and before the earliest recorded flood of 1820—but no specific date could be determined. Accordingly, for his Matawhero alluvium, Pullar was satisfied to adopt the author's dating of 1650.

As this contribution is in anticipation of a detailed paper by the author on the 1650 erosion interval in the Tukituki Catchment, it is sufficient to give here only an outline of the features related to that event.

Along the Tukituki River and its tributaries (Fig. 2) there are widespread indications that an erosion interval did occur about 1650. As in the Ureweras, the most convincing evidence is in the form of depositional terraces. These are composed of banded alluvial gravels, sands and silts which closely resemble deposits that are periodically and locally formed during large floods today, but they occur on a higher level. At Gisborne, Pullar (1965a) applied the name **Matawhero** to the presumed 1650 alluvium, and the same name is adopted here. Matawhero gravels are grey and clean and obviously little weathered, and the surface soil has weakly expressed A/C horizons even where sands and silts cap the gravels. On many sites in the upper section and on two in the middle, podocarp forest (**Dacrydium** & **Podocarpus** spp.) still exists and, in these, maximum tree ages were determined using an increment borer. All sites indicated a latest possible date for a great flood and erosion interval about 300 years ago, namely c. 1650.

PRESENT CHANNEL STATUS

The Matawhero deposits of 1650 are used firstly as a time base and secondly as fixed references for the determination of changes of channel geometry and flow regime (prevailing system). **Modern** deposits are taken as those laid down since the 1840s.

Upper River Section.

Rock erosion is severe and lateral corrasion of Matawhero terraces is marked. Early Modern terraces with forest are subject to over-deposits of coarse rock detritus. Travelling bed load quantities are large and intermittent bed aggradation is taking place widely; but there is considerable movement of bed load to middle reaches.

High intensity rain storms severely damage vegetation, and accelerate the supply of rock waste to channels. In the course of a storm, bed load waves have often exceeded channel limits in depth, and overflowed to seriously damage large trees growing on high banks. Such storms are limited in area and therefore damage in various tributaries is on a random basis. It is clear that such extreme events are at present dominant in the overall shaping of channels. And it is most important to appreciate that a major flood, and channel-shaping event, over a limited area of the upper section may produce only a minor fresh in middle reaches and only slight water turbidity and rise in stage in the lower. Hence, each damaging small-area storm may pass unnoticed; yet each successively increases the total area of denuded catchment and paves the way for greatly increased total sediment yields (bed load plus suspended sediment) during a storm that encompasses most of the river system.

Demonstrative of the rapidity of current changes is a reach (slope: 195ft/mile) on the Waipawa River, at the end of North Block Road, where cross sections were initially surveyed in April 1955. Subsequent changes at one cross section are tabulated below (measurements in feet, level datum assumed):—

Date	Active Bed Width	Mean Bed Level of Active Width	Lateral Corrasion of Matawhero Terrace
Apr. 1955	239	89.8	—
Dec. 1958	300	90.3	61
Apr. 1960	305	90.5	5
Dec. 1964	321	—	16
Apr. 1965	330	90.7	9
		Total in 10yrs:	91ft

If the current rates of change have been more or less constant since 1650, there would now be few Matawhero deposits remaining. One implication is that the combination of circumstances leading to such rapid lateral corrasion has not operated at the present rate for very long. A further outstanding feature is the devastation that occurs to the indigenous vegetation, even in a "reasonably satisfactory" condition (Cunningham & Arnott, 1964), during localised storms. This phenomenon has not existed at today's severity for a great length of time. And the same causal factor has increased bed load quantities and transport rates, and lateral erosion. Depositional terrace history indicates that a marked increase in the rate of change took place in the 1930s, and this became more pronounced in the late 1940s. It is postulated, therefore, that small-area rain storms have increased markedly in intensity since the 1930s. But even in this period there has been great variability, and tranquil spells tend to mask the true character of the regime.

Some of the observations of Colenso (1884) concerning his first crossing of the Ruahine Range in February 1845, by way of the Waipawa and Makaroro rivers, are worthy of special note. In the upper Makaroro River region he writes (p. 9) that narrow, steep stream beds were "partly choked with dead trees and shrubs, and masses of stone . . ." In the same area he continues (p. 10) ". . . fine forests of **Fagus** on the top; the trees of which were continually falling down along with the earth into the river beneath. Here and there an immense mass of earth had slipped quietly down the upright cliffs bringing the large trees with it . . .; in two or three spots during the day I noticed a double slip or subsidence of this nature . . ."

Near Te Atua-o-mahuru, 5,028ft, in the upper Makaroro he comments: "In our ascent we passed over two of the worst of the 'passes' and they were bad indeed! frightfully so. One in particular, as if an avalanche of half the mountain's side had suddenly slipped down into the distant gulph below, leaving a ragged razor-back edge of loose loamy sandy soil at a very acute angle. On this, which extended for 300 yards, connecting two peaks, nothing grew, as the sand and earth was continually rolling down." On the return journey, February 11th 1945, he states (p. 27): ". . . we halted for the night at a little wooded place on the banks of the Waipaoa (Waipawa) River called Motu-o-wai, and not far from the present village of Tikokino—formerly well-known, but now that isolated wood of white pine trees is washed away!"

On his second journey to the Ruahine Range, by the same route, in February 1847, Colenso (1884) made further pertinent observations on the range. He comments (p. 52) on stumbling over fallen trees and into holes of uprooted ones hidden in the thick undergrowth and ". . . sometimes passing along on the very edges of extensive landslips, down which it was fearful to look." In the beech forest below the summit on the western side he records that the party sank deeply at almost every step "among what seemed to be layers (**stratum super stratum**) of anciently fallen trees, which were all more or less rotten and lying across each other, and hidden under the long **Astelia** and 'Cutting-Grass' foliage . . ."

Colenso's observations can hardly be misinterpreted. **Firstly,** some time prior to 1845, areas of forest had been severely damaged. This could be placed c.1800 as N. L. Elder (pers. comm.) has observed, at medium to high levels on the Ruahine Range, that dead standing beech trunks usually decay and fall inside 50 years and frequently within 30 years of death. **Secondly,** his comments on erosion are vivid. No matter what the cause, the conclusion is inescapable that much of the scarring we see today on the Ruahine Range had its origin **before** the time of extensive European settlement and the introduction of animals. **Thirdly,** his single reference to the white pine stand on the middle Waipawa and its disappearance by lateral erosion between 1845 and 1878 is a strong indication that channel development was, even then, in a phase similar to that of the present day; but in between, there have undoubtedly been periods of relative tranquillity.

In both the upper Waipawa and Makaroro rivers, tree ages on alluvium below the Matawhero surface level indicate that a phase of erosion and deposition took place about 170 years ago, namely, a little before 1800. This deduction and the observations of Colenso seem to be mutually confirmatory, and together they establish a reasonable basis for proposing that the present unstable cycle commenced a little before 1800.

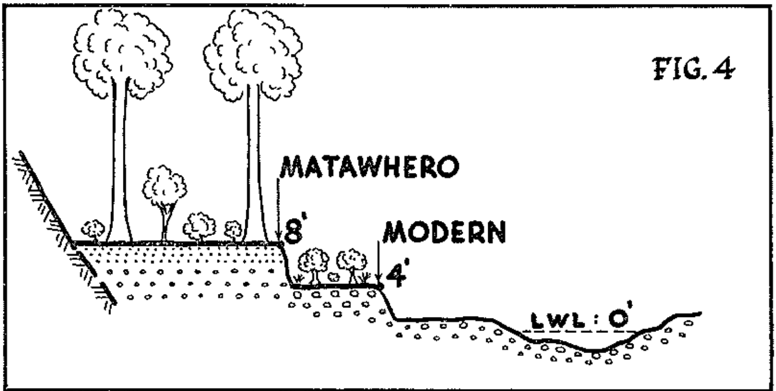
Middle River Section

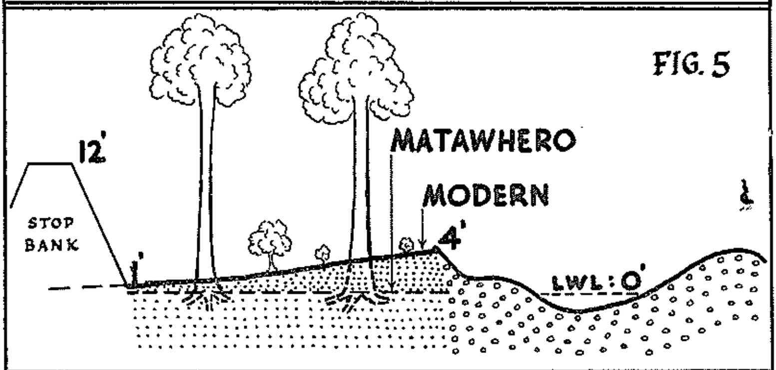
Braided channel patterns are the rule. Lateral corrasion of Matawhero deposits occurs locally, but edge protection planting with willows has retarded the process. However, there are local indications that an increased degree of protection may have resulted from channel aggradation and increased over-terrace flow during floods.

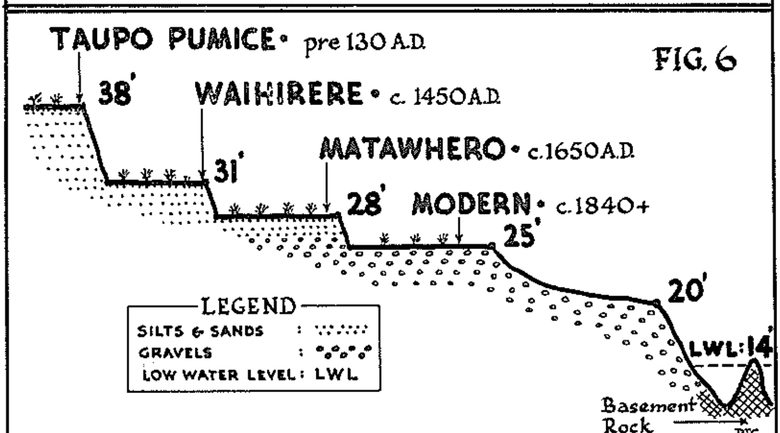
During the Matawhero catastrophe of 1650 major bank overflows with extensive deposition of alluvium are considered to have occurred in the Ruataniwha Plains area (Fig. 2). However, positive identification of Matawhero alluvium is restricted to deposits at Ashcott and Lindsay Reserve. The Ashcott terrace of Matawhero age (Fig. 4) carries a fine stand of podocarps, chiefly kahikatea (**Podocarpus dacrydioides**); it is about eight feet above present low water level (LWL) and it is not known to have been inundated by flood waters. On the contrary, Lindsay Reserve terrace, two miles upstream of Waipukurau, which also carries a fine stand of kahikatea, is frequently covered by flood waters and sediment. Soil profiles and channel cross section levels (Fig. 5) indicate that Modern sediment deposition on the Lindsay Reserve Matawhero surface is about 4ft towards the outer edge. The Matawhero surface is approximately at present low water level and bed gravels are 3–4ft higher. There could hardly be clearer evidence that very considerable channel aggradation has taken place in Modern times. Furthermore, Modern aggradation is suggested by the fact that from just below the towns of Waipukurau and Waipawa to near the upstream limits of major overflow in Matawhero times (Fig. 2), a stopbank system has had to be built to protect Matawhero and higher surfaces from modern floods—surfaces upon which in the 1840s existed large patches of forest, and Waipukurau Pa.

Sustained aggradation demands that supplies of detritus are readily available for transport. Four sources exist: (a) upstream river bed, (b) lateral alluvial deposits, (c) lateral parent rock, and (d) headwaters parent rock. Both river bed and lateral deposits have been the major sources, but the supply from the last two is undoubtedly increasing.

An increase in major flood sizes (climatic discharges) would increase bed loads, and also increase overflow quantities in the plains region (Fig. 2), leaving bank-full discharges with insufficient energy to transport bed loads; hence aggradation would result. On the other hand, an increase in flood sizes originating in the upper reaches only, as already postulated, would increase bed loads downstream, but due to downstream dissipation of a given discharge by channel storage losses, there would be a progressive decrease in the capacity for bed load, and aggradation would be







DIAGRAMMATIC CROSS SECTIONS OF DEPOSITIONAL SURFACES BORDERING TUKITUKI RIVER, SHOWING VERTICAL HEIGHTS.

Fig. 4—AT ASHCOTT. Native forest, chiefly kahikatea, grows on the Matawhero surface; willows, scrub and grasses grow on the Modern surface.

Fig. 5—AT LINDSAY RESERVE. Kahikatea rooted on the buried Matawhero surface have had their butts "drowned" by Modern accumulations. Near the river bed, the buried Matawhero deposits consist of silts and sands to a depth of at least 5ft—gravels are more than 9ft below the Modern surface.

Fig. 6—AT RED BRIDGE. Taupo Pumice surface has this ash in the topsoil and therefore is older than the eruption of 130 A.D. Waihihere surface is younger than the Kaharoa eruption of c. 1000 A.D. (Pullar, 1965a), and is provisionally dated here, from tree ages, at c. 1450 A.D. Matawhero surface is everywhere immediately below the Waihirere.

inevitable. In either case, or for any other explanation that might be proposed, reference to a fairly recent major change in flow regime seems necessary. Local tectonic warping, or tilting, could be invoked to explain the longitudinal profile of the Tukituki River reach about Waipukurau (Fig. 3) where a marked below-grade concavity exists.

No matter what the cause, aggradation was certainly initiated some time after the Matawhero deposition of 1650, possibly around 1800–1850, and general indications are that the tendency to aggrade in this portion of the middle section still exists. In essence, the middle section functions as a storehouse for much of the alluvium from up-river. It remains to be seen what effect the control works will have on the present trend.

Lower River Section

This commences immediately downstream of widespread bank overflows, viz, a little above the confluence of Waipawa and Tukituki rivers. The river is dominated by a meander pattern, and on many reaches basement rock is conspicuous in the bed.

While it has not been possible, due to the absence of primary vegetation, to distinguish Matawhero depositional surfaces with certainty, there are good indications that they exist widely and that locally they are quite extensive. A channel cross section at Red Bridge (Fig. 6) is valuable, as it demonstrates the vertical relationships between four depositional surfaces, and places the Matawhero surface of 1650 in better focus.

In the upper and middle sections, except in portions of the latter typified by Lindsay Reserve, Matawhero surfaces have seldom, if ever, been overtopped by flood waters. But at Red Bridge in the lower section, flood records for the period 1917–64 show that the Matawhero surface has been inundated on at least 12 occasions and the higher Waihirere surface at least six times.

In 1917 the peak discharge at Red Bridge was about 130,000 cusecs and this volume has not been equalled or exceeded since. This flood appears to have terminated a period, commenced in the 1860s, when many floods were greater than those since 1917; and during this phase much of the Modern depositional surface was formed. Subsequently, channel width has decreased and the channel appears to have degraded to basement rock; erosion of Matawhero deposits, and even of Modern, is relatively slight. Questions arise—why is apparent degradation a dominant feature, and why are Matawhero surfaces inundated so frequently?

The Napier earthquake of 1931 uplifted the land along the coast towards Napier (Fig. 2), but at Clive, barely two miles from Tukituki River, the land was lowered about 1.7 feet, and at Havelock North it was lowered from 2.0 to 2.5 feet. It appears safe to assume that the last eight miles of river bed were, if anything, lowered rather than raised. Yet within this length basement tertiary rock is exposed on many reaches. Degradation due to downward regrading therefore seems unlikely.

Another explanation, both plausible and possible, is as follows: Since some time after 1917, bed loads in the upper and middle sections have increased but the bulk has been trapped in middle reaches. As a consequence, lower reaches have received "undersized" bed load quantities and these have been either readily transported in the deep meandering channel or deposited laterally to increase the width of Modern accumulations.

The flooding of Matawhero surfaces has a bearing on the degradation aspect. Have they always been floodable in lower reaches, or has the phenomenon developed recently? In other words, have flood sizes increased since some time after 1650? Alternatively, are channel sectional areas now reduced by Modern accumulations, thus resulting in higher water levels for comparable floods? This latter proposition is, of course, unfavourable to the concept that degradation is a dominant process. Many questions can be posed but, at this stage, few can be answered with certainty. However, as forest once grew near Patangata on probable Matawhero and Waihirere surfaces and as such vegetation would not establish and develop readily with fairly frequent inundation, there is some justification for suggesting that, at least since the 1860s, flood sizes have been greater than in the preceding 200 years.

Finally, with respect to the apparent degradation throughout lower reaches one could, as for the middle section, invoke tectonic tilting. Ancient block tilting along the lower section is demonstrated by the marked upward tilt to the east of high-level terraces. Further movement since 1650 would not only induce local degradation but would also explain the apparent down-warping along the Tukituki River upstream of Waipukurau (Fig. 3).

POST MATAWHERO CHANNEL HISTORY

Following the great Matawhero flood and erosion interval of 1650 it is clear that widespread forest re-establishment took place both in montane regions and elsewhere. Podocarp forests established on Matawhero terraces. It is equally clear that, for some time after the deposition event, the flow regime was such as to permit plant colonisation; flooding of the new surfaces must have been either absent or very rare, notwithstanding that for some time channel sectional areas must have been very much smaller than they are today.

As time passed, channels degraded in the new deposits and meanders developed; and a phase followed of fairly steady channel widening, consistent with the discharge regime. But this process must have proceeded relatively slowly until about 1800, or a little earlier, when the tempo of development and change accelerated and marked the onset of the present unstable cycle. Certainly from the 1860s to 1917 the flow regime was characterised by many large floods and marked erosion of Matawhero deposits. This period probably saw the erosion of large quantities of rock detritus and its rapid transport and widespread deposition in the upper section; and the commencement of considerable aggradation in the middle. In many upper reaches, deposits traceable to this period (by tree ages) still exist. Since the turn of the 20th century the many great changes set in motion earlier have proceeded, at varying rates, to the present day.

A classification follows of five broad periods since 1650, based on relative rates of change (1. slow, 2. moderately fast, 3. fast, 4, very fast):

Period A.D.	Rate of Change
1650–c.1800	Slow
1800–1860s	Moderately fast
1860s–1917	Very fast
1917–mid 1930s	Moderately fast
1930s–1965	Fast (generally) Very fast (upper section)

SOME IMPLICATIONS

Only those features directly related to river history are here considered. The Matawhero erosion interval and its many implications will be discussed in a separate paper.

General

It is fitting to emphasize that since 1650 at least five broad regimes have influenced the Tukituki River system. Change, at greatly varying rates, has been remoulding the channel pattern since its last major and catastrophic reshaping in 1650.

Of great importance is the deduction that, prior to European settlement in the 1840s, the tempo of natural change had accelerated. And, since the start of the era of settlement and cultural activities on the land, marked fluctuations in the rate of change are discernible. In upper reaches during the last period (1930s-1965) channel changes have been exceedingly rapid and devastating, and this rate is being sustained, notwithstanding that during the latter part of this period, measures have been successfully improved to control fires and wild animals. There is scope for much contemplation in these facts. While we are eager to denounce the deleterious effects of many cultural activities, and rightly so, we are at the same time slow to appreciate that the tempo of natural events is seldom steady for long; and that some phases of the natural sequence may have an impact that far outweighs the effects of man and wild animals. To obtain a balanced picture of cultural effects we must firstly understand the natural order.

In case some foregoing statements are either misconstrued or improperly applied it seems desirable, in relation to upper catchment protection forest management, to make a positive statement concerning wild animals. The author has either stated or inferred that a great deal of current vegetation damage and erosion is primarily the result of high storm rainfall intensities. However, if such damaged areas are to become revegetated, it is **essential that efficient animal control measures are vigorously pursued.**

Hydrological and Climatological

The river changes discussed imply changes in the precipitation regime. Observations in the upper section furnish a basis for postulating that small-area rain storms have increased markedly in intensity since the 1930s. It is further proposed that the increase in intensity pertains particularly to rainfalls with durations of a few hours; certainly to periods shorter than a day. Hence, daily rainfall amounts may be of limited use for either determining or checking such trends. Studies such as the present one provide another line of attack in defining and understanding climate changes; other hydrological methods were discussed by Campbell (1963).

The recognition of natural changes and trends is basic for a better appreciation of:

(a) Flood frequency determination from short records.
(b) Normalisation of various flow and sediment parameters.
(c) The potential efficiency of river control works.

Measurements of river channels proposed by Campbell and Caddie (1964) are valuable, indeed necessary, but their interpretation would be aided if based on a knowledge of natural river trends. The determination and utilisation of old river depositional surfaces, such as the Matawhero, in the absence of any river records can assist greatly in the determination of recent river history and present trends. At the least, this type of study is valuable as a check on historical observations.

Geomorphological

River channel patterns have received much attention in the United States (Leopold and Wolman, 1957). These writers concluded (p. 71) that channel width is primarily determined by discharge; and Leopold and Maddock (1953:29) stated that there is a good basis for associating increase in channel width with an increase in bed load transport. Major channel changes in the Tukituki River system appear to conform with these findings.

Both braided and meandering patterns are forms of quasi-equilibrium, and the indications, at a given discharge, are that meanders occur at smaller values of slope than do braids (Leopold and Wolman, 1957). Conformity with these statements is also found in the Tukituki channel patterns. Dury (1963:93) writes: "Some braiding is probably a response to rapid bank-erosion. If so, meandering might well be associated with resistant banks." The author cannot support Dury's latter deduction because the lower Tukituki channel is dominated by a meandering pattern notwithstanding that the banks are composed of Modern alluvium which is highly susceptible to erosion.

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REFERENCES

Campbell, A. P. 1963: Methods of Obtaining Hydrological Evidence on Climate Change. **Proc. N.Z. Ecol. Soc. No. 10.**

Campbell, A. P.; Caddie, G. H. 1964: Definitions and Measurements of River Channels in New Zealand. **Prelim. Publ. of Soil Conservation and Rivers Control Council,** Wellington.

Colenso, W. 1884: **In Memoriam.** An Account of Visits To, and Crossings Over, the Ruahine Mountain Range, Hawke's Bay, New Zealand; and of the Natural History of that Region. Publ. by Daily Telegraph, Napier. (Read before H.B. Philos. Inst., 1878.)

Cunningham, A.; Arnott, B. G. 1964: Observations Following a Heavy Rainfall on the Rimutaka Range. **J. of Hydrol. (N.Z.), 3(2):15-24.**

Dury, G. H. 1963: **The Face of the Earth.** Publ. by Pelican Books.

Grant, P. J. 1963: Forests and Recent Climatic History of the Huiarau Range, Urewera Region, North Island. **Trans. Roy. Soc. N.Z. Bot. 2(12):** 143-72.

Kingma, J. T. 1962: Sheet 11, Dannevirke (1st Ed.) **Geol. Map of N.Z.,** 1:250,000. D.S.I.R. Wellington.

Leopold, L. B.; Maddock, T. 1953: The Hydraulic Geometry of Stream Channels and Some Physiographic Implications. **U.S. Geol. Surv. Prof. Paper 252.**

Leopold, L. B.; Wolman, H. G. 1957: River Channel Patterns: Braided, Meandering and Straight. **U.S. Geol. Surv. Prof. Paper 282-B.**

Pullar, W. A. 1965a: Recent Infilling of Gisborne Plains. In Press—**N.Z.J. Geol. Geophys.**

——— 1965b: Paper to be publ. in **Proc. 4th Triennial Conf., N.Z. Geog. Soc.**