Briseis water supply scheme 1901-1910: a premium investment

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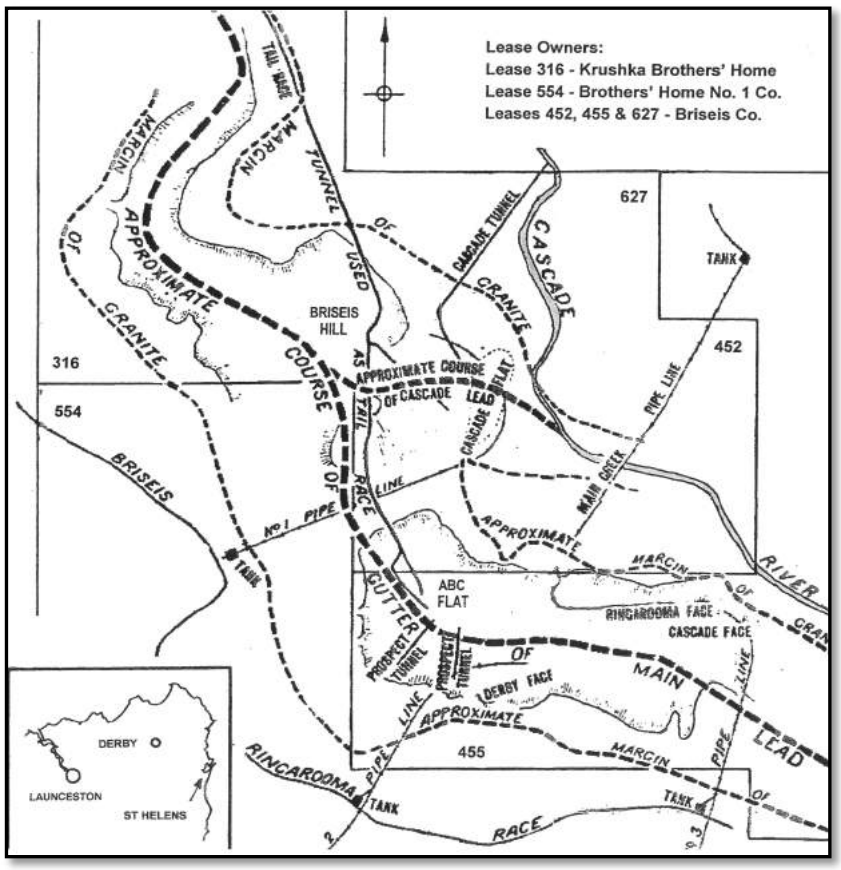
At the close of the nineteenth century, mining of deep tin leads along the Ringarooma Valley of north-eastern Tasmania by means of hydraulic sluicing was well established. In the vicinity of Derby, water supply and tailings disposal were critical factors in achieving viable operations along the Cascade Lead.[1] Mines on the south bank of the Ringarooma River competed for available water from the Cascade River, that flowed through the leases of the Briseis Tin Mining Company.[2] A limited water supply was also available from Main Creek to the east, but again restricted by competition from mine leases along that watercourse. Reduced summer flows usually curtailed tin production for several months as finance for the construction of storage reservoirs was generally unavailable.

Figure 1: *Sketch plan of the Cascade Lead showing original lease owners with subsurface features superimposed.*



Source: *The Argus*, 29 April 1902, p. 8.

On the south bank of the Ringarooma River the privately owned Krushka Brothers mine on Lease 316 dominated tin output prior to 1900, aided by a short headrace from the Cascade River that provided an adequate water supply and a river frontage that facilitated tailings disposal at minimal cost (Fig. 1).[3] The adjoining mines operated by Victorian based mining companies, the New Brothers' Home No. 1 TM Co. [NBH1 Co. hereafter] and Briseis TM Co. [Briseis Co. hereafter], were less fortunate in having to share water from the Cascade River and having no river frontage for tailings disposal.[4] By 1899 all mining operations were severely restricted by the need to remove large volumes of overburden from the 350ft high Briseis Hill to enable open cut working to proceed. While the Krushka Brothers were content to wait for a favourable takeover offer, antagonism arising from a series of conflicts between the Victorian mining companies prevented progress by establishing a joint venture. Each company pursued the acquisition of more water that was required for the economic removal of overburden by hydraulic sluicing and raising the required capital to provide the additional infrastructure.

The resulting fierce competition for sustainable water supplies resulted in the Mines Department reviewing water rights from the upper catchment of the Ringarooma River in September 1900. The main beneficiary was The Briseis Tin Mines Ltd, a company floated on the London stock market by venture capitalists backed by a £600,000 capitalization. A proactive Melbourne board of directors, assisted by mining engineering consultants, was focused from the outset on establishing efficient operating practices. Design of a 30 mile long headrace from the headwaters of the Ringarooma River was entrusted to highly respected surveyor Donald Fraser, with the assistance of Melbourne civil engineer Henry Champion. A design capacity of 100 sluice-heads (21.7 million gallons per day) was adopted and the Minister for Mines was pressured into granting the required water allocation, contrary to hydraulic engineering advice. The completed headrace was not fully operational until August 1902 when development costs of over £100,000 threatened the financial survival of the company.

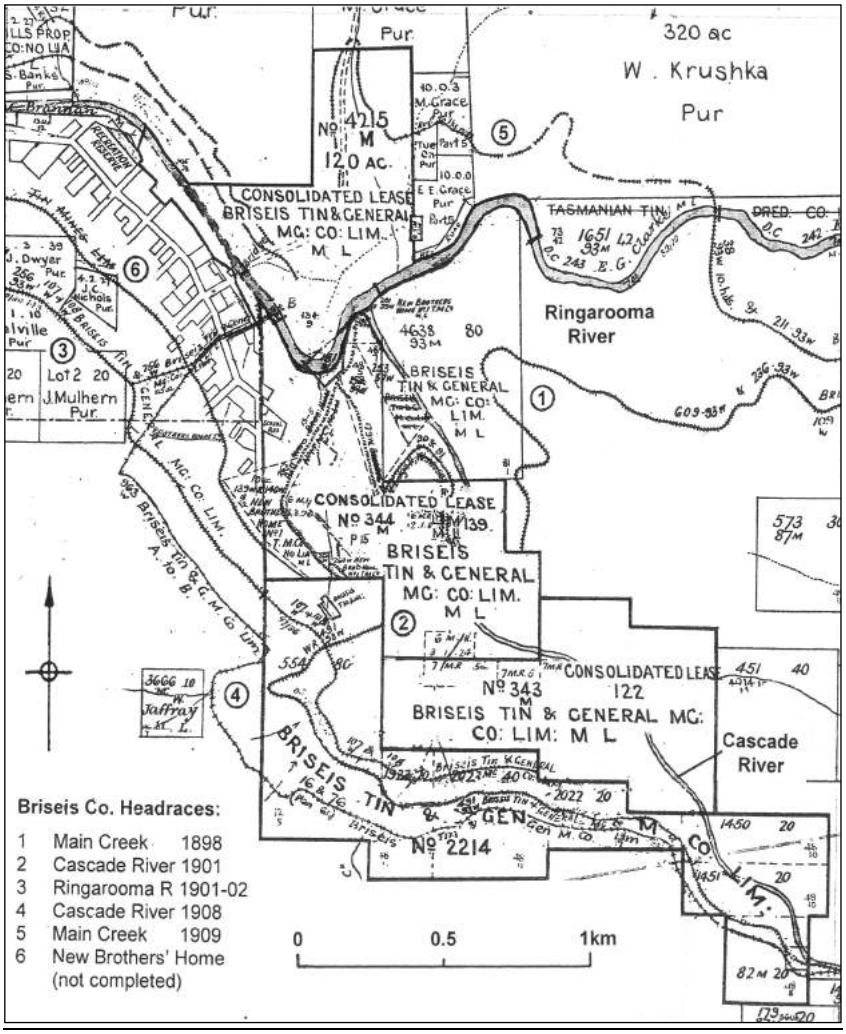
Increased water supplies a priority

Initially, the Briseis Co. sought additional water from the Cascade River by applying for 10 sluice-heads [SH hereafter] in March 1896, which was not granted until January 1899, providing a measure of the demand on the available supply.[6] Main Creek became the focus for obtaining further water allocations from December 1897, initially by purchasing existing water rights, then in July 1899 by applying for a further 7 SH – in all a total of 21 SH were secured.[7] Construction of a six mile long headrace proceeded in June-November 1898 at a cost of some £2,600 providing water for hydraulic sluicing with a 230ft pressure head via a 638yd column of 20in diameter pipes (Fig. 2).[8] The resulting increase in tin oxide production to 117 tons [t] for the eight months to June 1899 enabled monthly dividends of 1shilling to be paid through the following half-year period at a cost of £18,000 (excluding taxes).[9] This was the first sustained period of dividend payments since the formation of the company in 1883.[10] A further 10 SH from Main Creek was granted in June 1901 (Appendix 1).[11]

With water allocations from the Cascade River and Main Creek exhausted, attention turned to the only other practical alternative, the headwaters of the Ringarooma

River catchment to the southwest. Mine manager Thomas Bruce and engineer John Aiton first considered this option ten years earlier when a 22 mile long water race was surveyed.[12] This did not proceed however, due to a combination of factors including the resignation and premature death of Bruce from cancer eight months later; the rejection of a £25,000 purchase offer for the Krushka lease; and the high cost estimate for the race of £22,880.[13] A renewed attempt was made in late 1898 by mine manager William J. Shepherd, when an application for 30 SH from an intake immediately downstream of the Ringarooma/Maurice River confluence would entail a 23 mile long race.[14]

Figure 2: *Water supply races to the leases of NBH1 TM Co. (Lease 554) and leases of The Briseis Tin Mines Ltd (Briseis Tin & General Mining Co. Ltd from 1909.* (See Appendix 1 for water right details).



Source: Mineral Resources Tasmania, Mineral Chart 149d, April 1902 - October 1911.

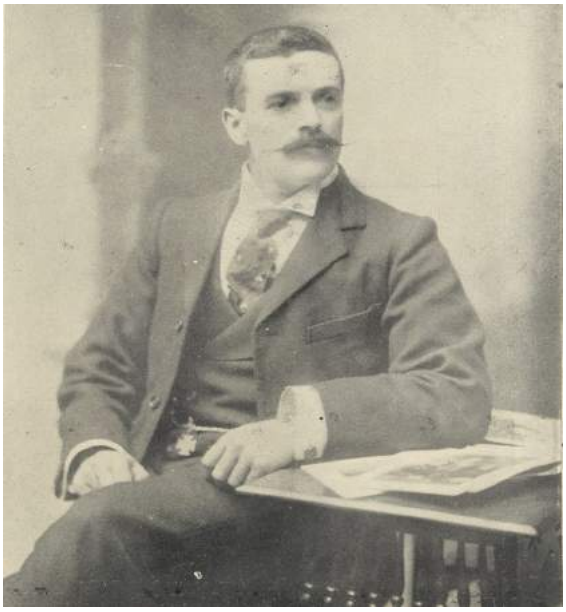
Six weeks later, the NBH1 Co. responded by lodging their own application for 10 SH from the Ringarooma River, the intended race at a lower elevation than that of the Briseis Co. having a reduced length of 16 miles (Fig. 2).[15] An application for an additional 10 SH along the same water race was lodged in June 1899 when accomplished surveyor Donald Fraser was engaged to finalise the alignment.[16] Victorian civil engineer J.B. MacKenzie prepared a detailed cost estimate for a proposed mine expansion that included

the headrace, a pressure main for an hydraulic elevator, and new tailraces to facilitate overburden stripping.[17] He stressed the financial benefits to be gained by both companies co-operating in order to work the tin drift[18] along the common boundary, pointing out that there was adequate provision within the 1893 Mining Act for arbitration, but this advice was ignored.[19] Estimates of almost £30,000 for overburden stripping and tin drift excavation, and £11,234 for the water supply infrastructure that included some £6,000 for the headrace and a 20% contingency, were clearly beyond the resources of a company with a nominal capitalization of £60,000.[20]

Capital raising (1899-1900)

Given the limited prospect of two sizeable capital raisings proceeding on the Australian share market, both of the Victorian mining companies sought to raise the required finance by floating in London, providing a measure of the intense rivalry that had developed. Mining investor Albert E. (Bertie) Langford negotiated an agreement in March 1899 with the Briseis Co to pursue the float and received a £3,000 advance payment. The sale terms were disclosed prior to any discussions in London: £150,000 cash plus a 25% interest in the market capitalisation and a minimum working capital of £40,000.[21] Langford engaged Mt Bischoff TM Co. general manager H.W.F. 'Ferd' Kayser to oversee preliminary prospecting, for which a drill crew and equipment were mobilised from Melbourne.[22] Prior to his departure for London in April, Langford was feted in Melbourne by the Briseis board of directors that included contractor Arthur T. Robb (chairman), William Allan, and three parliamentarians.[23]

Figure 3: *Don Fraser – surveyor and project manager for the Ringarooma-Maurice supply race*.



Source: *The Weekly Courier*, 13 September 1902.

The Briseis Tin Mines Ltd [Briseis Ltd hereafter] was registered on 25th November by The Venture Corporation, a London joint-stock company, with a nominal capital of £600,000 in £1 shares, 'the amount of cash received [£150,000] was probably the largest obtained for any mine in Australia, certainly by a Victorian company'.[24] Board members comprised The Earl of Chesterfield (chairman), Thomas Pyke (director Mt Lyell Mining & Railway Co. Ltd), Henry J. Bristow (director Waihi G.M. & Waitekauri Gold Mining Companies) and F.S. Drury (director of Stratton's Independence Ltd of Colorado).[25] A local board of directors based in Melbourne comprised: chairman Langford, Alexander J. Peacock MLA (Victorian Chief Secretary), R.S. Whiting, William Allan and legal secretary Thomas P. Husband. The London directors were assured that Ferd Kayser was 'a most reliable man' before he was appointed general manager to oversee the initial mine

development, assisted by Edwin Rickard 'a Colorado expert of large experience', and Don Fraser (Fig. 3) who was appointed to the post of engineer to oversee construction of the Ringarooma headrace.[26] The working capital was increased to £90,000 to make provision for the purchase of the Krushka Brothers lease for £35,000.[27]

Terms for floating the NBH1 Co. were finalised with Fergus McIvor, representing 'English capitalists', in December 1899. A capital raising of £150,000 was proposed that included £80,000 for purchase (£60,000 cash, the remainder in paid up shares) and £20,000 working capital. McIvor was given eight months (this included two months in transit to England) to arrange the float in return for his £1,000 fee.[28] Chairman Adolf A. Joske travelled to Tasmania the following month to arrange the survey for a 20 mile headrace of 25 SH capacity, a replacement for Don Fraser being required as Briseis Ltd had secured his services. The plans and specifications for the supply race were finalised six months later when the mine was described as 'idle, under protection, pending results of negotiations for a change of ownership'.[29] In September news that the float had failed reached the township and was conveyed to shareholders by chairman Joske.[30] A newly appointed mine manager, C. Campbell from New Zealand, had followed the recommendations provided by consultant Mackenzie in making preparations for a water supply from the Ringarooma River but now a revised strategy was required.[31]

A solution for overburden disposal (1900)

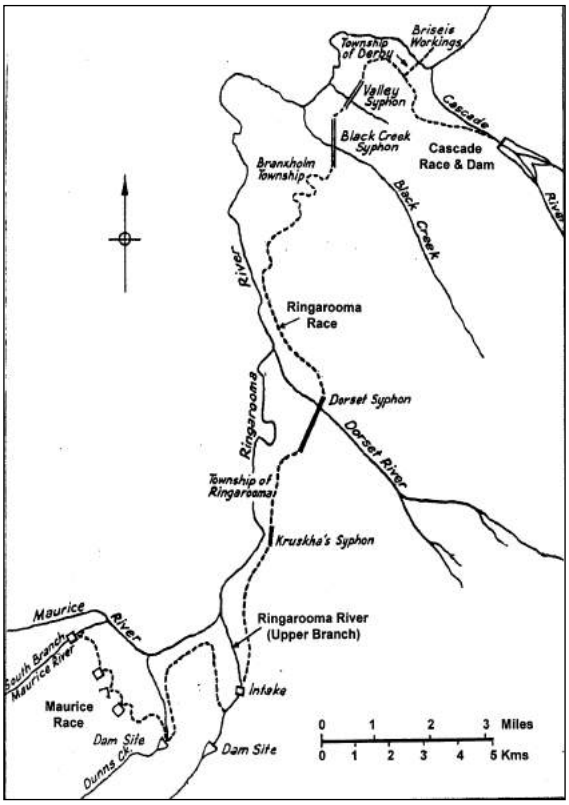
Prior to proceeding with the mine purchase, the prospective Briseis Company directors engaged London-based mining consultant David Currie (of Lake & Currie) to assess its development potential. Following a mine inspection in November 1899, he reported that the mine had 'been worked improperly and without system … find representations [by Ferd Kayser] substantially correct … the outstanding difficulties in the past have been the shortage of water and the stripping of the overburden'.[32] He considered that mine development would take 18 months to complete, twice as long as the estimate provided by Kayser.[33] Following mine visits in February in conjunction with Melbourne directors Allan and Husband, Kayser directed the initial mine development.[34] High priority was given to awarding a contract for driving a second tunnel within the granite bedrock for conveying overburden to the lower section of the Cascade River, the first tunnel driven to the Ringarooma River in 1885-90 to be used thereafter solely for treating tin drift.[35] Construction tenders for the Cascade Tunnel (Fig. 1) were called in mid-February with the contractors offered a bonus for early completion ensuring that two-shift working commenced three weeks later on sinking an 80ft deep dump shaft.[36] Previous experience ensured that a steam-powered air compressor plant for the drills was mobilised urgently with the boiler operational at the beginning of April.[37] Kayser now had an opportunity to make preparations in Melbourne for sourcing plant and materials.[38]

Tunnelling was completed in early December by contractors Treverton & Johnson ten days ahead of the contract date for completion, Fraser's surveying skills receiving justifiable praise: 'the levels were within one inch and the actual length of tunnel, as measured, agreed within one inch of his surface measurements'.[39] Prior to the commencement of overburden sluicing, the Mines Minister engaged Danish civil engineer Karl L. Rahbek to review the impact of further tailings disposal into the

Ringarooma River. The Briseis mine was identified as the impending largest contributor of some 30,000 cubic yards per week (approximately four times that of the NBH1 Co.), utilising up to seven nozzles. Rahbek recommended that a drystone retaining wall be constructed along the river flat at the mouth of the Cascade River to contain the gravel size component of the tailings as it discharged from the tailrace. This would be subjected to damage during periodic high-volume discharge during flood events however, and there is no record of the measure being implemented.[40]

Contest for Ringarooma water (1900-01)

Figure 4: *Sketch plan of the Ringarooma-Maurice and Cascade supply races, Cascade Dam constructed in stages 1924-28.*



Source: H.H. Dunkin, 'Sluicing Operations at Briseis Consolidated N.L - II', *Chemical Engineering and Mining Review*, vol. 38, August 1946, p. 397.

Fraser's survey of a 19.5 mile long headrace to the Ringarooma River and 10.45 mile extension to the main tributaries, the Maurice River and Dunns Creek, was completed in May when the proposed route was inspected by the Melbourne directors (Fig. 4). Following discussions in Melbourne at the end of the month, contract preparation was underway in June.[41] With all the design work completed within a hectic five-month timeframe, race construction was set to proceed when it was abruptly halted for the Minister for Mines (Edward Mulcahy) to order a review of water right allocations. Applications totalling 195 SH (42.2Mgal/day) for rights to water from the Upper Ringarooma catchment had been lodged over a two-year period, of which the bulk were intended for Briseis Ltd (108 SH) or NBH1 Co. (50 SH). Civil engineer Rahbek was engaged at the end of August to provide guidance on a sustainable level of water use for mining.[42]

Rahbek gauged the flows on the major tributaries at the beginning of September, ironically following an abnormally wet month (11.15in) in a drier than average year, when a total of 39in was recorded at the Ringarooma township.[43] He measured a flow rate of 494 SH near the Ringarooma township, of which 221 SH drained from the Upper Ringarooma River and the remainder from the Maurice River branch. These high flow rates were compared with measurements made by civil engineer G.J. Burke MICE between February-September 1885 when a minimum flow rate of 121 SH was determined.[44] Further gauging revealed that the flow rate at the proposed site of the intake weir on the Upper Ringarooma River was reduced to 160 SH, the implication being that

the summer flow would be substantially below the quantity sought by Briseis Ltd.. Rahbek recommended that the company be allowed rights to 78 SH from the Ringarooma River and 8 SH from Dunns Creek (total 86 SH), whereas the NBH1 Co.'s request for 50 SH should be granted in full.[45] Minister Mulcahy moved swiftly following the receipt of Rahbek's report, granting leases totalling 70 SH to Briseis Ltd and 25 SH to the NBH1 Co. on the 1st October (refer to Appendix 1). As Briseis Ltd was granted a further lease for 30 SH six months later, thereby attaining 93% of their requested allocation compared to only 50% for the NBH1 Co., it appears that Mulcahy was pressured into granting 100 SH (903,800gal/hour – 21.7Mgal/day) to Briseis Ltd – this being the headrace design capacity that had been adopted some months earlier.[46]

Design of the Ringarooma headrace

Construction of the Ringarooma supply race now formed the largest such undertaking attempted in Tasmania, supplying twice the flow rate of the Mt Cameron Water Race that was completed with Government funding in 1890 at a cost of some £26,700.[47] The overall design concept attributed to surveyor Don Fraser, incorporated four creek crossings associated with deeply eroded valleys that would entail a considerable increase in length if a conventional contoured race alignment was implemented.[48]

It appears that the use of inverted syphons was adopted at an early stage in the design process (by May 1900), probably at the instigation of Fraser, although at least one member of the Melbourne board of directors had considerable construction experience.[49] All of the Melbourne directors had inspected the mine in April and some also travelled to Gladstone to view the Mt Cameron Water Race where inverted syphons were operating.[50] A Melbourne civil engineer specialising in town water supply and piped sewer lines, Major Henry V. Champion, was engaged to undertake the technical analysis and provide design oversight of the syphons.[51]

The main portion of the race from the mine to the intake weir on the Ringarooma Race [hereafter the Ringarooma Race] was designed for a maximum flow rate of 120 SH providing for a loss of up to 20% from infiltration and evaporation. During construction the section of the race adjoining the intake weir was tested with a flow of 125 SH for 24 hours and found to be satisfactory.[52] Trenching proceeded in accordance with the following guidelines: excavation cut to a depth of 42in, a base width varying from 5ft to 6ft along the race with internal batters of 1 in 2 on the upslope side and 1 in 4 on the downslope side. Spoil placed on the downslope side was to commence 2ft clear of the edge of the race and be battered to 1 (vertical):1.5 (horizontal). Additional guidelines were provided where bedrock was exposed at the surface, or where the race extended across small gullies.[53]

New Brothers' Home No. 1 water supply dilemma (1900-1901)

Plans and specifications for a headrace from the Ringarooma River based on Don Fraser's survey were submitted to the Mines Department in July 1900.[54] News that the proposed London float had failed in September was soon followed by further bad news, as the Mines Department had only granted half of the requested water allocation of 50 SH (see

Appendix 1).[55] By this time, the cost of survey and preliminary design work amounted to £540, for a water supply scheme initially costed by Fraser at some £6-7,000, having increased to £10,000.[56] With a finance shortfall apparent to newly-appointed mine manager William J. Shepherd in November, due to reduced income resulting from a failing summer water supply, a new strategy was required.[57] This awaited a further change in manager, as James B. Lewis had been appointed by March, leading to a partial easing of frosty relations with Briseis Ltd. An offer for the NBH1 Co. to fund 25% (about £8,000) of the projected construction cost of the Briseis headrace and 25% of the ongoing maintenance for a proportionate share of the water allocation was revealed at the March shareholders meeting. This option would have the additional benefit of providing an increased pressure for sluicing from the more elevated Briseis headrace.[58] Attempts to obtain a bank loan failed however, and the prospect of increasing calls from 3 pence per quarter, which paid the maintenance costs, to 1 shilling was considered unacceptable by shareholders, as mining had been suspended.[59]

It was also revealed at the March shareholders meeting, that as the existing Cascade flumed headrace was 'almost falling to pieces, Briseis Ltd had consented to erect a new race about 100 feet above the present one, at their own cost'.[60] A contract was awarded to Edward O. Jones in January for a steeply-graded alignment where timber fluming formed about half of the 2.5 mile long race.[61] A pipe column to the Briseis workings was completed by early July and trialled seven weeks later, while another pipe column to the NBH1 Co. lease was connected in January 1902 thereby finally providing their lease with a supply of high pressure water for overburden sluicing.[62]

Figure 5: *Overburden removal from the NBH1 Co. lease by a combination of hydraulic sluicing and trucking of large basalt blocks, capping layer of Briseis Hill in top left corner.*

Source: Mineral Resources Tasmania, Photo 0009-35, December 1901.

A maximum water allocation of 90 SH available from the Cascade Race was now shared by the two companies, of which the bulk (80 SH) comprised the water rights initially granted to the forerunner of the NBH1 Co., these having being conveyed to the Cascade Water Trust to administer in 1887.[63] Prior to the pipe column being installed on the NBH1 Co. lease, manager Lewis implemented a process of 'dry stripping' whereby the large basaltic overburden was loaded manually into rail trucks from an elevated platform, for trucking to a waste dump (Fig. 5).[64] This continued through the first half of 1902 when 30 men were engaged stripping some 100,000yd^3 of overburden, approximately half sluiced at an average cost of 4.5 pence per cubic yard and the remaining large blocks trucked at twice the cost.[65]

Construction of the Ringarooma & Maurice Races (1901-02)

As a measure of confidence of the Melbourne board with surveyor Fraser's ability, he was engaged on a two-year contract to oversee the construction of the races. Local contractor Richard T. Hall had responsibility for the initial 12.15 mile section of the race extending from the mine to the southern end of the Dorset syphon (Fig. 4).[66] Briseis Ltd retained control of the remainder of the Ringarooma Race, together with the inlet weirs and dams on the Maurice Race and the erection of the four syphons. Extensive timber flumed sections were required to maintain a constant grade, forming approximately 10.7% (2.1 miles) of the alignment, the syphons a further 10.5% (2.04 miles).[67] Four sawmills were located along the race to produce the prodigious quantity of sawn timber, the first operational in May.[68] Director Allan and consultant Currie travelled to Pennsylvania (USA) in February to order mild steel plates from the Homestead Works of the Carnegie Steel Co. for fabrication of the syphons in Tasmania.[69] Specialist pipe and bridge fabricator Mephan Ferguson of Melbourne was awarded a £6,000 contract for the production of the 20ft 4in. long syphon pipes of two sizes: Valley (2,618ft long) (Fig. 6) & Black Creek (3,480ft) of 38in diameter, Dorset (3,748ft) (Fig. 7) & Krushka (905ft) syphons of 40in diameter.[70] Quality control was rigorously enforced, as Allan reportedly 'condemned certain portions … the work not being up to specification'.[71]

Mephan Ferguson commenced the production of large diameter riveted, wrought iron water supply pipes in 1885, patenting a spiral riveted pipe in 1892 that was adopted by the Tasmanian mining industry.[72] By the turn of the 20th century, mild steel was supplanting wrought iron for pipe production when Mephan Ferguson introduced the lock bar pipe to the Australian market. This system eliminated the need to punch rivet holes in the pipe sections and improved flow characteristics by providing a smooth wall profile.[73] Traditional riveted pipes were utilised for the Briseis syphons, the plant shipped from Melbourne comprising plate bending rolls, riveting and hydraulic testing plant and a dipping bath for applying an asphalt coating, that was operational by late-July.[74] Once the pipe sections had been placed in position by means of winching or temporary wooden tramways (Fig. 7), the joints (total 440) were lead sealed.[75] All of the syphon pipes had been fabricated by the beginning of January 1902 when the plant was dismantled and shipped back to Melbourne the following month.[76]

Construction of the intake weir on the Upper Ringarooma River and an embankment for a dam of limited capacity, immediately upstream of the Maurice Race

outlet (Fig. 4) proceeded through much of 1901.[77] About 15,000 cart loads of decomposed kaolinite granite placed in 9 inch thick layers were required to form the 528ft long dam embankment to a maximum height of 14ft, the weathered rock 'set almost as hard as concrete itself'.[78] In the absence of an accurate figure of the Upper Ringarooma catchment area, a spillway 10ft wide with a length of 116ft was found to provide adequate flood protection.[79] An official opening ceremony marking the completion of the Ringarooma Race was held on 16th April but work continued on the Maurice Race that formed approximately 35% of the overall length.[80] This was more steeply graded (1:792) than the Ringarooma Race (1:1320) as it contoured around the head of the catchment. No major structures were required, apart from another settling pond on Dunns Creek and further weirs of limited size on tributaries draining into the Maurice River (Fig. 4).[81] With completion of the headrace in August after 20 months construction, the Maurice Race was inspected by the Melbourne directors together with general manager Cecil E. Hawley and Don Fraser.[82]

Figure 6: *Valley Syphon*.

Source: Queen Victoria Museum & Art Gallery, QVM:1983:P:0610, April 1902.

Financial repercussions of the Ringarooma headrace construction

An initial estimate of £22,000 for construction of the headrace to the Ringarooma River was conveyed to promoter Langford by Ferd Kayser for inclusion in the prospectus of The Briseis Tin Mines Ltd. This figure originated ten years earlier when mine manager Thomas Bruce considered a headrace of much smaller capacity, probably no more than 30 SH, that did not proceed.[83] As Fraser's later headrace design of 100 SH capacity incorporated costly syphons and extensive fluming, spiralling costs that were apparent by mid-1901 forced the resignation of London chairman of directors, The Earl of

Chesterfield, together with Kayser at the second annual shareholders meeting.[84] With no detailed account of the meeting appearing in the Australian press, further clarification was not available until the following meeting in August 1902 when new chairman Henry J. Bristow provided a revised cost of £52,000. This figure, however, failed to include the cost of the Maurice Race extension of about £6,000, which, equated to some 10% of the Ringarooma Race cost.[85] The report of the Secretary for Mines (W.H. Wallace) provided an even higher figure of £67,000.[86] As a result of the continuing water supply deficiency, a small operating profit of £378 for the 1900 financial year was followed by a loss of £2,778 the following year.[87]

Figure 7: *Dorset Syphon with construction tramway*.

Source: Queen Victoria Museum & Art Gallery, QVM:1983:P:0609, February 1902.

A fuller picture of the financial account deposited with the Mines Department for the period ending December 1901 shows a further deterioration in the financial position. Expenditure 'on contracts and land purchased' together with development costs amounted to almost £60,000, which was financed in part by a bank overdraft of £19,397.[88] Tin output was constrained by the rate of overburden removal, this declining from 40-50,000 cubic yards a month through the latter part of 1902 to 15-25,000yd^3/month during the dry summer months – the corresponding decline in tin production from 35-40 tons of oxide to 23-30 tons per month.[89] In June 1903 the shareholders report painted an alarming picture: total mine development and operating costs of £98,000, London office expenses of £2,682, and an overdraft practically double that of the previous year, of £38,050.[90] Chairman Bristow outlined a further problem at the shareholders meeting – a dramatic reduction in the share price from 25-30s at the end of 1901 to 3s 9d due to a rift between mine manager Hawley and the Melbourne directors over the deteriorating financial

situation, becoming public knowledge. Bristow was under some pressure as he and his family and friends held 16-18,000 shares (up to 3%), leading to a view that 'the time has now come to make some reduction in the Melbourne board and staff'.[91] Consequently, drastic measures were implemented:

- Agreement was reached for Briseis Ltd to work the NBH1 Co. lease at a rate of 8d per cubic yard 'for the removal of the heaviest and hardest of the overburden of that portion of Briseis Hill that is within their boundary', and 4d/yd^3 for the remainder. All 'costs of mining, smelting, freight, insurance and selling are to be borne by the Briseis Co', in return for receiving 58% (NBH1 Co. - 42%) of the sale value of metallic tin from their lease. On completion, Briseis Ltd had an option of purchasing the NBH1 Co. rights & leases for £50.[92]
- Consultant David Currie was sent to Tasmania to review operating practices and assess ore reserves.[93]
- Civil engineering graduate Lindsay C. Clark was headhunted by Currie from the Anchor TM to manage both the Briseis and NBH1 Co. operations, replacing Don Fraser who had been appointed acting manager following Hawley's departure in October 1902. NBH1 Co. manager Lewis exchanged positions with Clark as the replacement Anchor TM manager.[94]

Currie calculated that 1,325,000yd^3 of overburden had to be stripped from Briseis Hill (450,000yd^3 on the NBH1 Co. lease), of which about 45% was required before large scale tin production could proceed – 'to do this work will take twelve months, from March 1903 and in the meantime the mine will have to produce 35 tons of tin oxide per month to cover costs'.[95] Manager Clark followed this recommendation religiously but it took longer than expected to achieve Currie's target, this not reached until the end of 1904.[96]

Headrace performance (April 1902-1903)

Upon completion of the Ringarooma Race (Fig. 8), Briseis Ltd operated 40 miles of headraces from the Main Creek, Cascade River and Ringarooma-Maurice catchment holding water rights to 232 SH (50.4Mgal/day), supplying an average rate of 'something less than two-thirds … expected that in the driest summer the supply from this race will never fall short of 60 sluice-heads [13Mgal/day]'.[97] This represented the state's largest mining company holding, forming 14.5% of the total state water allocation of 1,691 SH.[98] The first two years of operation provide a representative picture of the range of conditions as 1902 was a relatively dry year (37.9in – 22% below the 37-year mean value) and by contrast, 1903 was wetter than average (58.3in – 20% above the mean value).[99] Monitoring of water flow rates indicated that a total of 120-140 SH was supplied during the latter half of 1902 reducing to 82 SH the following summer (March), thereafter increasing to 130-195 SH from April 1903. Maximum flows attained during the winter months of 1903 were 14 SH from Main Creek, Cascade River – 70 SH and Ringarooma headrace – 112 SH (24.3Mgal/day).[100] The rate of overburden removal increased dramatically through the latter half of 1903 following Lindsey Clark's appointment, rising to some 60,000yds^3 a month, a rate that was maintained during the following year. Tin production in 1903-04 amounted to 35-40 tons per month, increasing significantly only when the bulk of Briseis Hill had been removed. On the NBH1 Co. lease, a second pipe

column was installed from the Ringarooma Race to facilitate increased overburden removal to 15-18,000yd^3 per month from October 1903.[101]

Figure 8: Stone-faced bundwall *& flumed sections of the Ringarooma Race.*

Source: H.V. Champion, 'The Briseis Water Race', *Proceedings of the Victorian Institute of Engineers*, vol. 4, September 1902.

Consultant Currie's June 1903 report was critical of the 'imperfect keeping of records on the Briseis mine … [it is] almost impossible to discover the duty obtained from the water actually used on the mines'. His best estimate for the removal of both overburden and tin drift during 1902 was 14,700gal/yd^3, falling to 12,000gal/yd^3 during the first quarter of the following year.[102] At the NBH1 Co. mine, manager Lewis with only 8 SH at his disposal was forced to economise on water use, achieving a miserly rate of some 6-8,000gal/yd^3. This he compared with practices on the Californian goldfields where an average rate of 4,000gal/yd^3 was considered acceptable in a more favourable overburden profile.[103] In December 1902, 60% of the available water supply was consumed by just two nozzles removing overburden on Briseis Hill, the larger 6 inch nozzle using 45 SH and a smaller 5 inch nozzle 30 SH.[104] A sophisticated monitoring system was implemented by 1910 whereby mine foremen were required to produce daily records of the size of nozzle tips used and the duration each was in operation, enabling the utilization of water per day for each face to be calculated. A detailed account of sluicing practices by mining engineer Edward Edwards C.E. in 1911 revealed that the average duty calculated for sluicing at Briseis Hill over a twelve-month period had been reduced to 8,000gal/yd^3.[105]

Given Clark's civil engineering background and his high workload, a vacancy for an 'assistant engineer and surveyor with experience in hydraulics' was advertised in August 1903. William A. (Bill) Beamish was recruited from the Mt Lyell Mining & Railway Co. where he had worked for five years as a mining engineer.[106] On his departure two years later, Samuel J. Gregory, a civil engineering graduate was appointed to assist with the engineering challenges that had to be surmounted.[107]

Further challenges before profitable working achieved (1904-05)

Progress with the enormous task of removing Briseis Hill was slowed in February 1904 when damage resulting from abnormal rainfall demonstrated the power of water flows in the steep-sided Cascade River valley, even in summer, when a wet January was followed by the highest recorded February rainfall (up to 1934) of 7.36 insches.[108] A rockfill

embankment 60-70ft high had been formed towards the confluence with the Ringarooma River in order to reduce the offsite disposal of tailings.[109] In the absence of an adequate spillway, the rockfill embankment was severely damaged by the ensuing torrent which formed a 'chasm 50ft deep and 50yds. across … carrying with it the tram lines, nozzle and pipe, races, fluming and thousands of tons of stripping and tin drift' that had been uncovered.[110] Although the breach in the dam embankment had been infilled within a month, and the flumed race and pipe column replaced, mine planning was disrupted leading to a reduced output until the middle of the year.[111]

By November 1904, after 30 months of concerted effort with overburden removal, tin deposits beneath Briseis Hill were finally exposed, a reporter from The Argus reminiscing that:

> the Briseis Hill rose in a solid face over 270ft. in height above the bed of the ancient gutter and was the most prominent landmark visible from the main street of the town-ship … a large portion of the massive rock and overburden – 130ft. thick – has disappeared.[112]

While tin oxide input increased gradually through 1905, it took nine months to clear the bank overdraft and commence accumulating cash reserves. Total development costs to June amounted to £236,000, an expenditure unmatched in the Tasmanian tin industry at that time.[113] With tin production exceeding 100 tons per month from February 1906, the first 9d dividend was declared at a cost of £22,500.[114] Profitability was accompanied by an unwanted record of human fatalities in an age of scant regard for work safety, conditions exacerbated by manual handling of large blocks of fragmented rock in the absence of mechanised equipment. In October 1903, long-standing employee of 20 years, water race caretaker Charles Courtney, was killed while 'cleaning an accumulation of debris from one of the tanks of the Cascade race, when he slipped and fell heavily in some rocks, 12ft below'.[115] Six months later John Conlon died at Launceston hospital from an unspecified injury. Further deaths of Michael Conlan and Francis J. Robinson towards the end of 1904 were due to rockfalls from the basalt capping layer. Robinson was employed loading trucks at the 25-30ft high Upper Cascade face that was 'composed of columnar basalt, generally very hard and difficult to break down, some portions are however, decayed and treacherous'. His death from a fractured skull occurred when trying to avoid a rockfall – the Coroner's finding: 'accidentally killed, no blame attached to anyone'.[116]

A golden period (1906-10)

After a five-year period of mine development, all major factors were favourable in 1906 for a record profit of £128,550 from an output of 1,408t of tin oxide that funded five dividend payments of 9d totalling £112,500 (excluding taxes).[117] With a substantial proportion of the overburden removed from Briseis Hill, stripping ratios averaged 1 (overburden): 1 (tin drift) on the Briseis property and a favourable 0.5:1 on the NBH1 lease.[118] A high rainfall for the year of 69 inches maximised tin output and a record tin price averaging £184 10s/ton led to an increased revenue of £168,000 (Table 1). A summer rainfall total of 3.2in (only half the 37-year mean) was followed by 24.2in during

May-June (225% of the mean value) resulting in an average flow of 156.5 SH from the headraces during the second half of the year.[119] Inevitably, torrential rainfall had consequences, as elevated flows in the Cascade River gorge swept away a pipe column from the Main Creek race that supplied an electric lighting plant, thus interrupting night working.[120] Mining operations also benefitted however, when flooding in the Ringarooma River resulted in scouring of tailings, lowering the river bed by 8ft at the beginning of June, and by 10-15ft at the end of the month.[121]

Table 1: *Production & Financial Summary*

Year	Overburden Stripped (yd^3) (1)	Tin Drift Stripped (yd^3)	Tin Oxide (t)	Tin Price (£)	Revenue (£)	Net Profit (£)	Dividend Payments
1902-04	1,612,400	552,600	961	121-129	105,024	c. 2,000	–
1905	551,000	481,300	971	150	96,236	57,626	£22,500 (1 x 9d)
1906	519,300	616,000	1,408	185	168,123	128,557	£112,500 (5 x 9d)
1907	449,800 R – 41,000	664,600	1,414	166	151,222	109,219	£90,000 (4 x 9d)
1908	97,300 R – 466,800	539,300	1,395	133	121,814	72,886	£60,000 (4 x 6d)
1909	88,500 R – 468,700	309,750	1,100	138	105,953	45,969	£15,000 (1 x 6d)
1910	R – 219,000	458,000	966	161	87,238	32,125	(£30,000) (2 x 6d)
Total 1905-10	1,705,900 R – 1,195,500	3,068,950	7,254	–	£730,586	£446,382	£330,000

Notes: 1) Overburden: combined total for Briseis & New Brothers' Home leases,
R = Ringarooma Lease 4215 in addition to leases south of Ringarooma River.

Manager Clark demonstrated considerable foresight in pursuing purchase of Lease 4215 of the failed Ringarooma Tin Mines Ltd on the north bank of the Ringarooma River, to access an extension of the Cascade Lead.[122] Tenders for the mining lease and water rights were requested in October 1904, Briseis Ltd purchasing the lease titles for £5,000 in May 1906.[123] Following exploratory drilling, the leases were transferred five months later as Consolidated Lease 5303-93M together with the water rights to 11 SH from Main Creek (Fig. 2).[124] Plans to convey water for hydraulic sluicing across the River from the Ringarooma headrace had been finalised by April 1907 when an application for a pipeline easement was lodged, with construction of a syphon underway three months later.[125] This consisted of a 29in diameter pipe some 3,400ft long that was conveyed across the Ringarooma River by means of a 300ft long timber bridge, enabling overburden stripping to commence at the end of the year.[126] Consultant Currie estimated that some 3.35Myd^3 million cubic yards of overburden overlaid a bonanza of some 6.45Myd^3 of tin deposits – an overall attractive stripping ratio of 0.5:1, but considerable expenditure was required before the tin deposits were exposed.[127] Initial progress with the monumental task of overburden stripping must have been disappointing, as in March 1908 pipes arrived for a second 'Pressure column … will be used for bringing over the

Cascade supply of water, which will give about 100ft more pressure than that obtained from the Ringarooma race'. This required the intake point on the Cascade River for water rights 16 & 76 to be further elevated and a new headrace constructed, thus forming a new high-level water supply (Fig. 2). Two giant nozzles were operational three months later.[128]

The Ringarooma Lease was also capped with variably weathered basalt, presenting considerable problems for removal due to the lack of a suitable water supply at high elevation on the north bank of the River. Previous mining ventures resorted to a headrace from the Main Creek that was piped across the Ringarooma River (Fig. 2). This was re-instated in mid-1907 to strip the top 50ft of overburden 'which contains most of the basaltic stones' up to 0.5-1 ton in size.[129] Considerable improvisation was required to dispose of the fragmented rock:

> To facilitate the falling of the lower layer of basalt a new tunnel tailrace was brought in at a lower level, which allowed of rather steeper races being employed. As most of our dumping area below this face has been used, it became necessary to raise the major portion of the stone … A belt conveyor driven by pelton wheel was installed.[130]

Although the new flumed tailraces were lined with steel plates to prevent damage from scouring, 11% of the overburden comprised larger blocks that had to be removed by a tramway. It took three years of unproductive work (until May 1911) to remove about 1,278,500yds^3 of overburden before the low grade upper tin deposits were reached.[131] By the end of the year, the figure had risen to 1.5Myd^3 at a total cost of £38,000.[132] On the south bank of the River, tin deposits from the NBH1 Co. and southern Briseis leases were exhausted by August 1910 when production concentrated on the northern portion of the former Briseis Hill and beneath the river flats of the former Krushka Brothers Lease 316.[133] In accordance with the agreement of May 1903, the NBH1 Co. lease was transferred to Briseis Ltd for £50 and the company wound up.[134]

Conclusion

When completed, the quantity of water supplied by the Briseis water scheme was exceeded in Tasmania only by the pioneering Cataract Gorge hydro-electric plant that powered Launceston.[135] The Ringarooma headrace was comparable in terms of supply volume with the water supply to the Central Goldfields of Victoria (the Coliban scheme) that was funded by the state government.[136] Public water supply schemes for Melbourne and Sydney developed during the 1880s and 1890s were also based on gravitational systems incorporating canals and tunnelled aqueducts of considerable length to transfer water into storage reservoirs.[137]While the public water supply schemes of Victoria and NSW continue to operate largely as originally designed, the Briseis scheme did not outlast the cessation of tin mining, being abandoned in 1960.[138]

Based on inadequate rainfall data and lacking an accurate estimate of the catchment area, it was believed that that the summer water supply from the Ringarooma headrace would not fall below 13Mgal/day (60% of design capacity). Although this figure was disproved within 7-8 years of the race being commissioned, the water supply system

enabled some 4.5Myd^3 of overburden to be stripped by 1910, and 3.5Myd^3 of tin deposits to be processed for an output of 8,200t of tin oxide (Table 1).[139]

Despite a high construction cost of about £67,000, the Ringarooma-Maurice headrace compares favourably with other significant water supply races in northeast Tasmania (Table 2), all of the examples quoted operating without the benefit of storage reservoirs to conserve supplies. When mining costs for 1909 were reviewed it was found that maintenance and repairs of the Ringarooma headrace formed just 7% of the annual operating cost, facilitating a cumulative profit of £446,000 by the end of 1910 (Table 1).[140] This funded the payment of dividends totalling 11s for each £1 share by the end of the year at a cost of £330,000 (excluding taxes). The New Brothers' Home No. 1 Co. shareholders received a greater benefit from the agreement for The Briseis Tin Mines Ltd to mine the tin deposits on their lease, a total of £53,500 distributed to shareholders during the same time period, equating to 17s 10d per share.[141] Based on economic considerations the water supply system was an outstanding success – a premium investment that enabled the high costs associated with the construction of a storage reservoir to be deferred. The route alignment continues to be shown on the TASMAP 1:25,000 topographic map sheets enabling the skills of the field surveyor, without recourse to present day aerial photogrammetric techniques, to be appreciated.[142]

Table 2: *Comparison of Significant Tasmanian Water Supply Races*

Water Race	Date Constructed	Length (miles)	No. SH	Cost Comparison (£)		
				Total	Per mile	Per SH per ml
Mt Cameron (State Government)	2/1889-8/1890	21.4	50	18,500	865	17.3
Anchor TM	5/1900-5/1902	26.7	10	14,335	537	54
Briseis TM: Ringarooma	1/1901-4/1902	19.5	110	c. 60,000	c. 3,077	c. 28
Briseis TM: Cascade	2/1901-8/1901	2.5	90	c. 3,000 (2)	c. 1,200	c. 13.3
Briseis TM: Maurice	11/1901-8/1902	10.45	30 (1)	c. 6,000	c. 574	c. 19
			40	c. 6,000	c. 574	c. 14

Notes:
(1) Originally designed with 50% having a capacity of 50 SH and the remainder 75 SH. Initial WR 484-93W dated 1 April 1901 allocated 30 SH, increased to 40 SH by addition of WR 107W dated 1 July 1903.
(2) Estimate based on contemporary costs of flumed races.

Appendix 1: *Summary of Principal Water Rights 1900 to 1910*

WR No.(1)	Source	Application Date (2)	Lease Date	No. SH(3)	Notes
Briseis Tin Mines Ltd					
16 + 76	Cascade River		(1/9/1883)	80	Cascade Water Trust
491-93W		23/2/1900	1/6/1900	10	Extension of original WR 76
			TOTAL	90	
256-93W	Ringarooma R	23/9/1898	1/10/1900	30	
355-93W	Maurice River	31/5/1899	Refused	30	
376-93W	Ringarooma R	11/7/1899	1/10/1900	40	Surrendered 30/6/1903, see WR 107W & 108W
482-93W		2/2/1900	Refused	8	
484-93W	Maurice River	7/2/1900	1/4/1901	30	
107W		24/12/1902	1/7/1903	10	
108W	Ringarooma R	24/12/1902	1/7/1903	30	
			TOTAL	100	
609-93W	Main Creek	21/12/1900	1/6/1901	10	
111W		(24/12/1897)	1/5/1903	4	Shift intake of WR 254-91W
113W		(22/6/1898)	1/5/1903	2	Shift intake of WR 144-93W
38-93W		(22/10/1894)	24/10/1906	10	From Ringarooma TM Ltd
211-93W		(21/12/1897)	24/10/1906	1	As above
			TOTAL	27	
New Brothers' Home No. 1 Co.					Transfer to BTM Ltd:
265-93W	Ringarooma R	10/11/1898	1/10/1900	15	6/4/1904 as 224W
364-93W		26/6/1899	1/10/1900	10	6/4/1904 as 225W & 226W
			TOTAL	25	

Notes:

(1) Register of water right applications (TAHO MIN120/1/1, MIN90/1/3 and AC39/1/1).

(2) Dates in brackets indicate transfer date of pre-existing water right to Briseis TM Ltd.

(3) Flow Rate measured in Sluice Heads, where 1 SH (Tasmanian) = 24 cubic feet/min, equivalent to 0.68 m^3/min or 41,000 L/hr.

Endnotes

[1] K. Preston, 'Underground mining of alluvial tin leads in Tasmania: a desperate measure', *Journal of Australasian Mining History*, vol. 16, October 2018, pp. 153-54.
[2] K. Preston, 'Development of Tasmanian water right legislation 1877-1885: a tortuous process', *Journal of Australasian Mining History*, vol. 15, October 2017, pp. 130-32.
[3] Preston, 'Underground mining of alluvial tin leads in Tasmania: a desperate measure', p. 163: Krushka Brothers production to December 1899 exceeded 4000t forming more than half of the total output from the Cascade Lead; see J. Beswick, *Brothers' Home – the story of Derby, Tasmania*, pp. 41-44 for details of the Krushka Brothers.
[4] Preston, 'Development of Tasmanian water right legislation 1877-1885,…', pp. 130-32: Cascade Water Trust formed in March 1887 to share 80 SH [sluice-heads] from Water Rights 16 & 76.
[6] 'Registers of applications for water rights', MIN90/1/3 - application for 10 SH as WR 104-93W granted 1 January 1899; transfer to Briseis TM Ltd as WR 491-93W, 1st June 1900, *Tasmanian Archives & Heritage Office* [hereafter *TAHO*].
[7] 'Register of applications of water rights from the Derby Office', AC39/1/1: WR 133W for 2 SH and WR 194W for 3 SH transferred 24 February 1900; MIN90/1/2 - WR 254-91W for 4 SH transferred 24 December 1897; WR 144-93W for 2 SH transferred 22 June 1898; WR 236-93W for 7 SH granted 1 July 1899, *TAHO*.
[8] *The Argus*, 9 June 1898, p. 7; *ibid*., 17 November 1898, p. 10; J.H. Smith, 'Report on the Alluvial Tin Mines at Derby', *Mineral Resources Tasmania* [hereafter *MRT*] OS141, 1 May 1899, p. 5.
[9] *Ibid*., 29 June 1899, p. 7; *Launceston Examiner*, 29 July 1899, p. 7; *ibid*., 21 September 1899, p. 2; *ibid*., 23 October 1899, p. 2; *ibid*., 15 December 1899, p. 8.
[10] *Launceston Examiner,* 30 March 1897, p. 2: first dividend of 6d paid; *ibid*., 3 May 1897, p. 3: further 6d dividend.
[11] MIN90/1/3 - application for 10 SH as WR 609-93W granted 1 June 1901, *TAHO.*
[12] *Daily Telegraph*, 29 January 1889, p. 3; *ibid*., 17 April 1889, p. 3.
[13] *Launceston Examiner*, 28 September 1889, p. 2; *ibid*., 8 January 1890, p. 2; *Daily Telegraph*, 7 November 1889, p. 3; *MRT* OS141, p. 5.
[14] MIN90/1/3 - application for 30 SH as WR 256-93W, 23 September 1898.
[15] MIN90/1/3 - application for 10 SH as WR 265-93W, 10 November 1898.
[16] MIN90/1/3 - application for 10 SH as WR 364-93W, 26 September 1899; *Launceston Examiner,* 13 July 1899, p. 8.
[17] *Launceston Examiner,* 19 May 1899, p. 3; *ibid*., 17 August 1899, p. 9.
[18] During the 1880s the term *tin drift* was widely adopted in Tasmania when referring to alluvial tin deposits, supplanting *washdirt* that was a term associated with alluvial gold mining. See for example *MRT* OS141.
[19] *1893 Mining Act* (57 Vict. No. 24) s.76-78, 14 November 1893.
[20] *Launceston Examiner,* 19 April 1890, p. 4: NBH1 Co. registered with a nominal capital of £60,000; *Cyclopedia of Tasmania*, vol. 1, 1900, p. 509: approximately 70% of nominal capital expended.
[21] *Ibid*., 17 March 1899, p. 3: £2,000 paid for a six-month option from 12th March, a further £1,000 for a three month extension; see G. Blainey, *The Peaks of Lyell*, (St. David's Park Publishing, Hobart, 1993, p. 103, for the source of Bertie Langford's wealth and mining influence.
[22] *Ibid*., 23 March 1899, p. 2; *ibid*., 31 March 1899, p. 3.
[23] *Ibid*., 25 April 1899, p. 2: Briseis board of directors comprised Joseph M. Pratt MLC, William L. Baillieu MLC, Theodore Fink MLA, Thomas Luxton (stockbroker & mining speculator), R.S. Whiting, Arthur T. Robb (of A.T. Robb & Co) & William Allan (pastoralist and politician); see *Australian Dictionary of Biography* for details of Allan, Baillieu & Luxton.
[24] *The Argus*, 21 December 1899, p. 9: the 60,000 shares each earning a payout of £2-10s per share.
[25] *Launceston Examiner,* 18 December 1899, p. 2; see www.victorheritagesociety.com/stratton's-independence-mine.html for the connection between The Venture Corporation and the Stratton Independence Mine of Colorado.
[26] *The Examiner*, 4 January 1900, p. 2; *ibid*., 11 April 1900, p. 3; *ibid*., 8 February 1901, p. 4; *Australian Mining Standard* [hereafter *AMS*], 10 May 1900, p. 431.
[27] *The Argus*, 5 December 1899, p. 9: working capital stated as £55,000; *ibid*., 29 April 1902, p. 8: Krushka Brothers paid £35,000; *The Examiner*, 4 January 1900, p. 2: working capital £90,000.
[28] *The Mercury*, 21 December 1899, p. 4; *The Argus*, 18 January 1900, p. 7.
[29] *The Examiner,* 10 January 1900, p. 3; *ibid*., 28 July 1900, p. 7; *Daily Telegraph*, 5 July 1900, p. 3.
[30] *Ibid*., 26 September 1900, p. 3; *ibid*., 4 October 1900, p. 2.
[31] *The Mercury*, 21 December 1899, p. 4: mine manager Campbell appointed December 1898.
[32] *The Examiner*, 15 May 1900, p. 2.
[33] *AMS,* 10 May 1900, p. 431.

[34] *The Argus*, 3 February 1900, p. 15; *Daily Telegraph*, 26 February 1900, p. 4.
[35] *The Examiner,* 15 May 1900, p. 2: tunnel contract period of nine months at £4-12s per foot – approximate cost of some £3,850 for the 836ft drive.
[36] *The Argus*, 3 February 1900, p. 15; *Daily Telegraph*, 6 March 1900, p. 4; *The Examiner,* 24 May 1900, p. 2; *ibid*., 14 December 1900, p. 2.
[37] *Ibid*., 19 March 1900, p. 3; *ibid.,* 5 April 1900, p. 2.
[38] *Ibid.,* 11 April 1900, p. 3.
[39] *Ibid*., 14 December 1900, p. 8.
[40] K.L. Rahbek, 'Inspection of the Ringarooma River from Branxholm to Boobyalla'*, MRT* OS180A, 8 November 1901, pp. 1-2.
[41] *The Examiner,* 24 May 1900, p. 2; *ibid*., 9 June 1900, p. 7; *The Argus*, 31 May 1900, p. 9.
[42] K.L. Rahbek, 'Water Rights, Ringarooma River', *Journals of the House of Assembly*, Tasmania [hereafter *TPP*], vol. 43, no. 62, 25 September 1900.
[43] 'Results of rainfall observations made in Tasmania', *Commonwealth Bureau of Meteorology*, 1936, p. 55: 37-yr mean annual rainfall at Ringarooma of 48.7inches for period 1898-1934; maximum monthly rainfall of 17.2inches in June 1934.
[44] G.J. Burke, 'Ringarooma Water-Race', *TPP*, vol. 6, no. 141, 20 October 1885, p. 4.
[45] K.L. Rahbek, 'Water Rights, Ringarooma River', pp. 3-4.
[46] MIN90/1/3 - 30 SH from the Maurice River WR 484-93W granted 1st April 1902 replacing WR 355-93W that was refused, *TAHO*.
[47] K. Preston, 'Hydraulic Sluicing on the Gladstone Tinfield, Tasmania', *Journal of Australasian Mining History,* vol. 11, October 2013, p. 130.
[48] H.V. Champion, 'The Briseis Water Race', *Proceedings of the Victorian Institute of Engineers*, vol. 4, September 1902, p. 24: adoption of the Valley & Black Creek syphons reduced the length by 3.5miles.
[49] *The Examiner*, 24 May 1900, p. 2.
[50] *Ibid*., 10 April 1900, p. 2.
[51] Champion, 'The Briseis Water Race', p. 37; see *Ararat Chronicle,* 8 January 1918, p. 2 for obituary, graduated M.C.E. at Melbourne University, also Associate Member ICE (London); *The Argus*, 20 May 1896, p. 6: consultant for North Yarra main sewer – 'the first example of subaqueous tunnelling completed in Australia'.
[52] *The Argus*, 3 September 1901, p. 8; *ibid*., 29 April 1902, p. 8.
[53] *The Briseis Tin Mines Ltd*, 'Specification of works in connection with the Construction of a Water-Race from Ringarooma River to The Briseis Tin Mines, Derby, Tasmania', State Library of Tasmania, TL.PQ 622.345BRI; Champion, 'The Briseis Water Race', pp. 44-45.
[54] *The Examiner*, 28 July 1900, p. 7.
[55] *Ibid*., 26 September 1900, p. 3; MIN 90/1/3 - 15 SH as WR 265-93W and 10 SH as WR 364-93W granted 1 October 1900, *TAHO*.
[56] *Launceston Examiner*, 17 August 1899, p. 2; *Hobart Gazette*, 28 February 1901, p. 903; *Argus*, 29 March 1901, p. 8.
[57] *The Examiner*, 30 November 1900, p. 2: Shepherd formerly the Briseis Co. mine manager until the London float; *ibid*., 4 January 1901, p. 2; *The Argus*, 28 December 1900, p. 3.
[58] *The Argus*, 29 March 1901, p. 8; *The Examiner*, 29 March 1901, p. 2.
[59] 'The Progress of the Mineral Industry of Tasmania', MININD 1899-4, 31 December 1899, p. 6: output 4.1t oxide, mining suspended, *MRT*; *The Argus*, 24 July 1901, p. 8: four quarterly calls on shareholders of 1s would raise a maximum of £12,000.
[60] *The Age*, 29 March 1901, p. 8; see Preston, 'Development of Tasmanian water right legislation 1877-1885 …', vol. 15, pp. 130-31, for construction of the first Cascade headrace, WR 76.
[61] *The Examiner*, 30 January 1901, p. 3: 180,000ft sawn required for the fluming; *TPP*, vol. 45, no. 4, 13 September 1901, p. xxxii.
[62] *The Argus*, 9 July 1901, p. 7; *ibid*., 28 August 1901, p. 10; *ibid*., 21 January 1902, p. 8; *The Mercury*, 18 September 1901, p. 6: race trial 3rd July conveyed 100 SH 'without filling it … estimated can carry 120 sluice heads when water is available'.
[63] Preston, 'Development of Tasmanian water right legislation 1877-1885 …', p. 131.
[64] *The Examiner,* 21 June 1901, p. 2; *TPP*, vol. 45, no. 4, 13 September 1901, p. xxxii.
[65] *TPP*, vol. 47, no. 13, 18 September 1902, p. xxxix; MININD1902-4, p. 9, *TAHO*.
[66] *AMS,* 31 January 1901, p. 159; Champion, 'The Briseis Water Race', p. 36.
[67] Champion, 'The Briseis Water Race', p. 36.
[68] *The Argus*, 7 May 1901, p. 3; *The Mercury*, 11 May 1901, p. 4.
[69] *Daily Telegraph,* 8 February 1901, p. 4; *The Examiner,* 23 November 1901, p. 12: total weight of 2,168 plates of 3/16th inch thickness, 390t or 3.6cwt per plate.

[70] *The Argus*, 27 March 1901, p. 10; *ibid*., 20 May 1901, p. 8.
[71] *Daily Telegraph,* 24 July 1901, p. 8.
[72] J.M. Ferguson, *Mephan Ferguson - a biography*, Ferguson, 1992, pp. 17-18; Peter S. Evans, 'Lives of Engineers – Mephan Ferguson', *The Old Machinery Magazine*, No. 202, April-May 2019, pp. 36-42.
[73] D. Beauchamp, 'Lock bar pipe, an Australian invention – a global success', *Proceedings 18th Engineering Heritage Conference*, Newcastle, 2015, p. 101.
[74] *The Examiner,* 25 July 1901, p. 2: dipping bath contained 30t 'Trinidad asphalatum' heated to 400^0 F, this a naturally occurring semi-solid form of petroleum; *AMS*, 22 August 1901, p. 249.
[75] *Ibid.,* 29 November 1901, p. 8; Champion, 'The Briseis Water Race', p. 27: labour for lead joints average 13s per joint.
[76] *The Mercury*, 29 January 1902, p. 4.
[77] Champion, 'The Briseis Water Race', p. 34: the Ringarooma Dam was referred to as a 'settling pond' by Champion for retaining tailings from upstream mining operations but was also intended to maintain a constant flow into the Ringarooma Race.
[78] *The Examiner,* 8 June 1901, p. 6; *ibid*., 23 November 1901, p. 12; Champion, 'The Briseis Water Race', p. 35.
[79] *AMS*, 22 August 1901, p. 249; Champion, 'The Briseis Water Race', pp. 32-33.
[80] MININD1902-2 p. 6, *MRT*; Champion, 'The Briseis Water Race', p. 22.
[81] *Ibid.,* pp. 38-40; D. Fraser, 'Plan of Survey of Water Rights Nos 355-93W & 484-93W, 31 Oct 1900, *MRT*.
[82] *Daily Telegraph,* 2 December 1901, p.2: Cecil Hawley AMICE (London) appointed General Manager; *The Examiner,* 28August 1902, p. 2: Melbourne directors comprised Bowes Kelly (replacement for William Allan who died October 1901), Lindsey Tulloch & Thomas P. Husband; for Bowes Kelly see *Australian Dictionary of Biography*, also Blainey, *The Peaks of Lyell*, pp. 57-59 & 247-48; for Tulloch see *Daily Telegraph*, 21 September 1918, p. 8.
[83] *The Examiner,* 18 September 1902, p. 3; MIN90/1/3 - application for 30 SH as WR 256-93W from the Ringarooma River dated 23 September 1898, *TAHO*.
[84] *The Argus*, 9 July 1901, p. 7.
[85] *The Examiner,* 23 November 1901, p. 12; *Daily Telegraph,* 20 August 1902, p. 8.
[86] *TPP*, vol. 47, no. 13, 18 September 1902, p. xlii.
[87] *Daily Telegraph,* 20 August 1902, p. 8.
[88] *Hobart Gazette*, 28 October 1902, p. 2196.
[89] Monthly production figures published in *The Examiner*.
[90] *Daily Telegraph,* 29 June 1903, p. 6; *Hobart Gazette*, 4 August 1903, p. 1996.
[91] *The Mercury*, 2 December 1901, p. 5; *Daily Telegraph*, 8 July 1903, p. 8; *AMS*, 9 July 1903, p. 42.
[92]*The Examiner,* 4 May 1903, p. 2.
[93] *Ibid.,* 18 June 1903, p. 8.
[94] *The Argus*, 6 April 1891, p. 7: Clark awarded M.C.E. at Melbourne University; *ibid*., 1 November 1902, p. 18; *The Examiner,* 21 May 1903, p. 2.
[95] *The Argus*, 18 June 1903, p. 8.
[96] Monthly production figures published in *The Examiner*.
[97] *TPP*, vol. 47, no. 13, 18 September 1902, p. xxxix.
[98] 'Report of the Secretary for Mines', AR1909, p. 57, *MRT*.
[99] *Commonwealth Bureau of Meteorology*, 1936, p. 55.
[100] *The Examiner,* 26 June 1903, p. 2; *ibid*., 20 July 1903, p. 2; *ibid*., 24 August 1903, p. 2.
[101] *Ibid.,* 3 August 1903, p. 2; Monthly production figures published in *The Examiner*.
[102] *The Argus*, 18 June 1903, p. 8.
[103] J.B. Lewis, 'The New Brothers' Home TM Co, Derby', *TPP*, vol. 49, no. 17, August 1903, p. xxxix.
[104] *The Examiner,* 31 December 1902, p. 6.
[105] E. Edwards, 'Notes on Tin Sluicing', *Transactions Australasian Institute Mining Engineers*, vol. xv, 1911, p. 283.
[106] *The Argus*, 26 August 1903, p. 10; *Zeehan Dundas Herald*, 24 September 1903, p. 4.
[107] *Daily Telegraph,* 22 November 1905, p. 3; *ibid*., 20 October 1910, p. 4: Gregory left for Victoria.
[108] *Commonwealth Bureau of Meteorology,* p. 55: combined January-February rainfall of 12.9inches, February rainfall 3.8 times the 37-year mean.
[109] *TPP*, vol. 47, no. 13, 18 September 1902, p. xlii.
[110] *The Examiner,* 7 March 1904, p. 2; *Daily Telegraph*, 27 February 1904, p. 5.
[111] *Daily Telegraph,* 16 March 1904, p. 8; *The Examiner,* 28 March 1904, p. 2; *ibid*., 27 September 1904, p. 2: alternative tin deposits worked at 'extreme south of old workings'.
[112] *The Argus*, 28 October 1904, p. 10.

[113] *Daily Telegraph,* 19 September 1905, p. 6; *ibid*., 26 September 1905, p. 6.
[114] *Ibid*., 1 February 1906, p. 2; MININD1906-1, p. 6, *MRT*.
[115] *Ibid*., 6 October 1903, p. 3; *The Examiner,* 7 October 1903, p. 3.
[116] Mines Department AR1904, September 1905, pp. 55-57, *MRT*.
[117] *Daily Telegraph,* 5 July 1906, p. 2.
[118] Monthly production figures published in *The Examiner*.
[119] *Commonwealth Bureau of Meteorology*, p. 55; Monthly production figures published in *The Examiner*.
[120] *Daily Telegraph,* 27 June 1906, p. 8; MININD1902-2, p. 6: lighting plant installed driven by 36inch pelton wheel, *MRT*.
[121] *Ibid*., 7 June 1906, p. 2; *ibid*., 28 June 1906, p. 2.
[122] *Ibid*., 8 June 1908, p. 2; Keith Preston, 'Tailings disposal at the Arba Mine: A legislative nightmare', *Journal of Australasian Mining History*, vol. 16, pp. 161-62.
[123] *The Examiner,* 12 October 1904, p. 7; *ibid*., 4 May 1906, p. 2; *Daily Telegraph*, 3 July 1907, p. 2.
[124] 'Registrations of applications for mineral leases', MIN83/1/15, transfer to Briseis TM Ltd as Lease 5303-93M dated 24 October 1906; further transfer to Briseis Tin & General Mining Co. Ltd as Lease 4215M dated 24 November 1910, *TAHO*; MIN90/1/3 - transfer 10 SH as WR 38-93W, 24 October 1906, *TAHO*.
[125] MIN90/1/3, Briseis Tin Mines Ltd application for a 1,980ft long pipeline easement as WR 756W, 11 April 1907, *TAHO*; *Daily Telegraph*, 26 July 1907, p. 2.
[126] *The Examiner*, 24 October 1907, p. 2; *Daily Telegraph*, 11 December 1907, p. 2; MININD1907-4, p. 10, *MRT*.
[127] *Daily Telegraph,* 8 June 1908, p. 2.
[128] *Ibid*., 25 March 1908, p. 2; *ibid*., 8 June 1908, p. 2.
[129] *Ibid*., 9 April 1907, p. 2: replacement syphon across the Ringarooma River required due to flood damage; *ibid*., 5 May 1909, p. 2.
[130] *The Examiner,* 28 December 1910, p. 2.
[131] *Ibid.,* 13 June 1911, p. 2: 10,000yds^3 upper drift sluiced; *ibid*., 20 July 1911, p. 2.
[132] *Ibid*., 24 May 1912, p. 2: 1,525,500yds^3 stripped at an average cost of 6d per cubic yard, equating to £38,074.
[133] *Daily Telegraph,* 4 August 1910, p. 2.
[134] *Ibid*., 4 May 1903, p. 6; *ibid*., 17 September 1910, p. 4.
[135] K.L. Murray, 'Electric lighting of Launceston, Tasmania', *Papers Victorian Institution of Engineers*, vol. 2, 1897, pp. 7-8: the 921 yard long water supply tunnel from the South Esk River had a design capacity of 10,000 cubic ft per minute or 90 million gallons per day (417 sluice-heads).
[136] *The Argus*, 7 August 1875, p. 4: the Coliban Main Channel supplied 20 million gallons per day to Castlemaine, Ballarat and Bendigo by November 1877.
[137] W.V. Aird, *The Water Supply, Sewerage and Drainage of Sydney*, 1961, pp. 263-267: the Upper Nepean Scheme completed in 1888 conveyed 50 million gallons per day from the Nepean and Cataract Rivers to the Prospect Reservoir via 33 miles of stone and concrete lined channels and 11.7 miles of tunnelled aqueducts; C.E. Oliver, 'Presidential Address: Description of the Works of the Melbourne and Metropolitan Board', *The Varsity Engineer*, Melbourne University Engineering Society, vol. 10, April 1916, pp 8-25.
[138] Mines Department AR 1960, p. 11, *MRT*.
[139] *The Examiner,* 17 March 1909, p. 2; *ibid*., 21 March 1910, p. 2; *ibid*., 19 May 1910, p. 2: Ringarooma Race flow rate reduced to average 9.3-10.9 million gallons per day in February 1909 & February-April 1910.
[140] *Ibid*., 17 December 1910, p. 3: mining cost of £12.235 per ton, headrace maintenance 0.88d per ton.
[141] MININD1905-1 to 1910-2: details of dividend payments, *MRT.*
[142] *TASMAP* Derby Sheet 5644, Edition 2, 2011; *ibid*., Ringarooma Sheet 5643, 1982.