



NEW ZEALAND JOURNAL OF ARCHAEOLOGY



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Archaeological evidence for the design of kauri driving dams in New Zealand

Bruce W. Hayward

New Zealand Geological Survey, Lower Hutt

and

John T. Diamond

16 Evans Road, Glen Eden, Auckland

ABSTRACT

Kauri driving dams were used in northern New Zealand between 1850 and 1940. Written descriptions and photographs of these dams are almost entirely restricted to those built after 1900, so that the archaeological data from their sites is the main source of information on their early design and architectural development.

The most common driving dams had a wooden framework and face which, once abandoned, rapidly rots away or is removed by floods. Where all woodwork has gone, the site consists of holes and recesses cut in the bedrock and earthworks dug into the stream banks. These footings can be interpreted to give an accurate picture of the dam's shape and size, its basic framework design, and the size and position of the flume around the gate. At some sites woodwork of the flume floor is preserved, giving a clue to the design of gate and trip mechanism. Four designs of gate, three of trip mechanisms and three of triggers are described, many known only from their archaeological remains.

Keywords NEW ZEALAND, HISTORIC PERIOD, KAURI LOGGING, DRIVING DAMS.

INTRODUCTION

The sites of well over 1000 kauri driving dams are present in the stream beds of some of northern New Zealand's roughest country. The methods of construction, use and design of the dams built during the period 1900 to 1940 are well documented (Reed 1964, Simpson 1973, Diamond and Hayward 1975), but little is recorded about the dams of the earlier period, 1850 to 1900. Thus the rapidly deteriorating remains of these dams hold an enormous amount of valuable information about this spectacular aspect of the kauri timber industry, unobtainable from any other source. This article describes the different parts of a driving dam and some of their varieties as an aid to the interpretation of their archaeological remains.

KAURI DRIVING DAMS

For 90 years (1850 - 1940) driving dams were used in northern New Zealand as a means of transporting logs, mostly kauri (*Agathis australis*), out of the bush-clad hills where they were cut, downstream to the timber mills. A dam was built across a stream, the water collected behind, and then was released as one "flood" to drive the logs downstream. Most dams had large built-in gates which could be completely opened with one pull of a tripwire. The logs either passed through the gate with the water or were picked up by the flood as it raced down the valley.

The dams were mostly constructed where the terrain prevented the economic use of other modes of transport, such as bullock teams, rolling roads and tramways. As a result, dam sites are generally found in the roughest country, such as the Omahuta Forest,

Waitakere Ranges and Coromandel Peninsula (Fig. 1). Driving dams are not known to have been used in New Zealand outside the kauri region of the northern North Island (Fig. 1).

Driving dams should not be confused with holding dams, which were built across streams often near their mouths and used to catch the logs that were driven down from above. Holding dams usually lacked a rapid release gate and in early times often incorporated a water wheel to drive the timber mill machinery. In later times most holding dams were replaced by pile booms.

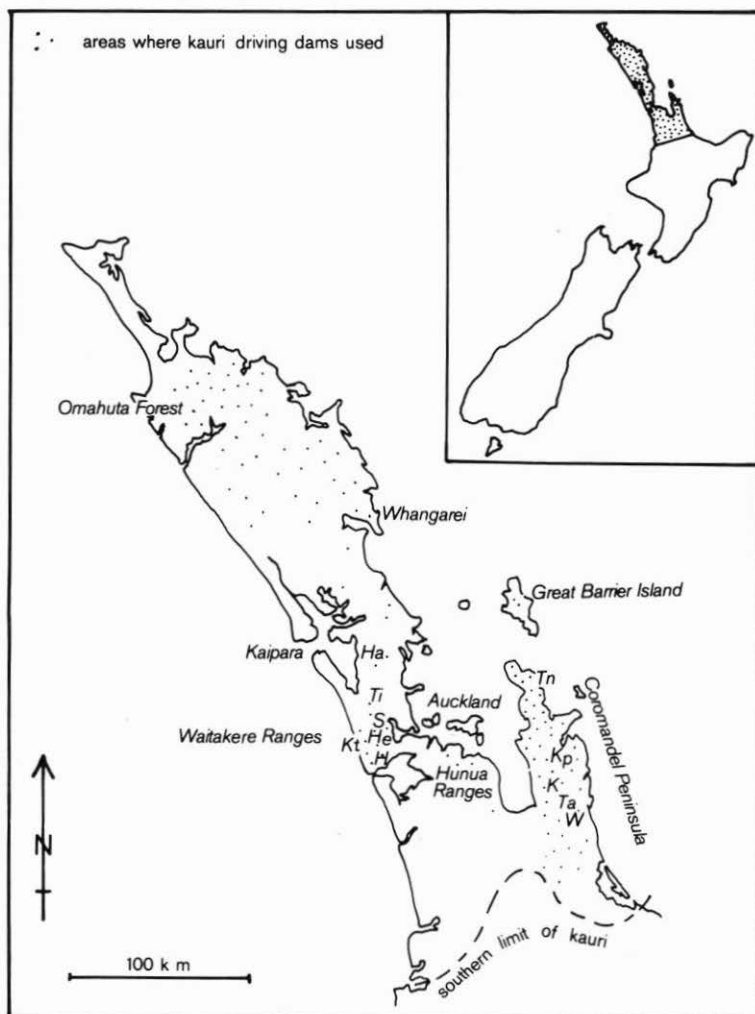


Figure 1 Map of northern New Zealand showing the distribution of kauri driving dam sites and localities mentioned in the text. H = Huia, Ha = Haruru Valley, He = Henderson Valley, K = Kauaeranga Valley, Kp = Kapowai Valley, Kt = Kitekite Valley, S = Swanson Valley, Ta = Tairua Valley, Ti = Tikokopu Valley, Tn = Tangiara Valley, W = Wharekawa Valley.

THE WRITTEN RECORD

Outline descriptions of the design and use of the two kinds of kauri driving dam used after 1900 have appeared in several popular texts (Reed 1953, 1964; Simpson 1973; Diamond and Hayward 1975). Although the use of driving dams in specified areas has been mentioned in numerous local histories, articles, and reports, the only known description of a pre-1900 dam is that of Baines (1874).

Unpublished sources of description, including a manuscript by Harsant (1966) and information obtained by one of us (J. T. D.) in the 1950s from Messrs Bill Barr and Charles Murdock, all refer to post-1900 dams. Tape recordings (held by Mr Brian Collins, Waimauku) made by the late Tudor Collins, who interviewed many old bushmen in the 1960s, also contain valuable snippets on later dam design.

Another valuable source of information is old photographs (Figs 2-4), many of which are held in public collections. The largest published assortments are to be found in Reed (1953, 1964), Diamond and Hayward (1975) and Hayward (1978). The earliest known photographs are of dams used in the 1870s - 1880s, but most are of later dams used in the 1910s and 1920s.

The information on the design of kauri driving dams presented in this article has been assembled from these sources, together with that obtained from field evidence.

THE ARCHAEOLOGICAL RECORD

Kauri driving dams were usually used for only a short period of time (three-five years) after which they were abandoned without being demolished. Over the years some have been burnt; others had their wood removed during the 1930s depression and Second World War; but the majority have been rapidly disappearing under the attack of rot and floods.

The best preserved dam sites are those used most recently (1910s - 1930s). Several, e.g. Kauaeranga and Tairua Valleys, Coromandel Peninsula, are in almost perfect structural condition, though the wood is badly rotted. The most interesting dam sites however are the earliest ones, built when a wide variety of designs and innovations were being tested (Baines 1874) and about which the least information is recorded. Unfortunately the remains of these 100- to 130-year-old structures are in poor condition, with most or all of the woodwork gone, leaving only parts of the flume floor, holes in the rock (Fig. 5), or earthworks on the banks.

The challenge for historical archaeologists is to reconstruct these driving dams by interpretation of their archaeological record. Eventually it may be possible to trace their historical development from early designs similar to those used overseas through to the two unique New Zealand designs that were widely used by 1900.

CONSTRUCTION MATERIALS

EARTH, CLAY OR ROCK

Driving dams built using a combination of these materials are extremely rare and known only from the southern Waitakere Ranges (late 1850s - early 1860s, Hayward and Diamond in prep.). Their remains vary from completely intact dams to only the earth and rock quarries left high on the stream banks.

EARTH AND WOOD

A number of driving dams were built using a combination of these materials. Several consisted of a low earth dam faced with planks and with a wooden structure on top, e.g. Henderson Valley, Waitakere Ranges, 1850s; Tikokopu Valley, south Kaipara, 1880s. In all recognisable sites, parts of both the earth and wooden structures remain.

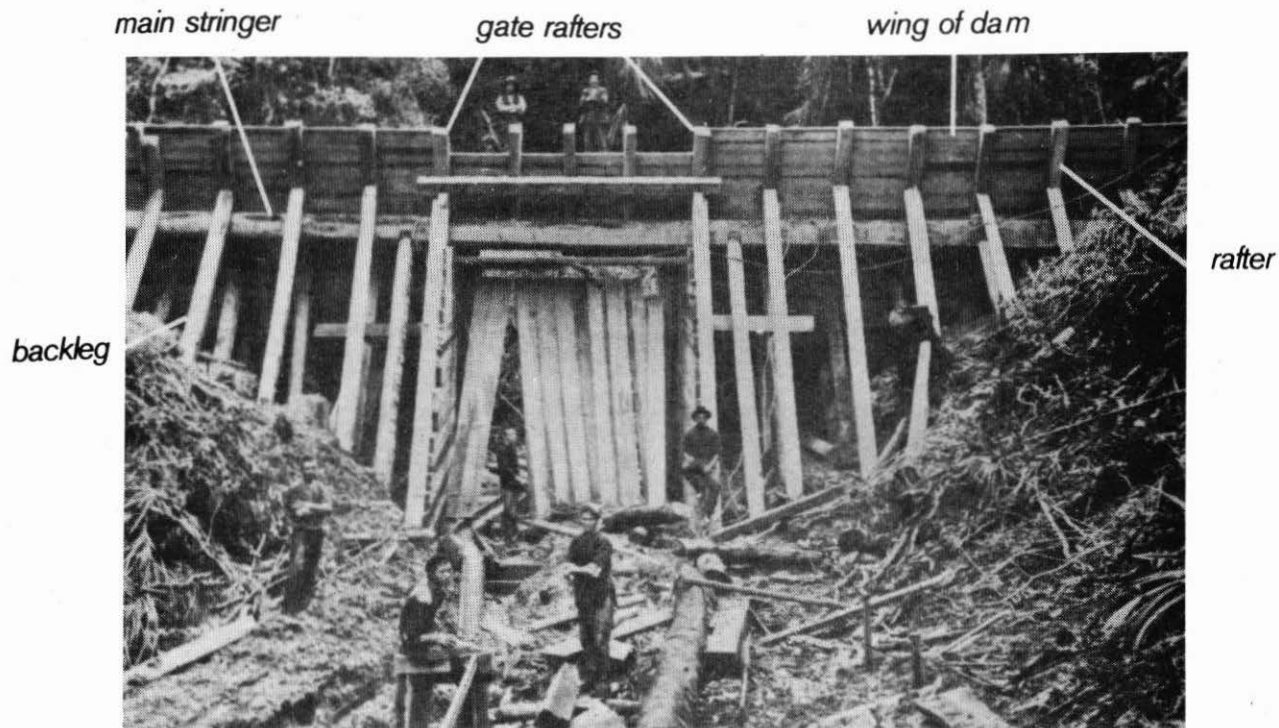


Figure 2 Downstream view of a small rafter dam with upright loose plank gate. The gate planks are hanging loose in an unset position. Parts of the dam are labelled.

face planking

gate rafter

stringers

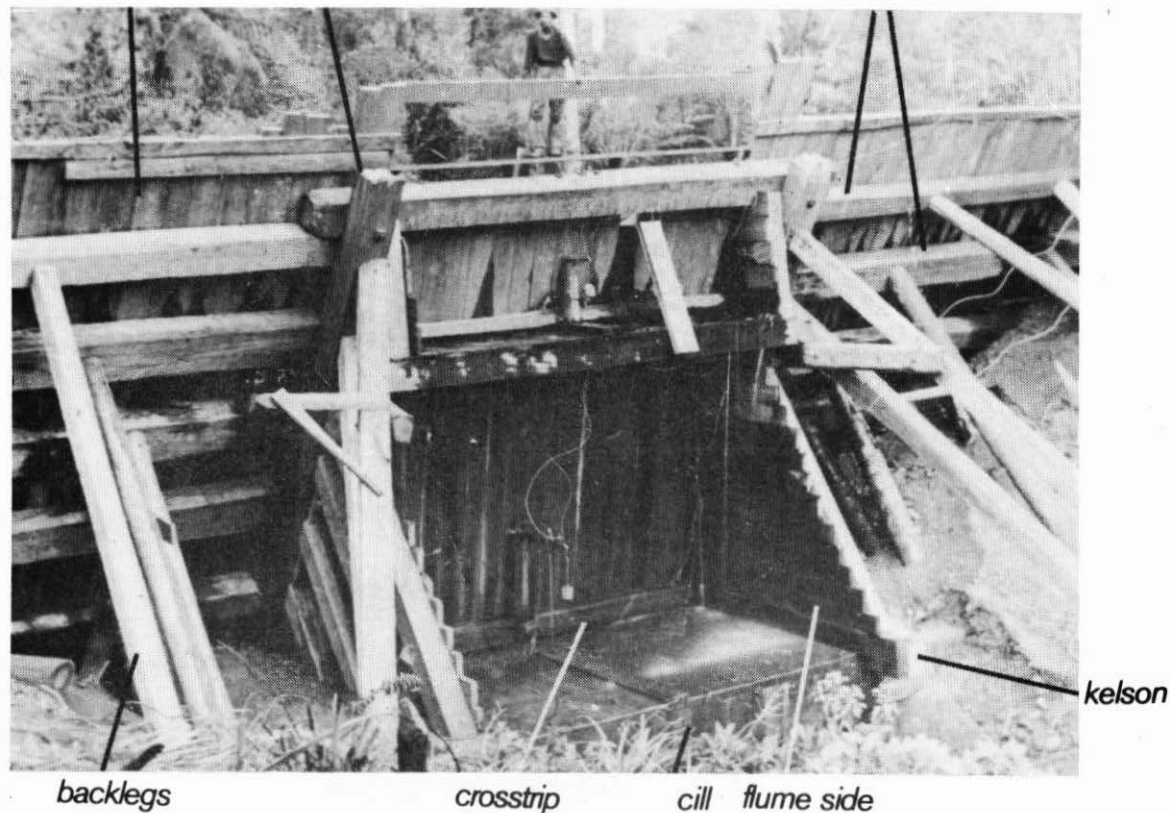


Figure 3 Downstream view of a stringer dam with two upright loose plank gates. The wooden tom trip mechanism in the centre of the main flume is set ready for tripping. Kitekite Falls dam, Waitakere Ranges, 1910s.

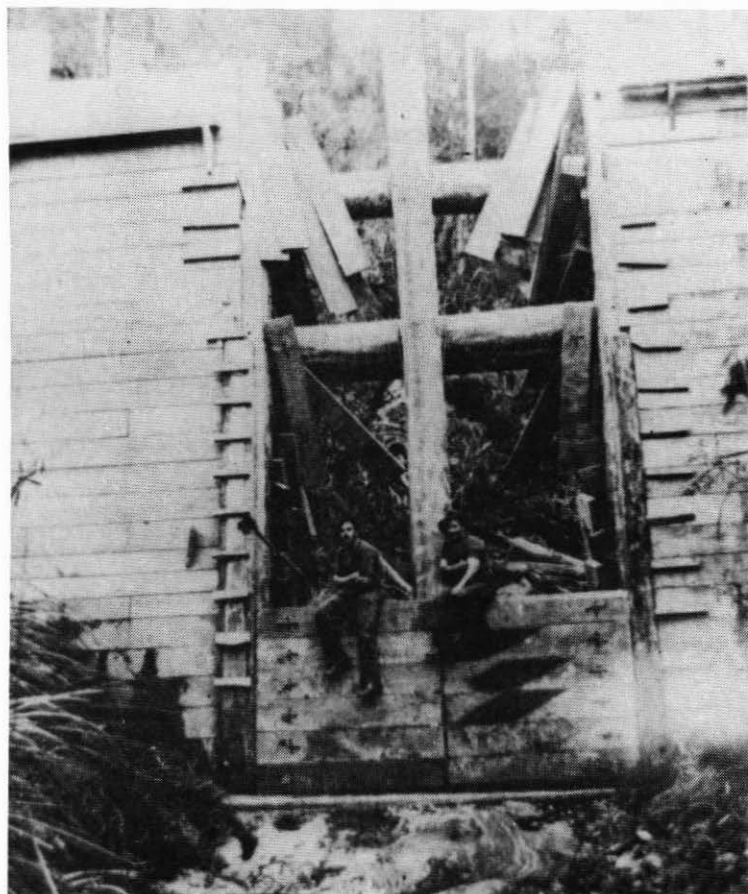


Figure 4 Upstream view of a swinging rafter dam, with the lower gate planks set in position and the upper ones hanging loose. Kauaeranga Valley, Coromandel Peninsula, 1920s.

WOOD CRIBWORK AND ROCK

Driving dams made from a cribwork of logs infilled with rocks were the most common type used overseas, e.g. north-east America and Korea, but no dams of this design have yet been recognised in New Zealand. The site of a dam in Karamatura Valley, Huia, Waitakere Ranges (late 1850s, Hayward and Diamond 1975, site no. 25) may have been a cribwork dam, but the archaeological evidence is inconclusive.

PONGA (TREE FERN)

Ponga driving dams had no gate and could only be used once. They consisted of a single tree (stringer) placed across the stream and another across the stream bed. A wall of pongas was built against these and made water tight with kiekie leaves, nikau fronds and



Figure 5 Site of 1910s stringer dam shown in Fig. 3. The only archaeological remains are the recesses for the cills cut in the solid rock on either side of the stream bed.

wet clay. Usually deep footings or earthworks were not required. The water was released by chopping through the stringer and the entire structure was then washed away. There are a number of written descriptions of these dams (Reed 1964:313, Simpson 1973:85, Diamond and Hayward 1975:12), but not surprisingly no archaeological remains are known.

WOOD (MOSTLY KAURI, BUT ALSO RATA AND TOTARA)

Over 95% of driving dams were made of planking fixed to a framework of stout wooden beams. The various parts of these dams were usually sunk deeply into the ground or solid bedrock, and thus the sites contain a great deal of archaeological information. The remainder of this article deals almost exclusively with these wooden framework dams.

DESIGN OF WOODEN FRAMEWORK DAMS AND THEIR ARCHAEOLOGICAL REMAINS

FRAMEWORK DESIGN

Wooden framework dams had built-in gates and a framework of beams for the face, called stringers (horizontal) and rafters (upright). The ends of the stringers and rafters were set snugly and firmly into holes cut for them in the solid banks or stream bed. Where no framework remains, the former size and position of these beams can be determined from their footings. The holes occur in a line across the stream and up the banks, corresponding with the original position of the dam face (Fig. 6).

The stringers and rafters were supported by backlegs (Figs 2, 3) which were also set into holes cut in the banks or stream bed downstream of the dam face.

Each dam had a main stringer (a baulk up to 2m square) which completely spanned the stream and formed the top of the gate. Each also had two gate rafters, one on either side of the gateway (Fig. 2). Beyond this there were two basic framework designs depending whether the main elements were uprights (rafter dam) or horizontals (stringer dam).

1. *Rafter dams* (Fig. 2). The framework of these consisted of a row of sloping rafters, at least 0.3m square, supported at their upper ends by the main stringer (and occasionally a higher stringer) and dug into solid rock at the base. The rafters were spaced 1-2m apart between the gate rafters and banks.

2. *Stringer dams* (Fig. 3). The framework of these dams consisted of stringers placed horizontally across the stream above the main stringer, and between the gate rafters and either bank below the main stringer. Stringers could be as much as 1m square, depending on their spacing (generally 1-2m apart) and the size of the dam. The length of the stringer varied; those beneath the main stringer usually spanned the gap between the gate rafter and the bank with one log. The main stringer was usually a single log but in several known cases two or more logs were used (Fig. 3). Stringers above the main one spanned either the entire stream or only part of it.

The sites of rafter and stringer dams can be distinguished in several ways. If no wooden framework is left, an examination of the holes left on the banks (Figs 5, 6) can be used to determine whether the major framework elements were upright or horizontal. It is also possible to distinguish the two designs using the backleg holes. Rafter dams usually had the backlegs arranged in regular lines behind each rafter (Fig. 2), whereas stringer dams usually had the backlegs less regularly arranged and angled outwards towards the banks (Fig. 3).

FACE OF THE DAM

Dams were faced with planks of timber, about 0.25m wide, 0.03m thick and 1.5 - 4m long, attached to the framework by spikes. In rafter dams the planks were attached horizontally on to the rafters to form the wings. In these dams the style of face planking above the gate varied according to the framework chosen. Some dams had supplementary rafters above the main stringer on to which horizontal face planks were spiked (Fig. 2); others had two or more short stringers spanning the gap above the gate and upright planks were used. The style of face above the gate cannot be determined from most sites.

The faces of stringer dams were formed by planks spiked upright between the stringers. Occasionally the remains of a little face planking, left high on the banks of the stream, is all that is available for determining whether the dam was of rafter or stringer design.

To help anchor the dam firmly and to assist water-proofing, the line along which the face was to be constructed was usually excavated down to bedrock across the stream and up the banks if possible. A trench was dug on either bank in which the lower parts of the wings were built. Face planking was generally fitted tightly into a groove cut in the bedrock and the join was sealed with impervious clay.

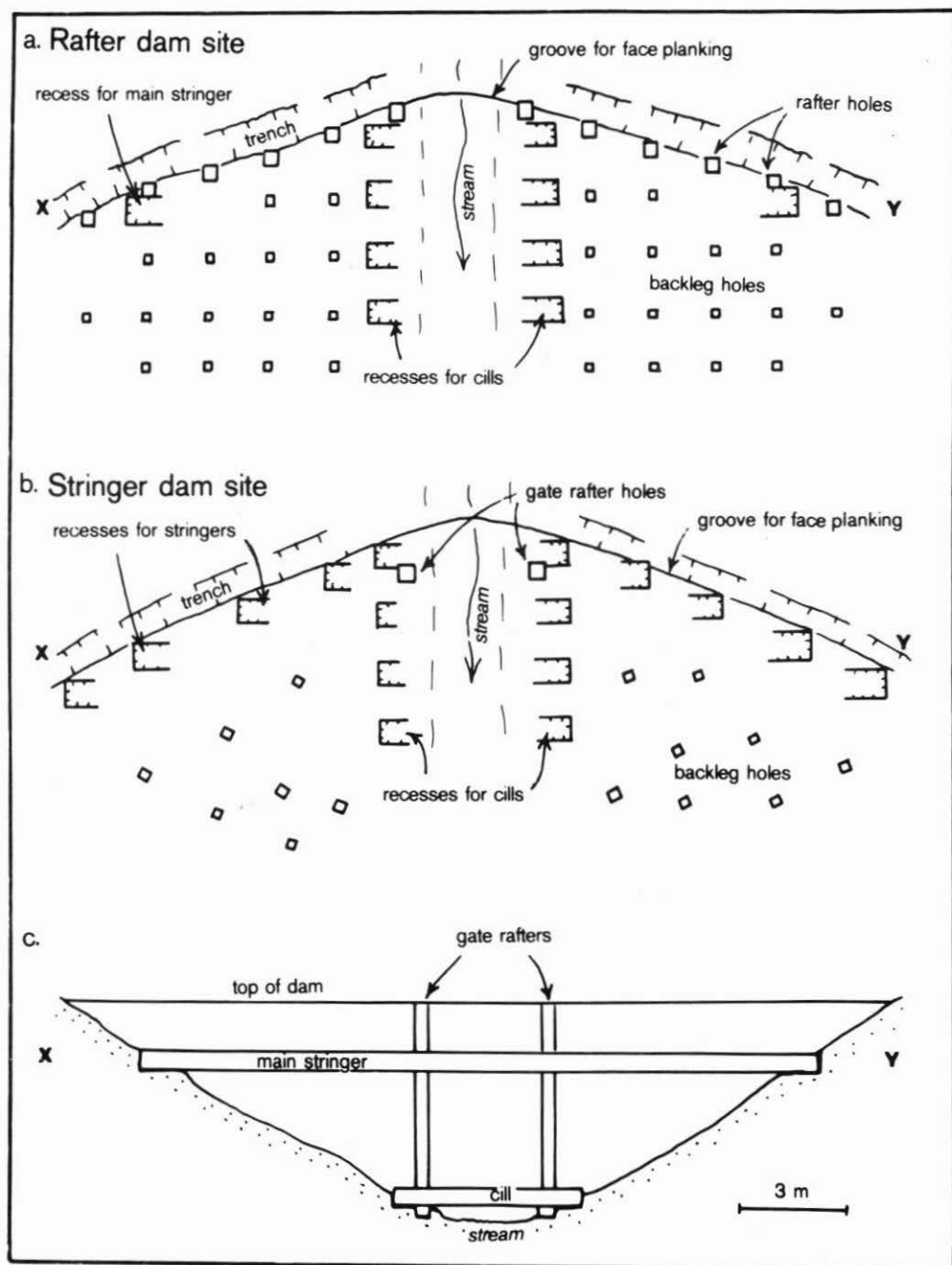


Figure 6 a, b. Plans of the earthworks, recesses and footings dug for the construction of wooden framework driving dams of rafter design (a) and stringer design (b). c. Stream profile showing position of basic elements of both designs and their relation to the footings.

Almost all wooden framework dams had faces sloping upstream at angles varying from 33° to 70° to the horizontal. The angle of the face is often a useful indication of the approximate age of a dam. The angle can be measured in a number of ways in dam sites. Where woodwork is present, direct measurements can be made, though often the face is slightly collapsed. The most accurate result is usually obtained by measuring the slope on the downstream side of the holes cut in bedrock for the rafters. Where the groove, cut in the bedrock for the face planking, is preserved, a reliable reading for the face angle is also obtainable. Face planking beneath the gate, however, was often inclined at a different angle from the main structure.

A general estimate of the angle of the face can also be obtained, where no other means are available, from the slope of the trench that was dug on either bank during construction (Fig. 6). The slope of the upstream side of the backleg holes is not a reliable measure as the backlegs were not always fitted at a perfect right angle to the slope of the face.

FLUME

The majority of wooden framework dams had built-in flumes around the gate and extending downstream from it. The floor of a flume was formed of planks spiked to a framework of cills (baulks of timber up to 1m square), which were spaced 1-2m apart across the stream bed (Fig. 7). The cills were fitted tightly into recesses cut deeply into the bedrock. The number of cills varied from two to seven, depending on the length of the flume and the slope of the face of the dam. Two kelsons (baulks of timber 0.2 - 0.3m square) were placed across the cills on either side of the planked flume floor (Fig. 7). The kelsons were important in strengthening the dam, closing the gate (see later) and supporting the backlegs behind the gate rafters. The planks forming the sides of the flume were spiked to these backlegs (Figs 3, 7).

The purpose of the flume was to direct outwards, down the stream, the water and logs which gushed forth when the gate was tripped. Directing the flow this way protected the banks close up to the dam, and prevented the foundations for the backlegs being washed away. Flumes were sometimes omitted from dams through which water but no logs were passed, e.g. forms with swinging rafter gates and those with upright, loose-plank gates and only one cill, Kauaeranga Valley (Hayward 1978:29). These dams always had a single cill placed directly behind the base of the gate rafters.

In sites where no woodwork remains, the presence and size of a flume can usually be determined from the recesses cut in the bedrock for the cills (Fig. 6).

GATE

Three designs of gate are known to have been used in New Zealand. The archaeological remains of one dam in the Huia Valley, Waitakere Ranges, (Hayward and Diamond in prep.) suggest a fourth design similar to one common overseas.

1. *Upright loose plank gate* (Figs 2, 3, 7). This was the most common type of gate used. It consisted of loose planks (about 0.3 x 0.08 x 5m) placed upright, side by side across the gate opening. The top of each plank rested against the main stringer while the bottom rested against a cross trip on the flume floor. Each plank was loosely chained or wired to the main stringer so that after they were released for a drive, they could simply be placed back in position and the dam refilled for another drive. The gate planks were never vertical but were positioned to slope upstream at an angle of approximately 80° .

The average size of the gate was 5m square, but they could be as small as 3m square. The largest known gate was 4m high and 10m wide. This was in the main dam in the Kauaeranga Valley, built in the 1920s (Hayward 1978:32). Several large dams had two gates of this design, set side by side within the structure, e.g. Kapowai Valley, 1910s; and Wharekawa Valley, 1880s, Coromandel Peninsula (Diamond and Hayward 1975:30, 33), and one other dam had three (Tairua Valley, Coromandel Peninsula, 1900s).

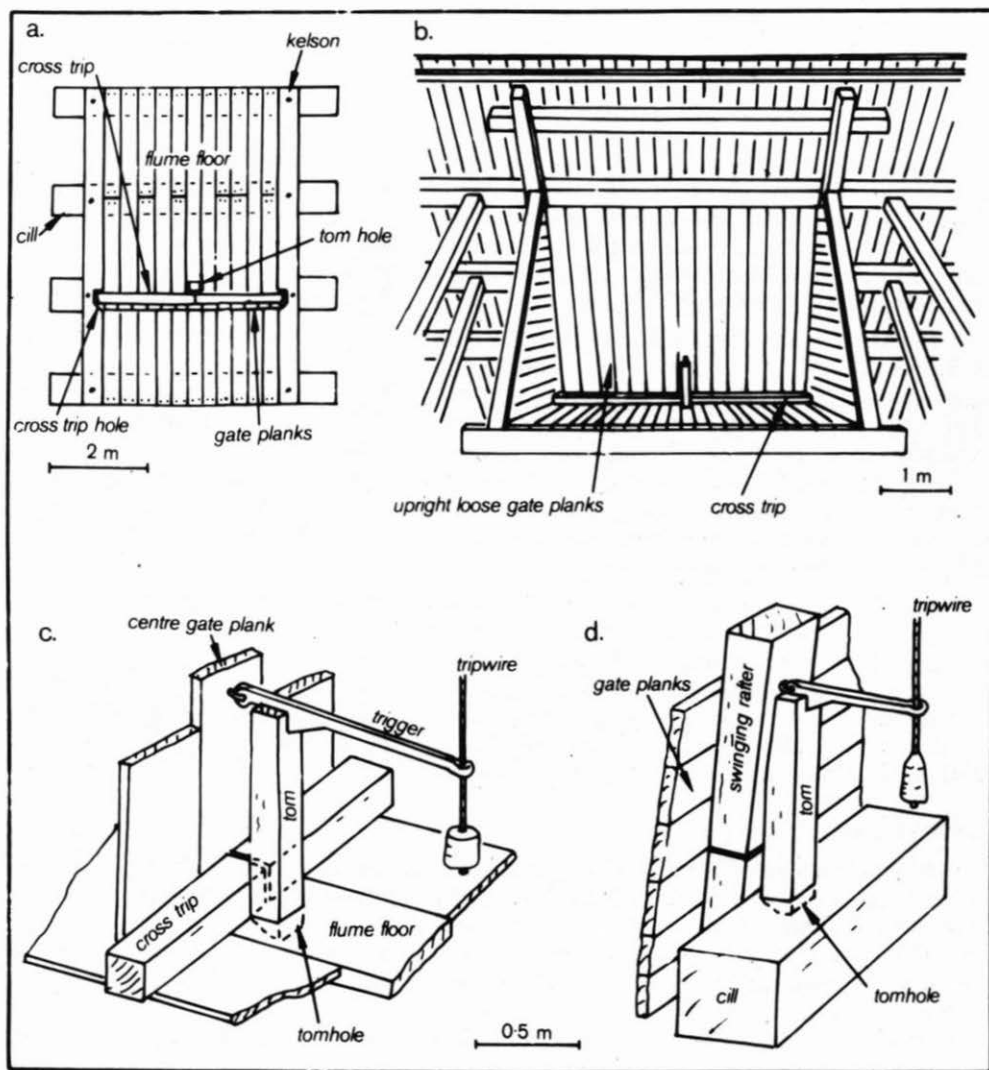


Figure 7 a. Plan of the flume floor of a typical stringer dam with upright loose plank gate. b. Downstream view of the flume and upright loose plank gate of a typical stringer dam. c. Wooden tom trip mechanism of an upright loose plank gate. d. Wooden tom trip mechanism of a swinging rafter gate.

One driving dam (Fig. 3) is known to have had a normal sized upright loose plank gate with a second shorter gate of the same design set directly above the first. The second gate was added later when the structure was converted for use as a holding dam. Another dam (Swanson Valley, Waitakere Ranges, 1860s) is recorded as having had two gates (of unknown design) one above the other (Hepburn 1933), but its archaeological remains neither confirm nor disprove this.

2. *Swinging rafter gate* (Fig. 4). Dams with this kind of gate were quite common after 1900 and were generally confined to small streams, where logs did not pass through the gate. The gate design was only used in rafter dams that had a single cill and lacked a flume. A free swinging rafter slightly wider than the others was placed upright in the gate opening. Its top rested against the main stringer, to which it was loosely wired, and at the bottom it was held by a tom. The gate planks, two end to end, were fitted horizontally across the gate opening. One end of each plank rested against a gate rafter and the other ends butted together in the centre of the face side of the swinging rafter. Each was loosely wired to its respective gate rafter and was able to be reset in position after a drive. When set, the swinging rafter and gate planks were at the same angle as the face of the dam. These gates were usually narrower than the upright loose plank gates and most had the swinging rafter and horizontal gate planks extending above the main stringer to the top of the dam (Fig. 4) although this was not always so (Diamond and Hayward 1975:31).

3. *Double door gate* (Fig. 8). This type of gate is known only from the written description of Baines (1874:175) and was one of a number of early designs used. Their use may have been more widespread than the literature suggests. The gate consisted of two solid doors that were hinged to the flume walls and met together at the centre of the gate. When released the doors swung open against the sides of the flume.

4. *Vertical drop gate*. This was the most commonly used gate design in driving dams overseas. It consisted of a solid vertical gate set in runners on either side of the flume. It could be slowly raised or lowered using a wooden lever as a pry. Its use in New Zealand has not been proven unequivocally.

Since the gate was an internal part of a dam, information on its design from archaeological evidence depends upon the amount of woodwork remaining. Where no woodwork is left, it may be possible to determine the gate size if the recesses and footings for the cills, gate rafters and main stringer can be identified. The gate design can only be determined if woodwork remains. Clues to this often lie in the remnants of the trip mechanism that are preserved in the flume floor, cills or kelsons, although in later dams part or occasionally all of the original gate still remains.

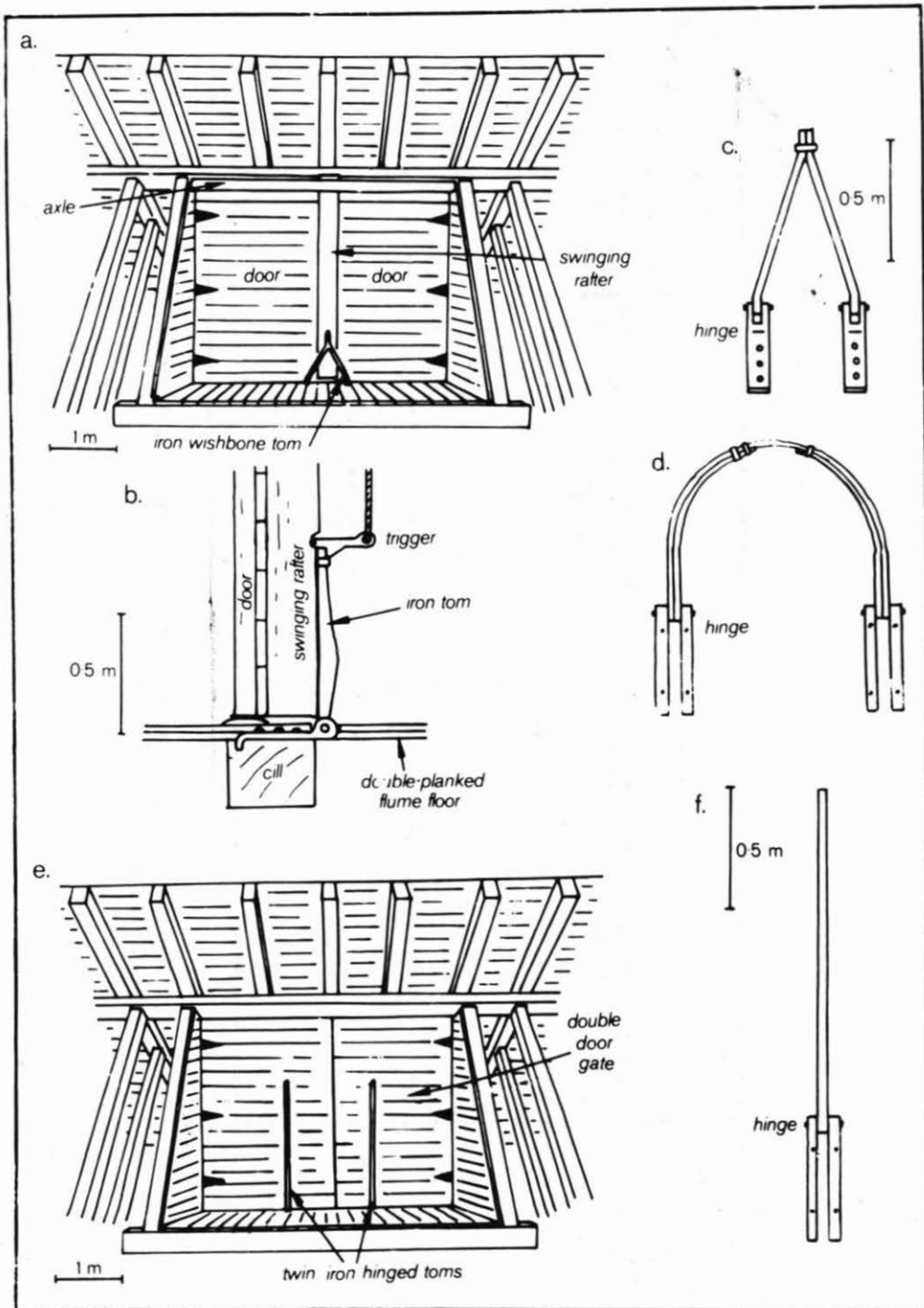
GATE TRIP MECHANISM

A trip mechanism was required to open gates that were designed for the rapid release of the stored up water, and thus all gate designs other than the vertical drop gate had some sort of quick release mechanism. Three trip designs are known.

1. *Wooden tom* (Fig. 7). This is the only trip mechanism known to have been used after 1900 and the only one featured in old photographs. All known, upright, loose-plank and swinging rafter gates had this kind of mechanism.

With upright, loose-plank gates the trip mechanism consisted of four parts – two cross trips, a wooden tom and a trigger. The two cross trips were placed end to end across the flume floor and against these the bottom of the loose gate planks were placed. The cross

Figure 8 a. Downstream view of the flume and double door gate of an early rafter dam with the inferred arrangement of the iron hinged tom and axle trip mechanism (simplified to show trigger mechanism). *b.* Lower portion of the iron hinged tom and axle trip mechanism as it probably appeared when set. *c.* Wishbone shaped iron hinged tom (found on dam sites in the Waitakere and Coromandel Ranges, 1850s - 1880s). *d.* Semicircular iron hinged tom (found on dam sites in Tangiaro Valley, Coromandel Peninsula, 1880s). *e.* Downstream view of the flume and double door gate of a rafter dam with the inferred arrangement of twin iron hinged toms when the gate was set. *f.* Front view of straight iron hinged tom (found on dams in Haruru Valley, Kaipara, 1890s).



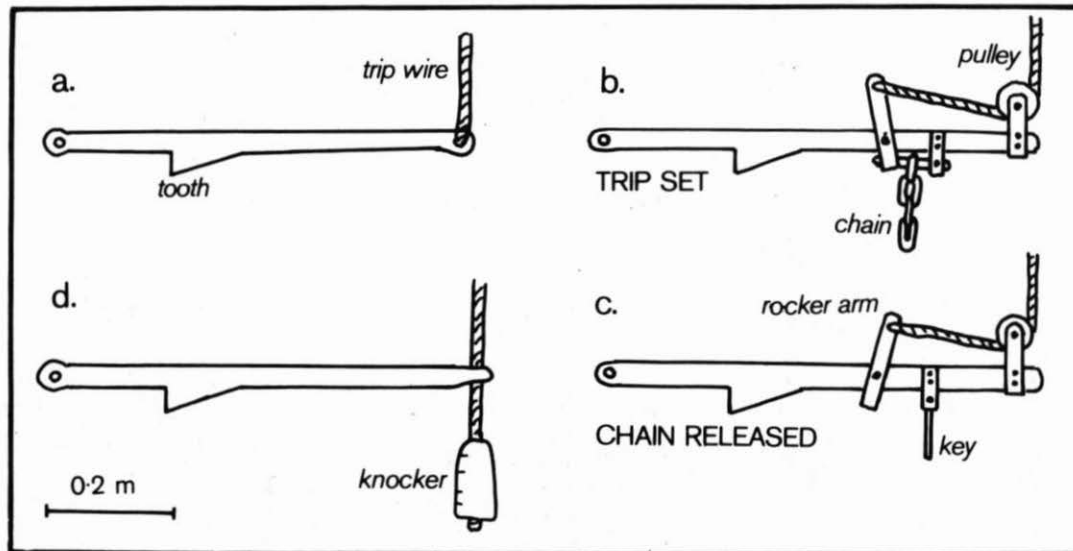


Figure 9 Designs of iron triggers used in trip mechanisms on kauri driving dams. All are drawn from archaeological remains.

trips fitted into cross trip holes cut in the kelsons on either side of the flume, and butted together behind the centre gate plank where they were held by the tom (Fig. 7). The tom was a baulk of timber, up to 1.5m long and 0.2 - 0.3m square, placed upright, with the bottom held in a square hole (tom hole) in the centre of the flume floor beneath the main stringer. The top of the tom was held in position by a downward projecting tooth on an iron trigger that was attached to a ring bolt through the centre gate plank. Attached to the end of the trigger was a wire which passed up to the top of the dam and across to one bank.

To trip the gate the wire was tugged upwards, thus pulling the trigger tooth off the top of the tom which was then released and forced out of the tom hole. With nothing holding the cross trips, these were swept aside and the gate planks released, allowing the water and logs to surge out through the flume. The tom and cross trips were attached by wires to the dam so that they were not lost when the gate was tripped.

The trip mechanism of swinging rafter gates operated on the same principle but did not require cross trips as the base of the swinging rafter rested against the tom (Fig. 7).

2. *Iron hinged tom and axle.* Various designs of large hinged iron toms (wishbone and semicircular, Fig. 8) have been found in the sites of a number of early dams. The design of gate in these dams is unknown, but the presence of a flume and lack of cross trip and tom holes argue strongly against their being upright loose plank or swinging rafter types. It seems most probable that iron-hinged tom trip mechanisms were used with double door gates since Baines (1874:176), in describing such a gate, mentions a trip mechanism which included "an ingenious arrangement made very strong, of three-inch bar iron, too complicated in structure to describe without diagrams".

The complete trip mechanism, as deduced from Baines' description and our own field observations, consisted of four parts (Fig. 8) — axle, swinging rafter, iron hinged tom and trigger. The axle was a heavy beam of timber that spanned the flume above the double door gate. The axle's rounded ends were fitted into wooden sockets so that it could rotate. The swinging rafter (a squared spar) was fixed at right angles in the middle of the axle and hung vertically down to hold the edges of the two doors along their junction. The rafter reached almost to the flume floor where it was held by the raised tom. The tom hinges were securely bolted through the centre of the flume floor to a cill, so that the tom could be raised to an upright position (Fig. 8). The top of the tom was probably held in position by a downward projecting tooth of an iron trigger that was attached to the swinging rafter, as in the wooden tom trip mechanism.

To trip the gate a wire attached to the trigger was pulled upwards, releasing the tooth from the top of the tom, which then swung downwards to lie flat in specially constructed grooves below the level of the flume floor. With the tom gone, the swinging rafter, possibly aided by a pulley system, swung outwards and up as the axle above rotated, thus freeing the doors which were forced open by the weight of water.

The dam referred to by Reed (1964:120) as an axle dam (Tairua River, Coromandel Peninsula) was probably of this design.

3. *Twin iron hinged toms.* Two dams (Haruru Valley, Kaipara, 1890s) had twin hinged toms attached to the flume floor, approximately 1m apart and 1.5m from the gate rafters. The toms were straight, 1.7m high when raised, and made of stout iron (about 0.07 x 0.05m). We deduce that they were possibly also used on double door gates. They need not have been associated with an axle or swinging rafter, but instead may have directly held each gate. When raised, the top of each straight tom could have been held by an iron trigger in the same way as the other designs (Fig. 8).

As with gates, the design of the trip mechanism can only be determined where the archaeological remains include some or all of the wooden flume floor or kelsons. The iron hinged tom designs, for example, are known only from field evidence.

TRIGGER AND TRIPWIRE (FIG. 9)

Three methods of attaching the tripwire to the trigger have been identified.

1. The hole in the end of the trigger was oriented horizontally and the tripwire tied directly through it (Fig. 9a). An upward pull on the wire raised the trigger and thus released the tom.

2. A chain anchored to the flume floor was attached to some triggers to ensure that they did not lift off the top of the tom until released. The chain was released when the tripwire was pulled. For this the following attachments were fitted to the trigger (Figs 9a, b); a rocker arm and a pulley on top of the trigger, and underneath a key which fitted through a link in the chain and was held in place by the U-shaped base of the rocker. The tripwire was fed around the pulley and secured to the top of the rocker arm. A pull on the tripwire moved the rocker arm forward freeing the key and releasing the chain (Fig. 9c), thus allowing the trigger to be lifted off the tom with further pulling.

3. The hole in the end of the trigger was vertical and the tripwire moved freely up and down through it but was prevented from pulling out by a knocker, a wooden or metal weight tied to the end (Fig. 9d). To trip the dam, the knocker was lowered 1m below the trigger and the tripwire was pulled smartly upwards, knocking up the trigger. This design enabled a series of hammerlike blows to be given by the knocker if the trigger was obstinate, rather than the direct tugging necessary in other designs.

Triggers are often found still attached to the centre gate plank or swinging rafter of later dam sites but very few pre-1900 dams are well enough preserved to retain the trigger.

CONCLUSION

To date our studies on the archaeological remains of kauri driving dams in the Waitakere and Coromandel Ranges show that there is a definite developmental sequence in their design (Hayward 1977). During the 1850s and 1860s a wide variety of structural types, mostly introduced from overseas, were being tested. These included earth dams and cribwork dams probably with vertical drop gates, as well as framework dams of rafter design with low angle faces and double-door gates. The two unique New Zealand designs of dam (stringer dam with upright, loose-plank gate and rafter dam with swinging rafter gate) which were the only types used after 1900, appear to have developed in the 1870s and 1890s respectively. Along with their development came a steepening of the angle of the face, a decrease in the number of cills, a change from iron hinged toms to wooden toms and refinements in the design of the trigger.

We hope that further research on the remains of kauri driving dams in other parts of northern New Zealand will assist in completing the hitherto unwritten history of their development.

ACKNOWLEDGEMENTS

We would like to thank Messrs J. R. McKinlay, N.Z. Historic Places Trust, and P. R. Moore, N.Z. Geological Survey, for reading the manuscript and making helpful suggestions.

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Received 16 October 1978