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Little Forest Legacy Site – Summary of site history until the commencement of waste disposal in 1960

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ANSTO Institute for Environmental Research

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Institute for Environmental Research
Australian Nuclear Science and Technology Organisation

IMPORTANT NOTE

This report is an outcome of the research study of the Little Forest Legacy Site (LFLS), which is being implemented by ANSTO's Institute for Environmental Research. It contains archival material which was obtained prior to 31 December 2014. It is possible that additional relevant operational records will be located during this ongoing project. If significant new information is found, a revised and updated version of this report may be issued.

The author welcomes all feedback and suggestions for improvement.

This version issued: 2 March 2015

Summary

The Australian Atomic Energy Commission (AAEC) disposed of low-level radioactive waste at a site in the Little Forest area on the southern periphery of Sydney between 1960 and 1968. Following common practice of the period, a clay-rich site was selected in the vicinity of the AAEC's facility at Lucas Heights, and waste was mainly disposed by burial in closely spaced unlined trenches. During the time of operations (and subsequently until 2014), the site was known as the 'Little Forest Burial Ground' (LFBG).

In recent years, ANSTO has been implementing a detailed scientific study of the status of the disposal site, now referred to as the Little Forest Legacy Site (LFLS). This study includes sampling of vegetation, groundwater and soils. As part of the research, documents related to the disposal operations have been reviewed, as well as information and data from over 40 years of monitoring and studies of the LFLS. During these investigations, it has become clear that although numerous records have been preserved, there are nevertheless some key information gaps. Furthermore, while there is evidence of several previous attempts to summarise the material, none of these has led to a definitive summary of the history of the site and disposal activities.

The present report aims to summarise the history of the site until the commencement of disposal operations in 1960. This document contains information on the technical justification and other factors involved in the selection of the site, and some comments on the site selection process are presented in the final section. The main objective of this report is to provide a record of the events during this period, which will assist in understanding the disposal operations at the site and provide a context for interpreting subsequent monitoring data.

Acknowledgements

The current research project at the LFLS is being implemented by personnel of the Nuclear Methods in Earth Systems Project within ANSTO's Institute for Environmental Research (IER). The staff members currently involved are: Dioni Cendon, Josick Comarmond, Stuart Hankin, Jennifer Harrison, Cath Hughes, Mathew Johansen, Lida Mokhber-Shahin, Tim Payne, Brett Rowling, Sangeeth Thiruvoth, Chris Vardanega, Kerry Wilsher, Henri Wong and Atun Zawadzki. We thank ANSTO Waste Operations for access to records and useful discussions. The specific assistance of ANSTO Records staff and National Archives in obtaining much of the material discussed in the present report is greatly appreciated. The author thanks Mat Johansen, Cath Hughes and Jennifer Harrison for reviews of this document.

Related reports

J. Twining, J. Harrison, M. Vine, N. Creighton, B. Neklapilova and E. Hoffmann (2009). Analytical Method Development for Tritium in Tree Transpirate from the Little Forest Burial Ground [ANSTO report NMESP/TN1].

T.E. Payne (2012). Background Report on the Little Forest Burial Ground Legacy Waste Site. [Report No. ANSTO / E-780].

S. Hankin (2013). Little Forest Burial Ground – Geology, Geophysics and Monitoring Wells [Report No. ANSTO / E-781].

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LIST OF ABBREVIATIONS

AAEC	Australian Atomic Energy Commission
ANSTO	Australian Nuclear Science and Technology Organisation
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CEC	Cation exchange capacity
EDC	Effluent disposal committee (of the AAEC), often referred to as the "effluent committee"
HIFAR	High Flux Australian Reactor
IAEA	International Atomic Energy Agency
LFBG	Little Forest Burial Ground (name of the LFLS at the time of operations, and in subsequent years until 2014)
LFLS	Little Forest Legacy Site
NRX	National Research Experimental Reactor (Canada)
UKAEA	United Kingdom Atomic Energy Authority

1. Introduction

From 1960 to 1968, the Australian Atomic Energy Commission (AAEC) disposed of radioactive waste in trenches at a site known as the Little Forest Burial Ground (LFBG), near its Lucas Heights research facility on the southern periphery of Sydney. The waste was disposed in accordance with international practices which were used at that time for the disposal of low-level solid and liquid wastes. The materials disposed in the trenches were primarily derived from the operations of the research facility, and included waste drums, chemicals, radioactive sources, disused equipment, laboratory trash and beryllium-contaminated items. The successor to the AAEC, the Australian Nuclear Science and Technology Organisation (ANSTO) controls and manages the site. Since the cessation of disposal operations, the AAEC/ANSTO has undertaken continuous care, maintenance, surveillance and monitoring activities at the site, now referred to as the Little Forest Legacy Site (LFLS).

It has been internationally recognised that a major challenge in managing legacy waste sites (particularly those which were in operation around the world in the 1950s and 1960s) is the difficulty of determining the history of disposals and the waste inventory, because these sites were operated long before current regulatory, safety and quality management requirements were established (IAEA, 2007). This IAEA report also stated that “a problem with the archived historical information is that pieces of it may be scattered in various places, some of which may not exist any longer”. The present report, and its companion volumes, are intended to help ensure that information relevant to LFLS is brought together and preserved for the future.

This report aims to summarise the history of the LFLS until the commencement of disposal operations in 1960. This document contains information on the technical justification and other factors involved in the selection of the site, and some comments on the site selection process are presented in the final section. The main objective of this report is to provide a record of the events during this period, which will assist in understanding the disposal operations at the site and provide a context for interpreting subsequent monitoring data.

2. The need for waste disposal at Lucas Heights

The *Atomic Energy Act* was assented to by the Australian Governor General on 15 April 1953 and was followed by the appointment of three designated Commissioners two days later (Hardy, 1999). The major issue for the AAEC to deal with was planning and building a research establishment, including a research reactor, for the primary purpose of developing nuclear energy for electrical power generation. After initially considering a location in the coastal Sydney suburb of Maroubra, an area of vacant Crown Land at Lucas Heights about 32 km south of Sydney was selected, with construction started on the site in October 1955.

In the meantime, the AAEC was recruiting staff, many of whom spent a period at the Harwell research establishment of the UKAEA, located at Didcot in Berkshire. At Harwell, problems associated with waste generation had already been encountered, and various disposal options were being implemented, including discharges into the local river, waste burials, and ocean disposals. From this distant location, Dr Charles Watson-Munro (who was appointed to the position of AAEC chief scientist in 1955) reported on some discussions with some of the other AAEC personnel on the subject of waste management for the new Australian facility[1]. The outcomes of the discussions had apparently been somewhat discouraging, and Watson-Munro reported that "the sooner we develop techniques to handle active effluents in a country that is so short of water the better it will be". To reduce the volume of the effluent and facilitate disposal, a solar evaporation plant was under consideration for the AAEC facility, and Watson-Munro sought data to be provided on solar evaporation rates in Sydney, as well as the locations of suitable cliff faces for ocean deposition and/or a pipeline to the sea. He reported that "we are not giving as much thought to this subject as we should and the more we look at the effluent problem, the more complicated it seems to become" (Document #1 [see page 8]).

At this time, an "effluent disposal committee (EDC)" for the AAEC had been formed and was meeting regularly at Harwell. The fifth meeting of the EDC was held on 25 August 1955, with attendees including Dr Grant Miles (later to become the Officer-in-Charge at Lucas Heights) and the eminent scientist Professor (later Sir) Philip

[1] Letter from Dr CN Watson-Munro to the secretary of the AAEC, 11 May 1955.

Baxter. They discussed sea-disposal of effluent and experiences involving releases of active effluent into a swamp at the Oak Ridge facility in the USA. Whilst the swamp was effective in retaining radioactivity, this practice had been stopped because local birds and insects had become radioactive[2]. The committee considered the technical feasibility of a disposal pipeline and the acceptable levels of discharges from the Lucas Heights site into the nearby Woronora or George's River. It was expected to take at least a year to finalise an acceptable discharge figure. The minutes of this and subsequent meetings attest to some of the issues which were considered relating to future waste disposal from the AAEC facility.

In mid-1956, the EDC discussed both release of effluent from the AAEC facility into local rivers, and the selection of a "Burial area" near Lucas Heights[3]. It was considered that this might be used for the ground burial of wastes or emergency disposal of liquid from a "reactor disaster" (this was a topical issue, because a partial meltdown had recently occurred at the NRX reactor in Chalk River, Canada). A request for detailed information on the soils of the Lucas Heights area was communicated to Dr Miles (who was by then in Sydney) in a letter from Dr Richard Temple, the secretary of the EDC (which was still meeting at Harwell)[4]. However Miles' response indicated that the "matter of burial areas" was not urgent and could best be dealt with locally in Sydney, and that this issue should be left for later discussion[5]. Despite this apparent lack of urgency, Dr Temple and another colleague provided a detailed report on the disposal of solid and liquid wastes at Harwell[6], which discussed various waste treatment and disposal methods, including volume reduction using an evaporator or active incinerator, liquid low-level waste discharges to the Thames River, and sea-disposal in the English Channel and Atlantic Ocean (many countries disposed of various types of wastes at sea until this practice was restricted by the London Convention of 1972). There was very little mention of shallow land burial in the report on Harwell waste disposals, with the exception of beryllium wastes which were buried in trenches which were then back-filled.

[2] Minutes of 5th Effluent Disposal Committee meeting, 25 August 1955.
[3] Minutes of 8th Effluent Disposal Committee meeting, 14 June 1956.
[4] Letter from RB Temple to G Miles, 17 July 1956.
[5] Letter from GL Miles to CN Watson-Munro, 26 July 1956.
[6] RB Temple and DF Sangster, "The Disposal of Solid and Liquid Wastes at A.E.R.E." Report AAEC/EDC/P5, August 1956.

C/o United Kingdom Atomic Energy Authority,

Atomic Energy Research Establishment,

Harwell, Didcot, Berks, England.

AUST 6/1/1

11th May, 1955.

The Secretary,
Australian Atomic Energy Commission,
Box 5343 G.P.O. Sydney N.S.W.,
AUSTRALIA.

Attention Mr. Bisset

Many thanks for your letter of the 3rd May 1955 giving details of the Woronora River Flow. I am afraid your words of "not very encouraging" are an understatement of the situation. I do not think we can really put any active effluent down the river unless it is carrying a specific quantity of water. I am afraid the whole problem of water supplies has confirmed the suspicions that Dalton and I had when we were at the site in Sydney. However shortage of water in Sydney is not unique so the sooner we develop techniques to handle active effluents in a country that is short of water the better it will be.

xxx I enclose herewith a general statement by Dr. Miles on the problem, which will give you an idea of our thoughts here. You will note the summary of action required on Page 8.

At the moment we are thinking (when we get time to think) in terms of the possibility of a solar evaporation plant to reduce the bulk of the effluent to enable single tanker deposition in the sea.

Any information you can therefore send us on

(a) Solar evaporation rates in Sydney

(b) Suitable cliff faces for deposition, ideally we would like to think of the cliff faces with road access and no swimming. We would also like to think in terms of 50 ft of deep water and no habitation within a hundred yards.

I am afraid at the moment we are not giving as much thought to this subject as we should and the more we look at the effluent problem the more complicated it seems to become. I am certainly not keen on the idea of running a pipeline to the sea and certainly my thoughts are confirmed that we should investigate all other possible alternatives.

C. N. Watson-Munro

c.c. Dr. Miles
Mr. Berglin
Mr. Sangster.

Document #1. Letter from Dr C.N. Watson-Munro (AAEC Chief Scientist) discussing the emerging "effluent problem" at the planned AAEC facility at Lucas Heights.

3. Early deliberations about an AAEC waste disposal site

A brief document containing criteria for selecting a disposal ground was prepared by Dr Temple (in Harwell) and received by the AAEC in mid-1956. According to its author, the essential point was that no leakage of activity to surface water could be tolerated[7]. The importance of adequate siting studies prior to disposal, and of keeping detailed records of the disposal operations were emphasised. Following some delay, Mr J.C. Webb, a staff geologist at the AAEC, was asked to ascertain if there were suitable areas for a "burial ground" close to the Lucas Heights site[8]. Webb decided to investigate the area in the company of a geologist from the NSW geological survey (Mr E. Rayner)[9]. Three suitable areas were identified in October 1957 for later geological mapping, although it was stated that there was "no great haste in this matter".

In November 1957, the secretary of the AAEC advised officials in the Commonwealth government in Canberra of the plan to dispose of effluent with low radioactivity levels by burial under 10 feet of soil cover in the vicinity of the Lucas Heights site[10]. The selected areas were part of a military reserve and also potentially subject to mineral leases (due to their content of foundry loam and clays). It was noted that the same characteristics which made the site suitable for waste disposal also made it attractive for mining. Therefore, the AAEC sought to prevent the granting of mining leases. On 23 December 1957, Mr Rayner recommended a specific area[11] as a "solid disposal area" and the following day the AAEC intensified its efforts to gain control of the area and prevent the granting of clay-mining leases[12].

In January 1958, the AAEC contacted the department of the interior, advising that a suitable site had been selected, based primarily on its clay (rather than sandy) soil type, and noting that, if adjacent areas were quarried, they should be periodically monitored for radioactivity[13]. The following month, a local businessman, Mr A.R. Harrington, requested permission to mine the remaining portion of shale materials

[7] RB Temple. "Some Criteria for Selecting a Disposal Ground". Report AAEC/EDC/P6, June 1956.
[8] Minute from IJW Bissett (Technical secretary of the AAEC) to JC Webb, 10 June 1957.
[9] Minutes from JC Webb to IJW Bissett, 26 August 1957 and 22 October 1957.
[10] Letter from PC Greenland to the Secretary, Department of the Interior, 28 November 1957.
[11] Letter from EO Rayner to Mr Stewart of the AAEC, 23 December 1957.
[12] Minute from IJW Bissett to Mr Keher, 24 December 1957.
[13] Letter from PC Greenland (AAEC secretary) to the secretary, Department of the Interior.

adjoining the AAEC lease area[14]. The AAEC confirmed that they had no objection to mining activities on areas adjacent to the proposed effluent disposal area[15]. The major quarry adjacent to the LFBG became known as “Harrington’s Quarry” and some decades later the empty pit was filled with municipal waste. Figure 1 shows the location of the LFBG and the adjacent Harrington’s Quarry, in the central part of the clay lens.

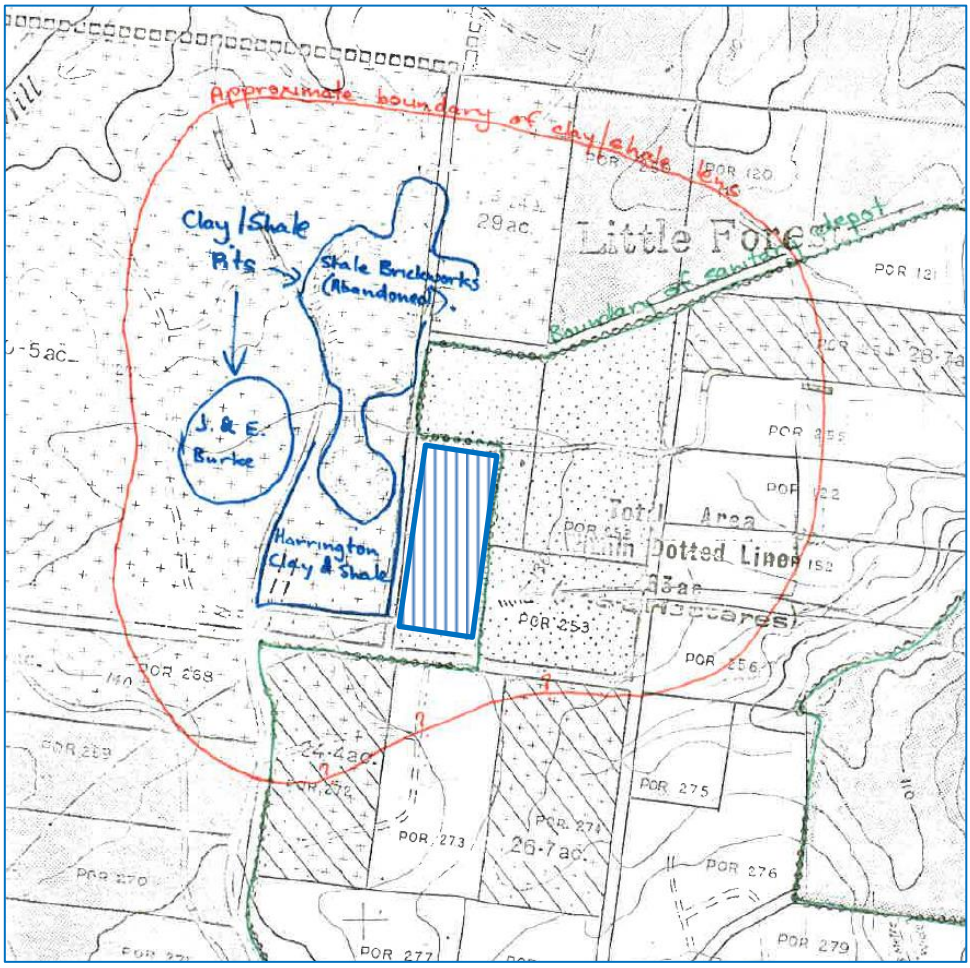


Figure 1. A sketch map prepared in 1982 by staff of the Department of Mineral Resources[16], showing the location of Harrington’s Quarry within the clay / shale lens (indicated in red). Harrington’s Quarry adjoins the LFBG site (hatched area, not shown on original figure).

[14] Letter from AR Harrington to Department of the Interior, 24 February 1958.
[15] Minute from IJW Bisset to the AAEC secretary, 7 March 1958.
[16] Figure attached to letter from ML Markham (Department of Mineral Resources) to JW Pearce, Assistant Secretary of AAEC, 6 December 1982.

On the 5th of May, 1958, the purchase of 40 acres of land at Little Forest was underway, with a cost allocation of £1000, some of which was expected to be used for the cost of fencing a portion of the area so that it would be ready for the disposal of solid radioactive wastes[17]. Shortly afterwards, the clearing of the site was being arranged[18] although this needed to be delayed until it was clear that the AAEC did indeed possess the property. The clearing of trees from the proposed burial ground was complete by December 1958[19].

Around this time, the Sutherland Shire Council was operating a sewerage disposal facility immediately across the road from the AAEC's Lucas Heights site. This was a source of "obnoxious and putrid smells"[20] and it appears that the AAEC was encouraging the council to move this "Night-soil" facility to the Little Forest area, which was further away from the AAEC research establishment. On the 26 June 1958, an AAEC memorandum[21] discussed the Little Forest disposal site, which was "admirably suited for the disposal of radioactive waste and sewerage". It was noted that the AAEC was likely to acquire title of this land. Presumably the purchase was imminent, since the AAEC annual report for the year ending June 1958 announced that a site in the Little Forest area had been secured and set aside for the "safe sealed storage of waste materials".

4. Waste generation by AAEC activities in the late 1950's

The securing of the low-level waste disposal site appeared timely, since the HIFAR reactor, which had been under construction since 1956, had been recently completed at Lucas Heights. Criticality was achieved in 1958 on Australia Day (26 January) under the supervision of the chief scientist (Dr Watson-Munro). The Prime Minister, R.G. Menzies, officially opened the Research Establishment on the 18 April of that year. The HIFAR reactor spent some time in commissioning and was not taken up to its full power level of 10 MW until 20 October 1960. A key aspect of HIFAR was the presence of heavy water, containing tritium which built up as the

[17] Minute from CN Watson-Munro to the AAEC secretary, 5 May 1958.
[18] Minute from IJW Bissett to CN Watson-Munro, 19 May 1958.
[19] Minute from CN Watson-Munro to GL Miles, 9 December 1958.
[20] IJW Bissett, "Land acquisition at Lucas Heights – Little Forest Area". 16 June 1958.
[21] AAEC memorandum 19/1958. "Area for burial ground for radioactive waste and alternative sewerage disposal site". 27 June 1958.

reactor continued to operate. For this reason, many waste items buried at the LFBG contained tritium, e.g. sludge from deuterium pumps (Payne, 2012).

In order to further interpret the waste disposal records at LFBG, it is necessary to understand the types of research activities being undertaken on the AAEC site during this period, and the consequent waste generation and disposal issues which would arise.

The AAEC at this time was very strongly focused on nuclear power (as the inclusion of "Atomic Energy" in its name implied). It is perhaps surprising, when viewed in retrospect, that it was considered necessary for Australia to develop its own type of power reactors when many other countries had made considerable progress with various designs. This was explained by Watson-Munro in 1956 as being because "it would be unwise to develop the kinds of power reactors which have received major attention overseas…. As Australia will have access to the results of much of this work as it develops overseas"[22]. This decision led to research into alternative fuel cycles involving U-233 and plutonium, as well as significant amounts of beryllium. It was the waste arising from this research which ultimately led to the disposal of these substances at the LFBG site.

Another factor which became of relevance to the LFBG operations was the method of treating the AAEC's liquid waste. Due to the amount of liquid waste being generated on the site, it was decided to employ solar drying to reduce the liquid volumes. These evaporated sludges were transferred to numerous 44-gallon drums, several hundred of them being later disposed at the LFBG site. Initially, little consideration was given to the radioactive contents of these drums. However, as they contained the concentrated spills and effluents from the operations at the AAEC site, where significant quantities of actinides and beryllium were handled, their accumulation and disposal became a significant issue for the AAEC.

Throughout the disposal era, waste drums were stored on the Little Forest site (photographs show long lines of 44-gallon drums along the southern boundary of the site, extending from the area occupied by an interim waste storage hut). It was

[22] CN Watson-Munro, "AAEC Research program", *Nuclear Engineering,* August 1956, pp183-185 (cited in Hardy, 1999).

reported that some of these drums were badly deteriorated and it was difficult to move them in this state (Bonhote, 1964). Ultimately 760 drums were disposed in various trenches at LFBG. (A full account of the disposals at LFBG during the operational era will be the subject of a separate report).

Finally, it should be noted that the issue of disposal of waste for other institutions emerged in the late 1950's and would later become a significant question for the AAEC during the operational period of the LFBG. The earliest external disposal request on record originated from Sydney University, in December 1958[23], prior to the commencement of operations at LFBG, and it was decided that the AAEC was not yet in a position to help with disposal. However, after the LFBG became operational, radioactive wastes were disposed for external clients, including various universities, CSIRO, the navy, and hospitals[24].

5. Beryllium becomes an issue

In May 1958, the government approved a new construction program at Lucas Heights, including a building for fabrication of beryllium fuels, which required special handling facilities on account of the toxicity of beryllium and beryllium oxides. At the time, key staff-members were considering the dangers associated with beryllium, with a summary report on its health hazards being prepared in 1958 by Dr G.M. Watson, the AAEC leader of medical research[25]. In another report, Dr R.B. Temple reported that it is "probably the most toxic non-radioactive material that we shall encounter at Lucas Heights"[26]. While it was clear that beryllium was a serious inhalation hazard, there were notable gaps in the published data on its toxicity. Based on the available information, Dr Temple concluded that it was "by far the most toxic to fish of the metallic poisons".

Dr Temple expressed further reservations about the discharges of beryllium from the new beryllium building (Building 2), urging that these amounts needed to be severely

[23] IJW Bissett, File Minute, 22 December 1958.
[24] Various documents sighted by the author.
[25] GM Watson. "Beryllium. Health hazards and control". AAEC report K-233. Undated, circa 1958.
[26] RB Temple. Disposal of beryllium waste at Lucas Heights. AAEC report K-199. March 1958.

limited to prevent unacceptable beryllium levels being released from the site[27]. Following the receipt of these comments, Dr A.R.W. Wilson (then chair of the EDC) expressed similar concerns, noting that "the scale of beryllium work at Lucas Heights will be somewhat larger than at Harwell"[28]. Dr Wilson was sufficiently concerned about this issue that he raised it with a senior staff-member of the United States Atomic Energy Commission, also copying the inquiry to Dr Watson-Munro, the AAEC chief scientist[29]. Because of the issues raised regarding releases of both beryllium and radioactivity, Watson-Munro decided that it would be necessary to restrict the proposed work involving beryllium, noting with regret that this would produce very severe delays to some aspects of the research program, but choosing to "work on the safe side"[30].

6. Training of AAEC personnel involved in waste disposal operations

It is beyond the scope of this document (and other reports in this series) to provide extensive biographical information on the members of the AAEC staff supervising, or implementing, the LFBG operations (more information can be found in other sources such as Hardy (1999), Binnie (2003) and annual reports of the AAEC). However, a few of the key staff will be discussed with the specific objective of identifying their role in disposal activities at LFBG and examining the rationale of their decisions. Some of the more senior staff have already been mentioned, such as the chief scientist (Dr Charles Watson-Munro), Dr Grant Miles (who was "Officer-in-Charge" at Lucas Heights) and the eminent scientist Professor Philip Baxter. Many of the senior scientists had been seconded to UKAEA Harwell in the UK during the lead-up to the commencement of AAEC operations. This enabled them to become familiarised with nuclear facilities and their operations. Dr Richard Temple, a member of the Effluent Committee, had also spent time at Harwell.

The available records show that many operational decisions related to LFBG, and particularly disposal activities, were implemented by relatively junior staff with little or

[27] Minute from RB Temple to AR Wilson (head, Health Physics section), 22 August 1958.
[28] Minute from ARW Wilson to the chairman, Beryllium Building sub-committee, 15 October 1958.
[29] Letter from ARW Wilson to Dr JA Lieberman (USAEC), 27 October 1958.
[30] Minute from CN Watson-Munro to the chairman, Building 2 procedures committee, 28 November 1958.

no background in nuclear science prior to joining the AAEC. (For example, it appears that the successful applicant for the position of "senior technical officer for effluent services" had no background in handling radioactivity, having worked for chemical companies and other industries[31]). Unlike the more senior scientists, the technical support staff may not have been given the benefit of a secondment to Harwell.

Furthermore, disposal operations at the LFBG commenced only a few years after the establishment of the AAEC. The situation was similar to many radioactive waste disposal operations in overseas countries, which were commenced without extensive (or any) prior experience and in the absence of research into the problems likely to be encountered. For example, the nuclear weapons program at Hanford (Washington State, USA) produced large amounts of waste during World War II (and subsequently), which were stored in tanks or released into the local environment. The problems of radioactive contamination at the Hanford sites are much greater than those resulting from the LFBG disposals, and are expected to take decades to remediate.

Thus, in common with personnel employed in radioactive waste disposal in other countries, the AAEC staff-members who were involved in operations at LFBG had only a few years of experience before having to confront the pressing issue of how to solve the developing radioactive waste problems.

7. Site characterisation and reservations about site suitability

Initially there was enthusiasm for the suitability of the Little Forest site, with possible ground disposal of not only "low-level" but even "medium and high level active wastes" under consideration. Dr Watson-Munro cited the promising experiences at various sites, including Oak Ridge, where waste effluents of intermediate activity were discharged into unlined pits, and there had been little migration to the closest monitoring well just 8 ft away[32]. Dr Watson-Munro commented favourably on the clay and shale content of the LFBG site, and urged that it should be assessed for possible disposal of both liquid and solid effluents of medium and high activity.

[31] Minute from CL Miles to CN Watson-Munro, 23 October 1956.
[32] Minute from CN Watson-Munro to GL Miles, 9 December 1958.

However, in February 1959, the head of the AAEC Chemical Engineering section, Dr R.C. Cairns, wrote with concern to a counterpart at the Sellafield UKAEA facility (Mr K. Saddington) inquiring about a "much different and unfavourable impression" of ground disposal that might be formed from his reading of some published accounts[33]. Clearly there were some different pictures emerging of the degree to which land disposals had been successful. The reply received from the UK was not encouraging, with the author stating there is "far less optimism on this means of disposal now than there was two or three years ago"[34] The author stated that unless conditions were exceptionally favourable, ground disposal should only be used for "virtually uncontaminated" liquids. He concluded it would need "a lot of thought and a tremendous amount of work before it can be regarded as completely satisfactory".

In early 1959 the LFBG site was the subject of increasing discussion, and a meeting in February considered "various problems connected with the use of the burial ground"[35], and other issues including:

- A direction from the Chairman of the AAEC (Prof Baxter) to investigate the possibility of an unlined pit for disposal/storage of intermediate and high level wastes
- A request from the Chief Scientist (Dr Watson-Munro) for the provision of high level storage pits
- A concern expressed by Dr Temple that seepage from the area would eventually find its way into natural watercourses.

To address these issues, further site investigations were commenced. On 4 February, 1959, four bores were sunk to various depths: 6, 9, 12 and 15 feet. These indicated the presence of thin bands of shale and allowed observations of the depth of water (which was reported at 11 to 12 feet). The bottom portion of both the deeper holes collapsed, and water slowly entered these two holes. Dr Temple placed some fluorescein tracer solution in the deepest (central) hole with the intention of studying its movement.

[33] Letter from Dr R.C. Cairns to Mr K. Saddington, UKAEA, Sellafield, 11 February 1959.
[34] Letter from K. Saddington, UKAEA to the AAEC chief scientist (att: RC Cairns), 24 February 1959.
[35] Minute from ED Hespe to LH Keher, 10 February 1959.

On the 19th February several members of the EDC visited the site after a period of heavy rain, and observed that the boreholes drilled for Dr Temple's experiment were full of water, and there was evidence of seepage at the junction of the shale and sandstone near the boundary of the selected disposal area. Following this site examination, one member of the committee concluded that "we possess only a meagre knowledge of the geology and possible course of groundwater movement at the site"[36]. In the same minute, which described potential problems with the hydrology of the site (as well as a lack of knowledge), the author (Mr E.D. Hespe) noted that active procedures had been commenced in Building 2. This necessitated that all solid waste from the active areas be treated as contaminated. He continued: "This will shortly impose an intolerable load on the available storage space". The author went on to urge the purchase of a tractor, capable of operating both a back-hoe for trenching and a bulldozer for back-filling, and also suitable for pulling trailers of waste. A Chamberlain tractor was recommended, at a cost of £1946. In the same minute, it was mentioned that several back-hoes had been demonstrated on the burial area. This minute of 27 February 1959 is a key document, encapsulating both the increasing doubts about the LFBG site as well as the growing pressure for a solution to the waste disposal problems at the AAEC facility (see document extracts #2(a) [on page 18] and #2(b) [page 19]).

[36] Minute from ED Hespe to LH Keher, 27 February 1959.

E.S.8/13
EDH:JS

Burial Ground - Little Forest Area

27th February, 1959.

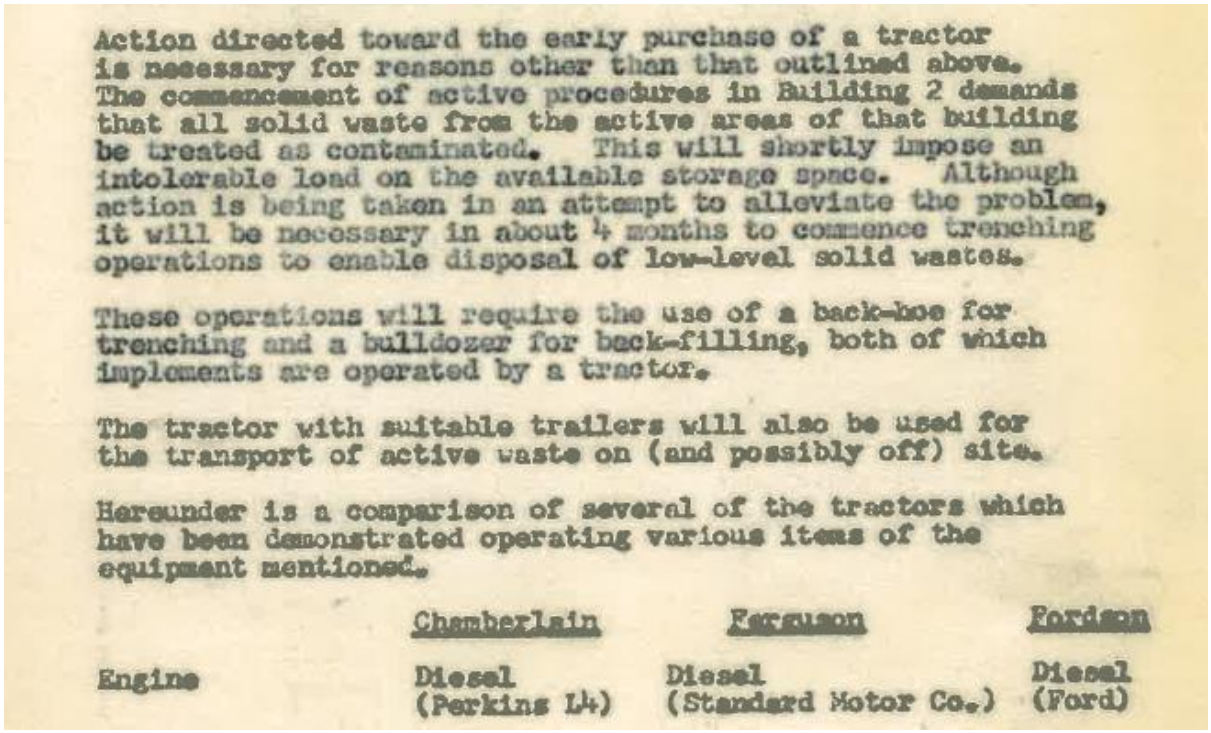
Mr. L.H. Keher

I refer to my letter of the 10th instant on this subject. The surface survey mentioned has been arranged by Mr. Webb and is now being carried out by Mr. Rayner of the N.S.W. State Geological Survey.

From the answers to questions put to Mr. Rayner during an inspection of the Little Forest Area on the 16th February, 1959, it became obvious that we possess but a meagre knowledge of the geology and possible course of ground water movement of the site which can be increased only by a detailed boring programme on the cleared area and further boring as indicated by the results of the surface survey.

This was strikingly illustrated during a visit to the area by several members of the Effluent Disposal Committee (on the 19th instant) after a period of very heavy rain. The four boreholes which had been put down for Dr. Temple's experiment were full, there was no evidence that surface water had entered directly, but there was no fluorescein in any hole but the one in which it had been placed. With our present knowledge, such a happening is difficult to explain. The party also saw evidence of water seeping to the surface at the junction of the shale and sandstone at the boundary of the area. This water fed a creek which drains to the Georges River.

Document #2(a). Minute from E.D. Hespe to L.H. Keher, 27 February 1959 (opening section), indicating the need for more knowledge of geology and groundwater movement at the LFBG site.



Action directed toward the early purchase of a tractor is necessary for reasons other than that outlined above. The commencement of active procedures in Building 2 demands that all solid waste from the active areas of that building be treated as contaminated. This will shortly impose an intolerable load on the available storage space. Although action is being taken in an attempt to alleviate the problem, it will be necessary in about 4 months to commence trenching operations to enable disposal of low-level solid wastes.

These operations will require the use of a back-hoe for trenching and a bulldozer for back-filling, both of which implements are operated by a tractor.

The tractor with suitable trailers will also be used for the transport of active waste on (and possibly off) site.

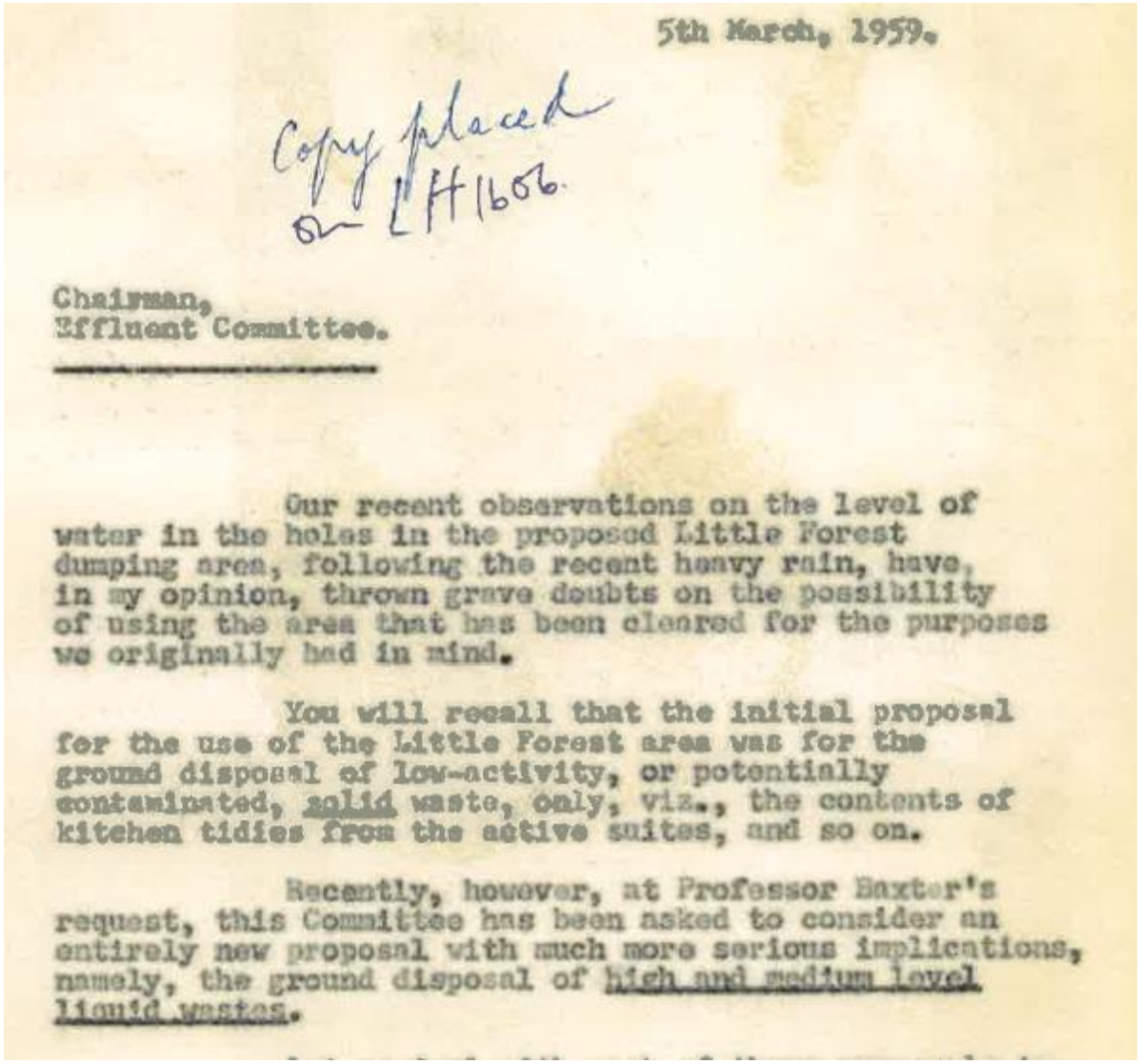
Hereunder is a comparison of several of the tractors which have been demonstrated operating various items of the equipment mentioned.

	Chamberlain	Ferguson	Fordson
Engine	Diesel (Perkins L4)	Diesel (Standard Motor Co.)	Diesel (Ford)

Document #2(b). A section of the minute from E.D. Hespe to L.H. Keher, 27 February 1959, discussing the tractor purchase.

A few days later, Dr R.B. Temple sent a minute to the chairman of the Effluent committee stating that “recent observations on the level of water in the proposed dumping area have “in my opinion, thrown grave doubts on the possibility of using the area that has been cleared for the purposes we originally had in mind”[37] (i.e. disposal of low-activity, solid waste). But Dr Temple was even more concerned about the proposal for “the ground disposal of high and medium level liquid wastes (Document #3 [see page 20]). Dr Temple reiterated that after the heavy rain in early 1959, the four test holes had filled up to the brim. He concluded that this was most undesirable for ground disposal in non-waterproof trenches and stated that “as the water level rises after rain it is obvious that the trenches will fill with water which will become contaminated with leached out radioactivity from the waste”. Dr Temple concluded his minute by recommending dropping ground disposal of any kind of active material in the Little Forest area. He felt that above-ground silos might be a better option. The recipients of this minute included many of the senior AAEC scientists and staff of the time.

[37] Minute from RB Temple to the Effluent Committee Chairman, 5 March 1959.



5th March, 1959.

Copy placed on LH 1606.

Chairman,
Effluent Committee.

Our recent observations on the level of water in the holes in the proposed Little Forest dumping area, following the recent heavy rain, have, in my opinion, thrown grave doubts on the possibility of using the area that has been cleared for the purposes we originally had in mind.

You will recall that the initial proposal for the use of the Little Forest area was for the ground disposal of low-activity, or potentially contaminated, solid waste, only, viz., the contents of kitchen tidies from the active suites, and so on.

Recently, however, at Professor Baxter's request, this Committee has been asked to consider an entirely new proposal with much more serious implications, namely, the ground disposal of high and medium level liquid wastes.

Document #3. The opening sentences of a minute from Dr R.B. Temple to the effluent committee chairman, dated 5 March, 1959.

In April 1959, staff of the NSW Geological Survey reported on their earlier site survey at LFBG. The available copy of this document is in a deteriorating condition, however the meaning is clear [square brackets in the following extract are an assumed reconstruction of missing text];

> "It is probable that the outlier of the Wiannamatta Shale has a v[ariable] thickness, up to 30 feet or more, its actual thickness and baseme[nt con-] tour being indeterminate without further boring. The shales will [be] underlain by Hawkesbury Sandstone with the probability of passage[s] consisting of thinly-bedded sandstones and shales before reaching the more massive sandstone. At the base of the shale, water is likely to be encountered, the interface between shale and sandstone forming a perched aquifer. Water from this source may, therefore, emerge at the limits of the outcrop of the shale and enter the stream systems (Mill and Barden Creeks) which flow northwards into Georges River. Thus, though the shale may be a favourable host for radioactive waste in terms of adsorption or ion exchange, the danger of radioactivity moving from the area in waters at or below the horizon referred to above should not be overlooked"[38]

Thus, both the observations of the area after rain, and the drilling undertaken by the NSW Department of Mines, raised concerns about the suitability of the selected site. However, it appears that the findings of the site survey did not cause the plan for disposals at LFBG to be significantly delayed. In mid-1959 the AAEC was finalising its position on disposing low-level waste for outside bodies, with the disposal ground at Little Forest anticipated to be operating in the near future[39]. The AAEC was also under pressure regarding its waste disposal practices, with concerns apparently raised by the Transport Workers Union and Sutherland Shire Council, and unwanted photographs being taken in the Little Forest area[40]. The Sutherland Shire District News published a letter from the president of the local electorate council of the Australian Labor Party, urging that land adjacent to the reactor should not be used

[38] Report from EO Raynor (geologist, NSW Department of Mines), to JC Webb, Field Engineer, AAEC, 21 April 1959. Note that the edge of the original has been torn and the assumed missing words are indicated in square brackets.
[39] ARW Wilson, "Radioactive Waste Disposal: Offer of Assistance to Outside Bodies. AAEC memorandum 119/1959. 12 June 1959. AAEC Commission Minute, Decision 404. 19 June 1959.
[40] DF Sangster, Memo to AAEC head office. 13 August 1959.

for disposing of radioactive waste[41]. A local MP, Mr L.R. Johnson, expressed concerns to the AAEC, which in reply stated that investigations of the structure and properties of the soil and subsoil were underway, with the results to be “carefully considered before any action is decided on”.

Various exploratory drilling activities were being carried out at the LFBG site, as well as an experimental waste disposal of non-active waste plus nitrate ion as a tracer. In addition, further trials of the back-hoes had been undertaken[42] and these may have been used to excavate the various trenches sketched in Figure 2.

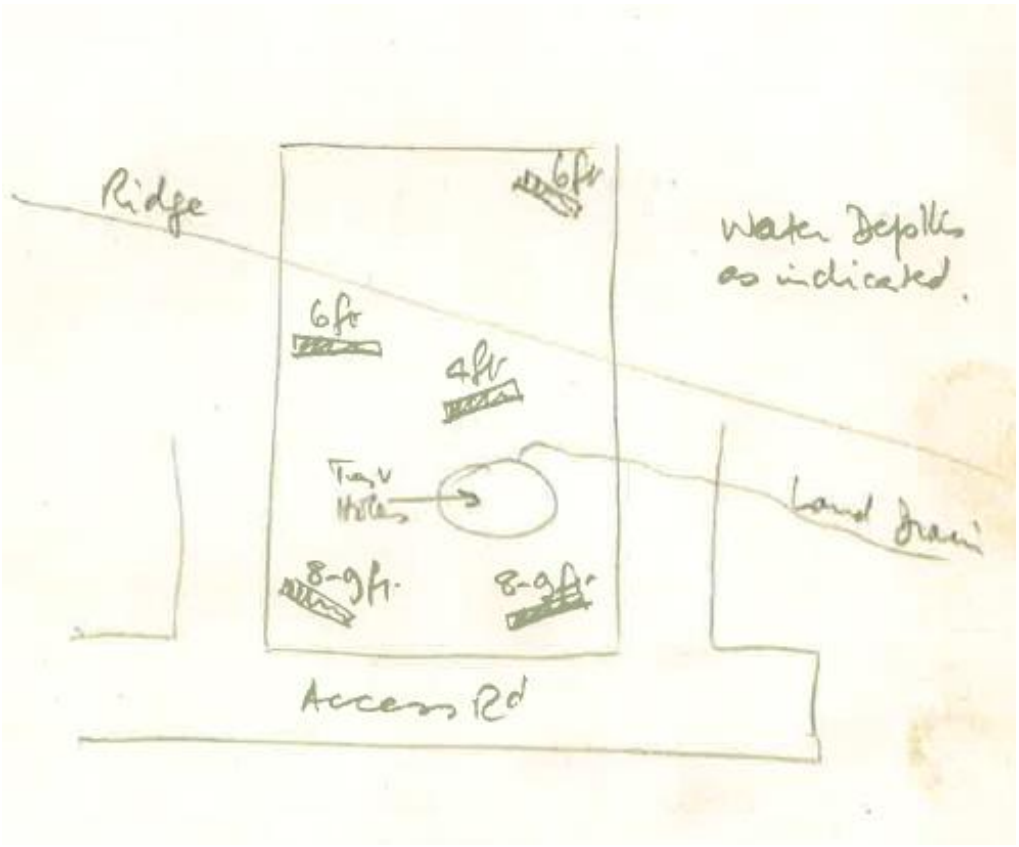


Figure 2. Sketch drawing by Dr R.B. Temple showing trenches and test holes at LFBG in early 1959[43]. The water depths in the test trenches are indicated.

[41] FC Pollard, Letter to the editor, Sutherland Shire District News, August 13 1959.
[42] Minute from ED Hespe to LH Keher, 27 February 1959.
[43] Minute from RB Temple to the Effluent Committee Chairman, 5 March 1959.

Some months later, a report appeared on the cation exchange capacities (CEC) of soils from the Little Forest area, as well as sediments from the Woronora River (Temple and Smith, 1959). The CEC (~10 meq / 100 g) was consistent with the reported mineralogy of the soils (with the clay mineralogy dominated by kaolinite and illite), although concern was expressed in this document that due to the salinity of the waters encountered at the LFBG, the clays would have "little spare cation exchange capacity". However, it is clear from the historical records that the deciding factor in the selection of the LFBG site was the presence of clays in the subsurface, and from the viewpoint of radionuclide retention this was considered to be a desirable feature.

A paper presented at an international conference in Monaco in November 1959, discussed the waste facilities at Lucas Heights (Berglin et al., 1959). It described how low activity solid waste would be buried in an adjacent site (i.e. LFBG). An experiment then underway was reported, which involved burying 11 m^3 of solid waste with negligible activity in a trench 3.6 m deep with 1.8 m of earth cover. A strong nitrate solution was added to the waste as part of an experiment to assess the suitability of the area for waste disposal. According to a flow-chart (which showed tentative disposal strategies), the burial ground was being considered for disposal of all types and levels of wastes, i.e. liquids, solids, beryllium wastes, and low, medium and high level wastes. Consideration was being given to converting medium and high level wastes to a solid form by addition of cement, with subsequent disposal at the burial ground. However, the definitions then used for these categories of wastes were different from modern terminology. It is notable that Dr Temple (who had expressed the strongest concerns about the LFBG) was not among the authors of this report. It might have been expected he would be involved, given that he was responsible for setting up the experiments at the LFBG earlier in the year.

In February 1960, the Atomic Energy Attache at the Australian Embassy in Washington warned of possible problems the AAEC may face at Little Forest, on account of reported experiences in the United States of disposal of radioactive wastes in the ground[44]. By this stage the commencement of disposals at the LFBG was imminent, with the first five trenches excavated and filled during 1960.

[44] Letter from IJW Bissett to Dr Wilson and LW Keher, 2 February 1960.

8. Comments on site selection and assessment process

While the site selection process undertaken for the Little Forest site had several shortcomings, which will be reviewed below, it should be realised that site disposal operations were hastened by the urgent operational environment, and the staff involved were relatively inexperienced. As has been discussed, this lack of experience with disposal of radioactive substances was a worldwide problem, particularly during the "Cold War" when the perceived urgency of developing nuclear weapons (and other nuclear technology) was driving the rapid development of nuclear facilities and associated disposal sites in many countries.

Nevertheless, many defensible decisions were made during the site assessment of the LFBG site, and appropriate actions were undertaken, specifically the following:

- Appropriate (if incomplete) site investigations were implemented.
- Some of the senior the staff were trained at Harwell.
- The AAEC officers tried to take into account experiences overseas and followed practices which were considered to be internationally acceptable.
- Geologic records were considered and the advice of geologists was sought, particularly from the NSW Department of Mines, and a site was selected in the centre of a shale / clay lens.
- Senior management decided to delay the commissioning of Building 2 while waste issues were being resolved[45].
- Open discussions occurred during which reservations were expressed, and decisions and discussions were preserved in the historic record.

The selected site at Little Forest was within a lens of shale, leading to significant quantities of clay minerals in the local soils. Therefore, in terms of preventing groundwater transport of radionuclides, which was a major consideration in site selection, the choice of the Little Forest disposal site was defensible. Nevertheless, there were several apparent shortcomings of the selection and assessment process of the Little Forest site, summarised as follows:

[45] Minute from CN Watson-Munro to the Chairman, Building 2 procedures committee. 28 November 1958.

- The site selection was hasty with lack of consideration of alternatives.
- The site selection was largely driven by proximity to AAEC facility rather than optimal geology.
- Although problems with similar facilities overseas were not realised in the early stages of site selection, they were known about before disposal operations commenced[46]. Following a discussion of how well activity had been retained at various disposal sites, Dr Watson Munro commented that, "I understand that the 6' figure achieved at Oak Ridge has not been repeated at other localities and has run up to many hundreds of feet." While the presence of abundant clays at LFBG has ensured that the migration of radionuclides (other than tritium) in groundwater has been very limited, it is possible that the disposals would not have commenced if the shortcomings of disposal trenches overseas had been more widely known.
- Advice regarding the LFBG site from the Department of Mines, that highlighted some potentially unfavourable aspects of the site, was not adequately taken into consideration.
- Similar advice from an AAEC staff-member was also ignored: (i.e. "Our recent observations on the level of water in the holes in the proposed Little Forest dumping area, following the recent heavy rain, have in my opinion thrown grave doubts on the possibility of using the area that has been cleared for the purposes we originally had in mind"[47]).
- Although the clay soil had some advantages (e.g. high sorption capacity), the associated drainage problems were not properly considered, despite evidence of hydrological problems from investigations of the site made after heavy rainfall. However, it is noted that the cause of the "high water levels" was typically misinterpreted as being a locally high water table (Isaacs and Mears, 1977), rather than as a warning sign of possible direct infiltration of rainwater which could lead to rapid saturation of the trenches. This process has subsequently been implicated in the release of radioactivity from the LFLS trenches (Payne et al., 2013).

[46] Letter from Dr CN Watson-Munro (Chief Scientist) to Dr G Miles, 9th December 1958.
[47] Minute from RB Temple, 5 March 1959 (see Document #3).

In addition to the above considerations, other issues encountered during the operational period included:

- Perturbations of hydrology and hydrogeochemistry due to adjoining land-uses (particularly the nearby quarry), which were not anticipated at the time of site selection.
- Suburban encroachment became an increasing concern.

While some of the shortcomings of the site were discussed prior to the commencement of disposals, and problems were starting to become apparent at some similar sites overseas, there was considerable pressure developing from the accumulation of wastes at the research establishment. Furthermore, trench disposal was an internationally accepted method of dealing with low-level wastes, and based on the characterisation of the site, the Little Forest site was considered to be the best available location in the proximity of Lucas Heights. These factors were probably the dominant considerations in the final decision to commence disposals at the LFBG site during 1960.

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