A STUDY OF SOME EFFECTS OF THE WAIRAKEI GEOTHERMAL POWER STATION UPON THE WAIKATO RIVER

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SUMMARY

The effects of heated discharges from the Wairakei Geothermal Power Scheme upon the Waikato River have been investigated. Water temperature, oxygen content and mercury concentration were measured at a number of points above and below the station and aquatic life was studied (the data on the flora has yet to be fully analysed and can thus only be described briefly here). Marked local effects on both the aquatic life and parameters of water quality were observed. However, although further investigation is warranted, particularly of the discharge rates of heavy metals such as mercury, the scheme does not appear to contribute significantly to the pollution of the Waikato River.

INTRODUCTION

A number of reports dealing with various aspects of the Wairakei Geothermal Power Station and its effects on the Waikato River have been published since the station became operative in the late 1950's. This work has recently been summarised by Axtmann1 who included a number of New Zealand Electricity Department reports in his references. However certain topics such as thermal mixing and the effects of the outputs from both station and bore fields on the aquatic life, have been virtually ignored. It was chiefly to provide some information on these that the present study was initiated. The study was confined to a single week in the mid-winter (11 to 16 August) of 1974.

The power station-bore complex has two outlets into the Waikato River, the more obvious one being the discharge of cooling water used to condense the stream which is used to drive the powerhouse turbines. This water is drawn from the river at a pump house (Fig. 1) and returned, together with the condensed steam, just down river from the station through a system of concrete baffles (Fig. 5). 18,500 litres of river water flow through this system every second2 — one eighth the normal flow of the river.

The second discharge is from the bore fields. Only 14% of the steam taken from the bores is dry enough for use in the turbines. The remainder, in the form of hot water, is diverted into the Wairakei Stream (Fig. 4) which runs adjacent to the northern side of the bore field and empties into the Waikato River some 1300 metres beyond the bore fields inlet, and just up river of the power house.

The study centred around these two outlets into the river. Oxygen and temperature recordings were taken along six transect lines across the Waikato

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Fig. 1. Map of the Waikato River adjacent to the Wairakei Geothermal Power Station. See text for further explanation.
River and along a further transect line across the mouth of the Wairakei Stream. Further temperature readings were taken at the point where the hot water from the bore fields is discharged into the Wairakei Stream, as well as at the power station where the cooling water from the turbines re-enters the river. Water samples were collected at a number of points on the river for analysis at the laboratory. The aquatic plant and animal life of the river edge along a 1300 metre stretch extending from well above to well below the power station was also investigated.

1: AQUATIC LIFE
Materials and Methods

Quantitative sampling was generally impractical. A standardised method of sampling was, however, employed in order to provide a means of comparing the abundance and variety of the flora and fauna in different areas. A 0.1 metre square area of river bed was cleared of all loose material which was then wet sieved, the residue being examined for plant and animal life. A mechanical grab was used to dredge material from the deeper water, but proved to be of use for qualitative work only.

Detailed studies were made at the two river outlets (sites B and D, Fig. 1). Further, briefer investigations were made above and below the two outlets (A and E) and in between them (C). However, as a result of the nature of the river bank and bed, strictly comparable work was not always possible.

Results

Site A:

The steep sloping river bed presented few areas of shallow water compared to the areas studied at the outlets. Those shallow areas that did occur, however, were composed of clean, coarse sand and gravel with stones generally no more than 80mm in diameter. No benthic weed was apparent and sampling revealed no animal life.

Site B:

The stream enters the river at an oblique angle facing up river. As a result of the direction of water flow, a huge eddy of warm stream water travels up river for about 40 metres along the near bank before turning and mixing with the river water (see section 3). On the down river side of this eddy, cold river water forms a stratified cross-current travelling up the Wairakei Stream under the stream water.

On the north bank and for about two thirds of the distance across the river, the water was shallow, warm and opaque. The bottom was composed of muddy sediment up to 15mm deep and covered with a blue green algal slime. On the up river side of the stream mouth, sampling revealed no live animals. However, large numbers of dead fish were discovered. Most of these were White Bait (Galaxias attenuatus) of about 10mm length which littered the bottom at an average density of one per square metre, with a maximum of three. A single dead trout (Salmo gairdnerii) some 45cm in length was also observed. On the down river side of the Wairakei Stream the bottom appeared to be formed of
calcaneous deposits, also covered with blue green algae. Sampling revealed numerous planarians living in the cooler water.

Site C:

The bank sloped sheer to a depth of two metres or more affording no opportunity to make a close study of the benthic life. From boat and shore, extensive beds of Nitella sp. were observed.

Site D:

The concrete buttresses of the outlet project about 5 metres into the river providing, on either side, an area of calm, shallow water. The discharge water itself emanated with some force to be lost in the general river current some 10 or so metres out from the bank. The bottom at all depths was composed of gravely clay. Nitella sp. flourished in the warm outlet water, but much of the bottom was covered in a grey moss, tentatively identified as a sewer fungus, which also occurred on any overhanging branches or twigs that trailed in the water. In the warm (17°C), shallow water in the lee of the buttress on the down river side, and on the Nitella the gastropod Potamopyrgus antipodarum was present in large numbers (between 30 and 50 per 0.1m²) together with a few specimens of Physa fontinalis. Also common in the shallow water was a small fish, Globiomorphus. In the comparable position on the up river side of the outlet only spined forms of P. antipodarum were found, and then only in reduced numbers (13 to 30 per 0.1m²). A local fisherman stated that trout congregated in high numbers close to the outlet, presumably attracted either by the warmer water or by the detritus discharged from the cooling system.

Site E:

The site was chosen as a point at which temperature and oxygen had returned more-or-less to normal. Thickly overhanging vegetation prevented any studies being made of the shallows fauna and flora. In the deeper water Nitella was again common and still carried the sewer fungus. Indeed this fungus continued down river for some distance to be finally lost in Lake Aratiatia, about two km downstream.

2: MERCURY ANALYSIS

Materials and Methods

Samples of river and stream water were obtained from a variety of points in 50ml plastic specimen bottles. These were stored and analysed four months later using an A3000 flame spectrophotometer. The detection limit of this machine was about 0.1ppm. It was callibrated against a standard solution with a mercury concentration of 1ppm, and against distilled water (0ppm).

Results

The mercury concentrations of most of the samples were too low for detection on the meter (i.e. less than 0.1ppm). The highest value recorded was 0.85ppm at the mouth of the Wairakei Stream while at the cooling water outlet, a concentration of 0.3ppm was recorded. In both cases, the concentration had
fallen below the detection level 80 metres down river.

3: TEMPERATURE AND OXYGEN PROFILES

Materials and Methods

Six transects were taken across the river and a further one across the mouth of the Wairakei Stream (see Fig. 1). All the transects were located using a theodolite, then marked with wooden pegs on either bank, between which a length of light nylon twine, marked at 5 or 10 metre intervals, was strung. Measurements of oxygen concentration and temperature were then made at identified points across the river, both at the surface, and at various depths to the bottom. Due to the strong current, it was sometimes impossible to reach certain parts of the river and as a result some of the transects are incomplete. The very swift current also made accurate measurements of river depth difficult and the error involved for some of the deeper places may therefore be quite large.

Oxygen was measured using a Hydrolab oxygen probe. This equipment was stringently calibrated on the first day, using the procedure outlined in the instruction leaflet, and thereafter maintained consistent readings throughout the week.

Temperature was measured using three different temperature meters which all produced comparable results:
1. Hydrolab probe, capable of recording temperature through a range of −5°C to 45°C with an accuracy of ±0.5°C.
2. Hewlett Packard Multimeter. This gives a reading of resistance, and in absolute terms was very accurate. However, in order to convert the values obtained to temperature readings, prior calibration against a thermometer was necessary and this reduced the accuracy to ±0.5°C.
3. A Grant Multichannel Temperature Recorder. Due to the cumbersome nature of this instrument, especially when compared with the H.P. Multimeter, it was not used much. The range was 0°C to 60°C, the accuracy ±0.5°C.

Results

The results of both temperature and oxygen recordings are summarised in Figs. 2 and 3 in the form of isotherms and isograms of dissolved oxygen content. Transect 1 and 5 recorded uniform temperatures of 11°C and an oxygen content of between 11 and 13 ppm. Transect 5 has therefore been completely omitted, while only the oxygen isogram of transect 1 has been drawn to indicate the situation in the unaffected river.

When examining the profiles, it should be noted that during the period of investigation, the ambient temperature in the river was 11°C, and the dissolved oxygen content was about 12 ppm.

As can be seen from Figs. 2 and 3, the most noticeable effects were found in transects 2 and 3. It was found that the hot water mixed very little either vertically or horizontally. There was a pronounced surface layer, usually much less than 1 metre deep, and the boundary on the surface between temperatures of 18 and 38°C was usually less than 50 mm deep. Despite the fact that initial
Fig. 2. Oxygen profiles (ppm) along transect lines. Figures indicate sampling points. Note:
Transect 4
Distance from north bank (metres)

Transect 6
Distance from north bank (metres)

Transect 7
Distance from north bank (metres)

Vertical scale is much exaggerated.

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Fig. 3. Temperature profiles (°C) along transect lines. Figures (save those in brackets) indicate sampling point temperatures. Note: Vertical scale is much exaggerated.
stratification occurred, mixing was complete by the time the water passed transect 5, 300 metres down river.

The highest recorded temperature was 46°C, which was observed near the shore at the commencement of transect 2. At this point the hot layer was about 48 cm deep.

The cooling water outlet had far less effect on the river, raising its temperature to only 16°C, despite the fact that the water before reaching the river was 27°C. By transect 7, 250 metres down river, the temperature had returned to normal, save for odd pockets of higher temperature. This remarkably efficient mixing can almost certainly be attributed to the method of discharge.

As the dissolved oxygen readings were made using the Hydrolab while the temperature values used in the isotherms are from records made with the H.P. Multimeter, the two were recorded at slightly different times. It was found that the patterns of temperature and, to a lesser extent, oxygen changed daily.

4: TEMPERATURE MEASUREMENTS AT THE BORE FIELD INPUT TO THE WAIRAKEI STREAM
Materials and Methods

The H.P. Multimeter was used to record the temperature of the water from the bore fields at the head of the chute by which the water entered the Wairakei
Stream, as well as of the temperature of the stream itself, both upstream and downstream of the culvert mouth.

Results

20 metres upstream from the culvert, the Wairakei Stream had a uniform temperature of 18°C. The culvert water entered the stream at 70°C and immediately opposite the culvert mouth (about 5 metres across the stream) the stream water temperature had increased to 55°C. The same temperature was recorded 10 metres down stream. 400 metres down stream, the temperature had fallen, but only to 52°C and the water finally entered the Waikato River at 46°C.

DISCUSSION

Before proceeding to the discussion of the effects of the power scheme on the Waikato River, it must be decided whether the quality and temperature of the water entering the river from the Wairakei Stream is due primarily to the outflow from the bore fields, or to natural thermal activity along the stream banks. Certainly natural thermal inflows do occur, but their effect on the stream would appear to be minimal, especially in contrast to the vast inflow from the bore fields. From inspection, the bore fields probably contribute up to two thirds of the total stream water entering the river, but information on the exact flow, or any data on the size and temperature of the stream prior to the building of the power station is not available. However, it is not unreasonable to assume that the condition of the stream can be almost entirely attributed to the presence of the bore field.

The effects of the Wairakei Stream and cooling water outlets upon the temperature and oxygen content of the Waikato River are measurable, but do not extend beyond 300 metres down river from the discharge points. A complete chemical analysis of the water was not attempted and the one heavy metal, Mercury, that was tested for revealed no concentration over 0.85ppm. This, however, is not surprising as most hot springs water contains very little Mercury (0.1 to 2ppm). The true effect of Mercury pollution results from its accumulative effect in river organisms, principally fish such as trout. Further study of the Mercury concentration in trout may be warranted although Axtmann has found that, while making some contribution to the Mercury contamination of the Waikato trout, Wairakei is a minor source when compared to such “natural” geothermal effluents as Broadlands, Orakei, Korako, Waiotapu and Rotokawa.

Thermal water taken directly from a depth of 300 to 1,200 metres may contain much higher quantities of inorganic solvents than natural surface outlets. Many of these would precipitate out of solution as the water from the bore fields cools before it reaches the river. Indeed, the concrete culvert and the stream bed are thickly encrusted with deposits which have presumably resulted from this process. Some salts, however, would survive in dissolved form until they entered the river. An analysis of the sediments just down river from the stream mouth could prove informative.

The heated discharges from the outlets undoubtedly have a significant
effect on the aquatic life. The slightly warmer water of the cooling outlet encourages the growth of plants and animals that are rare or even absent elsewhere. On the other hand the effluent from the Wairakei Stream apparently kills large quantities of fish, especially smaller ones, and encourages the growth of algae more typically associated with thermal waters than with rivers.

In conclusion it can be said that while a one week study is far too short a period to reach any firm conclusions on the effect of the Wairakei Geothermal Power Station upon the Waikato River, it would appear that there is a pronounced local effect on the river, with possibly more far reaching influences that may show up with further investigation. However changes in the oxygen concentration and temperature do not extend beyond 250 metres down river; effects on the aquatic life apparently extend somewhat further; effects on the Mercury concentration somewhat less.
Fig. 5. View up the Waikato River immediately opposite the Powerhouse. Far-distance: Discharge point of the Wairakei Stream. Mid-distance: Pumphouse. Foreground: Cooling water outlet.

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REFERENCES

2 Wairakei publicity leaflets and booklets. N.Z.E.D.