

CONCLUSIONS

The study has investigated I.K. Brunel's working and personal relationship with William Gravatt during the period 1826 to 1841. The research had three objectives: firstly to establish the particular roles of Brunel and Gravatt in the various projects in which they were jointly involved; secondly to examine the circumstances that led to the break-down in their relationship; and thirdly to evaluate evidence relating to aspects of Brunel's leadership qualities. The objectives of this final chapter are to review the body of evidence and to come to objective conclusions.

Under the dangerous and difficult circumstances in which they worked closely together on the Thames Tunnel it was inevitable that Brunel and Gravatt should become close acquaintances; Brunel himself would later say that they had been 'intimate friends.' There are clear signs that Beamish also had an affable rapport with Brunel. On the other hand, the relationship between Gravatt and Beamish became increasingly uneasy. There are no indications that either man gave grounds for complaint in terms of courage or capacity for hard work but Beamish repeatedly found reasons to criticise Gravatt's leadership and management styles, which Beamish characterised as an inability to delegate and a consequential tendency to meddle. However, there was a dramatic change in the mood and group dynamic as a result of the disastrous inundation of the tunnel on 12 January 1828; with it came the earliest strong evidence to have been found that Gravatt's character traits and behaviour had the potential to seriously undermine the relationships between him and his colleagues.

With Brunel and Beamish effectively out of action following the inundation, Gravatt quickly became protective of his privileged position as Marc's only able-bodied technical assistant during the hectic damage-assessment phase. Consequently he was mortified when he supposed Marc had promoted Beamish above him a week after the disaster and he became ever more apprehensive that Marc considered him to be less capable than Beamish. Just at that time Gravatt transferred to the class of 'Ordinary Members' of the ICE, when neither Brunel nor Beamish held any level of ICE membership, so his apprehension is understandable, but it represents an early example of one of the upsetting weaknesses to which Gravatt's obituarist noted he was prone:

Finding himself passed in the race of life by men who did not possess his qualifications, he was led to the inference that they did so, not because they were sounder mechanics than he, but because they were more men of the world.

Based on the evidence within the surviving correspondence, Brunel's conduct towards Gravatt throughout this episode was forthright and essentially supportive, but it is not altogether clear if this signified a genuine friendship and concern or if it was actually a calculated attempt by Brunel to achieve by all available means his stated objective:

... to consider above all, the interests of the Company for which we are now employed and whose interest certainly depends wholly under the guidance of my father upon the aspiration and zeal of all engaged.

Almost certainly it was the former. But whatever the case may have been, Brunel had identified another weakness in Gravatt's character - 'Your pride (which entre nous is your great fault).' Paul Clements' biography of Marc Brunel is the only 'standard work' to have drawn on the correspondence between Brunel and Gravatt during this episode, and Clements effectively made no more than a passing reference to it.¹

Beamish's opinion, that Brunel's incautious 'youthful confidence' was a major contributory factor in precipitating the inundation, is evident in his diary entries and, to a lesser extent, in his biography of Marc. If Brunel himself, and his other colleagues and contemporaries, also held the same view then the evidence has not so far come to light; in fact, Brunel's recollection of the emotion he felt during the inundation, as recorded in his private journal three months after the event, were of excitement, not guilt. Surprisingly, in general the standard works have not raised Beamish's disclosure of Brunel's lack of caution as a point of issue; the exception is Adrian Vaughan, who interpreted it as 'an early example of Brunellian self-deception.'²

Beamish's diary entries indicate that Gravatt became ever more protective and insular during the months between the inundation and the close-down of the tunnel in August 1828. In contrast, Beamish himself fraternised closely with the Brunels, both of whom concurred with his view that Gravatt demonstrated at times a lack of competence or, at least, of professional interest. The opinions of both Marc and Beamish, based on first-hand experience, that Gravatt could neither take instruction easily nor delegate easily, contradict the assertion in Gravatt's ICE obituary which presumably had a eulogistic anecdotal basis: 'The art of engineering men, such as the superior workmen at the Thames Tunnel, [Gravatt] possessed in an eminent degree.' Noticeably and perhaps significantly, Marc was not one of the three distinguished engineers who proposed Gravatt's transfer to full Membership of the ICE in February 1828.

¹ Clements P., *op.cit.*, p.170.

² Vaughan A., *Brunel* (1991), pp.24-25.

There appears to have been little, if any, ill-feeling between Brunel and Gravatt during the period immediately following the shut-down of the tunnel works; they attended meetings together at the ICE and other learned bodies, and they dined with mutual colleagues. Gravatt was one of Beamish's sponsors when he was admitted to the ICE as a Corresponding Member in January 1829, which suggests that Gravatt felt no animosity towards his former perceived rival. Indeed, even in February 1828, while he fumed with indignation at his supposed subordination to Beamish, he had assured Brunel that he had 'no personal feeling against Mr. Beamish but only a true 'lawful' professional regard.'

Gravatt's appointment as Engineer to the Calder & Hebble Navigation in mid-1832 provided him with the opportunity to design his first bridges and to impress the C&HN Directors, and his associates in the Halifax Literary & Philosophical Society and the Royal Society, with his mathematical and technical proficiency. On the other hand, his ineffectual leadership and management skills were once again made evident, and they resulted in his dismissal from the C&HN.

For some time between leaving Halifax, in the second half of 1833, and June 1834 Gravatt was employed by Brunel in 'making Calculations for the Great Western Railway.' This issue has been explored in Appendix 2 of this study, where it is concluded that any 'calculations' carried out by Gravatt during that time probably related to estimates and the design of the alignment, rather than to structural design; but it was at least an indication that Brunel was willing to employ him.

Brunel gave the promoters of the B&ER a highly approving recommendation to Gravatt at the start of the parliamentary survey in October 1835; in the event, Gravatt 'served him well' and the selected line was acclaimed as 'a good line.' However, it is a moot point whether Gravatt could justifiably claim in his letter to the shareholders in 1841, 'I chose the Line myself.' It is evident, and not surprising, that Brunel maintained overall control of the survey and made strategic on-site decisions during its progress – in the case of the alignment over the Blackdowns, for example, he was making decisions quite literally 'on the hoof.' It seems most likely that Brunel settled the strategic parameters – such as the general direction the line would take, where rivers and summits would be crossed, how closely towns were to be approached, the steepest acceptable gradient – and Gravatt was left to fit the line. Fine-tuning the route would have followed after the parliamentary line had been deposited, possibly even after construction had started, so Gravatt could then perhaps justifiably claim he chose the line that was finally

set out. Oddly, in early 1836 Brunel appeared to play down the level of technical expertise necessary to complete a parliamentary survey once the approximate line had been determined. When Thomas Gill, representing the Plymouth & Exeter Railway promoters, asked him to be their Engineer, he replied:

Your Committee does not seem aware that the Selection of the General Line of Country, or what in your Resolution is called the preliminary Survey, is in fact that which principally calls into operation the judgment of the Engineer; the determining afterwards the best of two or more lines which have been selected and surveyed is comparatively easy, and very hardly requires a professional opinion.¹

This conflicts with the statement he made to the Board of the B&ER in August 1840 regarding his attitude to selecting a line of railway:

... in the final examination of the ground & the selection of the line & determination of the works &c. I am not in the habit of trusting anybody.

From the outset of construction the B&ER Directors naturally assumed Brunel would take personal responsibility for all aspects of the project, and it is not surprising that he did keep to himself the major decision-making role. But, bearing in mind the increasing demands on his time that his other major projects were making, it seems reasonable that he would delegate as many as possible of the engineering tasks to Gravatt, if he believed him to be steady and trustworthy. In fact, Gravatt was soon taking a high-profile position; just four months after he officially took up his post as 'Assistant or Resident Engineer' a Bristol newspaper was referring to the 'well-known talents' of 'Mr. Gravatt, the engineer.' By early 1837 there were signs of a common perception spreading that Gravatt was more than merely Brunel's assistant, a misconception that Gravatt did nothing to correct.

The earliest clear indication that all was not well between Brunel and Gravatt can be seen in Brunel's letter of 15 April 1839, written when Hemming asked to be relieved from his contract because of the harsh treatment he claimed he was receiving from Gravatt and his staff. Brunel directed Gravatt to make amends to Hemming and to instil in his assistants a 'kindly feeling' towards the B&ER contractors. There were comparable problems on the GWR around that time, when festering antagonism between the contractor McIntosh and George Frere, the Resident Engineer of the western division of the GWR, led to Brunel criticising Frere in October 1839 for carrying too far his own ideas of what was expected of contractors:

¹ Brunel to Thomas Gill, 2 Feb 1836: BUL PLB 1.

I also fully appreciate the difficulties of your position with works greatly in arrears and tough hard-mouthed horses to drive. Still, if upon going into it with you I should think you much or little in the wrong you must try and alter the course of proceeding, as the only way by which I can prevent a storm brewing, and retaliation being used if we have been wrong, is by making myself thoroughly master of the facts ... If the Contractor turns out to be entirely wrong and his complaints utterly groundless it is still essential both for the interests of the Company and for your future standing with Contractors that there should be no litigation and that any difference should be settled amicably.¹

Gravatt and Frere were long-standing associates of Brunel: he would have appointed them in the knowledge of their faults and foibles. Now they had strayed beyond the limit of their authority as he perceived it and he was reining them in. Having directed Gravatt to make a fresh start with Hemming, Brunel went on to remind him that his powers and duties were less far-reaching than he seemed to believe. There must therefore be 'a return to the more careful observance of the relative position in which we stand.' He quoted examples of the situations in which he expected Gravatt to ask for guidance, stressing that Gravatt should particularly avoid 'advancing opinions [to the Directors] upon new subjects until you have communicated with me.'

The inability of the B&ER Works Committee to control and improve the performance of the contractors, combined with Brunel's pre-occupation with his other major projects and, possibly, the Board's waning confidence in Gravatt's capabilities, led to Charles Fripp's appointment as Managing Director of the B&ER on 10 May 1839. Within two months he found reasons to complain to Brunel about the disrespectful attitude of Gravatt's assistants. Brunel responded candidly by criticising Gravatt and his assistants; he admitted, 'It is exactly the subject which gives me more trouble than even conducting the works: the management of my assistants.' He also gave Fripp a copy of his letter to Gravatt dated 15 April. Fripp would now be aware of Brunel's opinions regarding Gravatt's faults and shortcomings. It may be significant that Gravatt did not attend the foundation-stone ceremony at Somerset Bridge in July 1839; it is highly likely that he would have stayed away from such a public occasion as the result of an understandable sense of humiliation, particularly as Fripp would be present and playing a major role in the ceremony. Despite this, the common misconception about Gravatt's standing in the B&ER was further reinforced in November 1839 when the Somerset County Gazette dubbed him the 'talented Engineer of the Company.'

¹ Brunel to George Frere, 8 Oct 1839: BUL PLB 1.

Towards the end of 1839 Gravatt over-reacted to a reproof for failing to attend a Board meeting, and it seems he expressed concerns to the Board about his perception of their confidence in his abilities. The situation deteriorated to the point where he became so convinced that Badham and some of the Directors were conspiring against him that he asked the Board to dismiss him. The actual cause of the ill feeling is not stated but as far as Brunel was concerned the 'peculiar difficulties and annoyances which you fancy surround & beset you' were imaginary – echoes of Gravatt's tantrums and Brunel's responses following the Thames Tunnel inundation twelve years earlier. Brunel told him he would be committing a 'most unprofessional act' if he insisted that the Board dismiss him. Gravatt withdrew his request. Then, in July 1840 Brunel learnt that Gravatt had disclosed to some Board members his own views and opinions on 'points of great importance' to the B&ER. The nearest Brunel got to identifying the 'points' was in a letter he sent Gravatt on 23 July 1840:

It appears that you entertain views & opinions differing very much from my own on important engineering questions which have been discussed & which have been settled as forming part of the plan of construction of the Bristol & Exeter Railway ... It would appear that you have for some time past imparted these views – these expressions of doubt as to the correctness of my views – privately to others, that you have furnished figures & calculations which you must have known differed from the calculations which I have publicly advanced and ... have asked for no information on a subject on which you are ignorant.

These two incidents raise the issue of Brunel's concept of 'professional' conduct. Brunel was a member of the ICE Council and it could therefore be taken for granted that he would wish to uphold the high standards of behaviour and conduct that had been promoted within the institution since its founding. Angus Buchanan reflected the generally accepted view when he wrote that Brunel:

... attached great importance to the professional status of engineering, and worked throughout his engineering career to maintain what he considered to be 'gentlemanly' standards of professional conduct ... Brunel's insistence on such conduct amongst his team can be demonstrated from a study of his correspondence.¹

From the standpoint of the evidence within his letters, Brunel was clearly dissatisfied with Gravatt's conduct at times. As noted above, in April 1839 he was compelled to tell Gravatt that there must be a 'return to the more careful observance of the relative position in which we stand'. This in itself was no more than a staff management issue,

¹ Buchanan R.A., Brunel, pp.153-154.

but in the same letter he stressed that Gravatt should avoid 'advancing opinions upon new subjects until you have communicated with me,' hinting that not only was he dissatisfied with Gravatt having overstepped his authority but also that he suspected Gravatt was behaving subversively. Some meaningful questions from a shareholder at the March 1840 General Meeting raised further suspicions that Gravatt was up to no good. Now, in July 1840, his suspicions were confirmed. Brunel felt there was 'nothing extraordinary' about Gravatt not sharing his views:

... but that connected as we have been as intimate friends of long standing, acting as my assistant in this concern for 4 or 5 years, constantly at my side when these subjects have been discussed in public or at the board, that you should never have hinted to me that you differed and that I should hear of it now for the first time and indirectly is extraordinary.

In Brunel's eyes, Gravatt's conduct had dropped him from unsatisfactory to unprofessional. Following the Board's unanimous resolution of confidence in Brunel on 25 July 1840, and by implication a censure of Gravatt's unprofessional conduct, Brunel limited Gravatt's duties to completing the line to Bridgwater. He wrote to Gravatt on 4 August:

... in the hope that you will adopt a totally different course in future ... Although I fear that other feelings & particularly a vanity almost incapacitating you from occupying the place of second to any man have been too powerful ... It must be understood for the present, that you give your word that you will neither directly or indirectly, either by your Acts or by the mode of omitting to act, express opinions or raise doubts against me or my views ... and that you will serve me faithfully according to my actions of fidelity – and if you find you cannot or think you ought not to do what I require, you will tell me so.

Gravatt's response is not known. He may have temporarily complied, but by March 1841 he was again overstepping his authority when, without Brunel's knowing, he engaged his pupil, William Cobbe, as an assistant on the B&ER, and misled the other assistants into thinking that he had could dismiss Peniston. Brunel was obliged to remind him 'you are acting as the organ of communication, not as the principal.' Far worse was to come; a few days before the line was due to be opened to Bridgwater Brunel discovered by chance that the Exeter Bridge was in such a dangerous state that he was obliged to order emergency strengthening measures, otherwise 'the bridge would have been in the river.' After 'such a course of deception or concealment, such constant neglect or perversions of my orders,' he dismissed Gravatt in June 1841.

That Brunel and Gravatt disagreed on certain fundamental principles relating to the 'plan of construction' of the B&ER is corroborated by the wording of the Board's unanimous resolution at their meeting on 25 July 1840, after both Brunel and Gravatt had given their points of view:

This Board are desirous of expressing their unshaken confidence in the principles recommended by Mr. Brunel for the construction of the Line and their full reliance on his judgment for the adoption of such measures as he may think necessary under any circumstances for ensuring the prompt & efficient execution of the Works.

Gravatt was reported to have said at the General Meeting in September 1841 that the quarrel between them originated when he urged Brunel to 'make correct estimates.' Certainly the alleged inaccuracy and misleading presentation of Brunel's estimates were the principal issues raised by Gravatt in his letter to the shareholders in September 1841, but his objection to 'fallacious' estimates alone would not be sufficient grounds for Brunel to declare that he held conflicting views on 'important engineering questions.' What, then, were these 'important engineering questions ... which have been settled as forming part of the plan of construction of the Bristol & Exeter Railway,' what were the 'figures & calculations' Gravatt furnished in support of his own views, and what was the subject upon which Gravatt was 'ignorant'?

It seems implausible that the settlement problems encountered during the construction of the B&ER 'Levels' bridges were in any way part of the 'engineering questions.' It is true that the unsuitability of their design was just coming to light, but at the General Meeting in September 1841 Brunel accepted full responsibility for the failures and, more to the point, Gravatt made no mention of the failed bridges either at the General Meeting or in his subsequent letter to the shareholders. The bridges referred to by the Taunton Courier in October 1842 as having been built 'so low that sufficient room was not allowed for the chimneys of the engines to pass through' were a different issue; publicly, Brunel accepted responsibility for the error, but privately he held Gravatt to blame, and Gravatt himself hinted that it was his mistake. However, in July 1840, when Brunel first wrote about the 'important engineering questions,' the disclosure that some bridges had been built too low was still some way in the future in any case.

An issue that was raised by Brunel in July 1840 concerned the state of the permanent way at Uphill. When he had limited Gravatt's duties to completing the line to Bridgwater, 'exclusive of the permanent way,' he told the Directors:

As regards the superintendence of the laying the permanent way, it will not surprise the Directors that I should consider it essential to have some

person whose wishes & opinions are known to be connected with the successful result of his work.

This was written less than two weeks after he had told Gravatt:

I was on the line yesterday and have much to say to you, as there appear to me many grounds of dissatisfaction ... amongst them was the singular state of the proposed piece of permanent way at Uphill.

Is there a hint here that Gravatt disagreed with Brunel's views on forming the permanent way? No other evidence to that effect has been found; indeed, in his letter to the shareholders Gravatt quoted without adverse comment the Board's stated intention to adopt whatever mode of construction was adopted by the GWR. In the event, the GWR Directors resolved on 9 January 1839 to retain the broad gauge but they also abandoned Brunel's original 'system' of piled permanent way in favour of larger timbers and a heavier rail.¹ Presumably the B&ER Board quickly adopted the same 'system', and it would be a long-established 'principle' by July 1840.

Another issue was raised in the Bristol Mercury report of the September 1841 General Meeting, which had Gravatt saying:

What right had Mr. Brunel, who had made so many mistakes both as to estimated cost and the calculations as to the gradients, to attack his character because he also may have made a mistake?

What were these 'mistakes' relating to 'the calculations as to the gradients'? The Board had resolved in September 1839 to steepen the gradients at Ashton, ostensibly on the basis of a report prepared by Brunel with Gravatt's assistance; but no evidence has been found to suggest that there were mistakes in whatever calculations were included in the report. However, it is possible that the Bristol Mercury reporter wrote 'gradients' in place of 'slopes' or 'batters,' meaning side-slopes in the cuttings, in which case Gravatt's statement would make better sense, as he claimed that he set out the side-slopes much flatter than Brunel had allowed for. Gravatt did criticise Brunel's deceptive presentation of the financial implications of altering the gradients, in the case where Brunel claimed he was justified in flattening the gradients because of the savings in the costs of working the line. The gradients had in fact been steepened; according to Gravatt, in one case from 12ft. in a mile (1 in 440) to 26ft. 5ins. in a mile (1 in 200):

And according to Mr. Brunel's own Report dated December 13th, 1838, an engine that could take 100 tons up an inclination of 12 feet a mile, would only take 20 tons up an inclination of 26 feet 5 inches a mile, so

¹ Resolution of the GWR Directors, 9 Jan 1839, quoted in Brunel I., op.cit., p.115.

that this would not be the way to make a Line work cheaply, but just the contrary.

The costs of working the line, and the projected traffic figures, would have been major considerations when the Directors were negotiating the terms of a lease with the GWR. Could one or both of these topics be the subject of the disagreement between Brunel and Gravatt? Gravatt was incensed by Fripp's rejection of the original traffic figures, which had been calculated in 1837 and which had never been challenged until Fripp stated in September 1840 that they could not now be supported. Gravatt claimed in his letter to the shareholders that the accuracy of the original estimated gross annual receipts once the line was opened to Taunton were borne out by the actual receipts for the first three months after opening the line to Bridgwater, implying that he felt the lease should not have been agreed with the GWR, or at least not on the terms presented to the shareholders in September 1840. In fact, it would be reasonable to conjecture that Gravatt's stance on both topics – the working costs and the projected traffic figures – matched the three sets of circumstances mentioned by Brunel in his letter of 23 July 1840. Firstly, they could be said to be, or at least relate to, 'important engineering questions ... which had been settled as forming part of the plan of construction of the Bristol & Exeter Railway.' Secondly, it is quite possible that Gravatt could have 'furnished figures & calculations' before July 1840 which he must have known differed from the calculations which Brunel had publicly advanced. And thirdly, Brunel could with some justification accuse Gravatt of being 'ignorant' on both topics. Added to this, Gravatt could rightly say that his quarrel with Brunel originated over the making of 'correct estimates.'

Turning next to Gravatt's claim that he:

... drew up the contracts, and designed all the bridges and culverts ... on the Bristol and Exeter Railway [between Bristol and Taunton] ... and I fixed the number and the situation of them, and saw to their execution; and ... by contriving the peculiar sort of bridges, now known by the name of Flying Bridges, I materially reduced (in some cases I halved) the quantity of masonry throughout the Line ... I got out all the contracts from Bridgwater to Taunton ... and with the exception of No. 3C I set them fairly at work.

There is sufficient evidence, including Gravatt's signature on two of the working drawings, to substantiate his claim to have designed the flying bridges. He could also justifiably claim to have got out the contracts between Bridgwater and Taunton.

However, the 'Levels' bridges and the two major river crossings – Exeter Bridge and Somerset Bridge – are not so straightforward.

At the B&ER General Meeting on 2 September 1841 Brunel admitted his own responsibility for the failure of the 'Levels' bridges, presumably because he had directed, or at least approved Gravatt's proposal, that the bridges should not be piled, despite having previously:

... ascertained that there was a certain thickness of clay, and under that a certain quantity of peat. Considering that the clay would bear the bridges, they were built upon it, but the weight of the embankments caused it to sink.

The peat layer occurs at about Ordnance Datum level and is colloquially known as the 'O.D. peat'.¹ Its presence was common knowledge by the time the B&ER was built, as were the consequential geotechnical difficulties.² It forms a slip plane which is a major factor in the initiation of slumps and collapses in the superincumbent alluvium when subjected to heavy and unequal loading, such as would be applied during the construction of the high approach embankments on the B&ER. The embankments would be of the order of 22ft. high above ground level, but the effective height would be increased considerably by the practice, referred to by Fripp, of building the embankments from material excavated from pits and ditches close alongside the ramps.³

¹ Whittaker A. & Green G.W., Geology of the Country around Weston-super-Mare (1983), p83.

² John Billingsley recorded in 1797 the problems encountered during construction of the King's Sedgemoor Drain:

There were numerous and alarming slides, the repairing of which cost a considerable sum, and there can be no doubt, but something of this kind will happen for years to come; for the substratum, at the depth of sixteen feet, is so soft and morassy, that it gives way to the superincumbent clay, and rises up in the middle of the drain:

Billingsley J., General View of the Agriculture of the County of Somerset (Bath, 1797), p.194. A layer of peat about 1ft. thick was noted at the same depth in 1826 when the B&TC basin at Huntworth was being constructed, and at 15ft. below ground level when Somerset Bridge was being built about 400yds. from the basin: Baker W., 'Geology of Somerset' Proceedings Somerset Archaeological & Natural History Society Vol.1, Part 2 (1851), p.137; Jones W.A., notice, Proceedings Somerset Archaeological & Natural History Society Vol.4 (1853), p.128; Poole G.S., 'On the Recent Geological Changes in Somerset' Proceedings Geological Society Vol.20 (1864), pp.118-120; Anon, 'Report on a General Excursion to South Brent, Brent Knoll and East Brent, 10 July 1868' Proceedings Bristol Naturalists' Society Vol.3, No.6 (July 1868), pp.43-48.

³ Of relevance here is a study undertaken by Malcolm Roy during construction of the M5 motorway across the Somerset Levels in the late 1960s-early 1970s. Extensively-instrumented trial embankments were built in order to assess the accuracy of the stability and settlement calculations. One trial embankment was built up until it failed when it

Brunel's predilection for spread-foundations was well-known:

Mr Brunel seldom employed artificially piled foundations to support masonry. When the ground was soft, he preferred to rely on a large extent of bearing surface, and ensured uniformity of settlement by an accurate distribution of the load.¹

Early on, he had recorded his aversion to wholesale piling when he inspected London Bridge with Beamish in 1831:

Well, the day is not far distant when a good bed of clay will not be pricked to pieces with piles unless in some cases perhaps sheet piling.²

But, given that there was early demonstrable evidence of the unsuitability of their design, it seems extraordinary that construction of the 'Levels' bridges was allowed to continue with no changes to the design.

The foundation design of Somerset Bridge was changed from spread to piled. Gravatt's ICE obituary cited Somerset Bridge as one of his 'boldest and best contrived' works. Despite this, the only primary evidence that has been found to show that he played any part at all in the design and construction of the bridge is a mention of his draft specification for contract 4B in the Board Minutes in May 1838, and the presence of his initials on the contract drawings that were signed in June 1838. Unlike the settlement that occurred at Exeter Bridge, the problems at Somerset Bridge were still some way in the future when Brunel dismissed Gravatt in June 1841 so that even if, as is almost certain, Gravatt played a major role in the design and construction of the bridge, and even if Brunel felt that Gravatt was to blame in some way for the Somerset Bridge fiasco, it was too late for recriminations.

Brunel's letters confirm that Gravatt played a considerable, if ill-fated, part in the final construction phase of Exeter Bridge. There is a strong hint that he also had a hand in its design: having discovered in late May 1841 that the bridge was in 'an alarming condition,' Brunel wrote to Gravatt:

reached a height of 7.9 metres (26ft.): Roy M., 'Predicted and Observed Performance of Motorway Embankments on a Soft Alluvial Clay in Somerset', unpublished University of Surrey M.Phil Thesis, 1975. The results of the trials formed the basis of a programme of measures which enabled the successful construction of embankments up to 8.5 metres (28ft.) high on the approaches to the bridges carrying side-roads over the M5. This was achieved by specifying lightweight fill at selected locations, controlling the rate of deposition, surcharging the embankments to speed up consolidation of the alluvium, and closely monitoring the settlements.

¹ Brunel I., op.cit., p.175.

² BUL DM 1306 II.3.1, Brunel's Private Diary, 1 Oct 1831.

I wish also to see the original sketches of this bridge to which ... I directed you to add something considerable in the thickness of the voussoirs – was that done?

This implies Brunel had directed that amendments be made to 'original sketches' made by Gravatt. I. Brunel laid most of the blame for the settlement problems on the contractor, Bromhead, for 'some imperfect workmanship in the interior masonry of the arch,' possibly exacerbated by 'some unequal yielding of the abutments,' whereas in Brereton's view it was a design issue:

The settlement was mostly due to elastic change of form and compression of the masonry, the curve of pressure being nearer to one edge than the other.¹

Turning now to the Parrett Navigation project, this study has shown that the scheme of improvements that was drawn up in late 1835 owed nothing to the previous navigation proposals that had actually reached the stage where parliamentary plans were deposited. Whitworth's 1769 scheme by-passed the Parrett upstream of Langport by means of a canal, and there appears to have been no intention of improving the Parrett downstream of Langport. The Ilchester Navigation project of the 1790s required no river control works in the Parrett itself. As to William White's 1795 proposals and Josiah Easton's navigable drain scheme of 1809, both included a canal by-passing the Parrett downstream of Langport, and there was no intended improvement upstream of Langport. Rennie's ship canal scheme of 1810 would have by-passed the Parrett completely. None of the drainage schemes in which Broadmead had been involved from 1817 came to fruition and, even if they had, any improvement of the navigation would generally have been incidental; safeguarding the navigation would be the best that could have been expected. But from his experience of these schemes Broadmead realised that the design and construction of the project now being promoted in 1835 required more advanced technical expertise than was locally available. Even though the Tone Conservators took no action on William Armstrong's recommendations, his comprehensive report on the state of the Tone Navigation in 1824 would have demonstrated the advantages of employing an experienced and competent engineer. Indeed, Sir John Palmer Acland, Lord George Cavendish, Walter Long and some of the other riparian owners were convinced that the drainage schemes proposed between 1824 and 1829 would only

¹ Brunel I., op.cit., 175; Brereton R.P., in discussion of: Gaudard J., 'On the Theory and Details of Construction of Metal and Timber Arches' Minutes Proceedings Institution Civil Engineers Vol.31 (1871), p.158.

succeed if they were given 'deep & expensive consideration from men well versed as civil Engineers in practical cases of this kind.' The two local land surveyors who were engaged in drainage and navigation proposals around this time, William Summers and James Warren, apparently never strayed far outside their surveying role, and Philip Ilett, who had so impressed the landowners in the 1820s with his 'good sense and ability', had retired by the mid-1830s. James Green's appointments as technical adviser to the West Moor enclosure project and the Chard Canal Company effectively barred his appointment as Engineer to the Parrett Navigation and, besides, it was at about that time that Green's professional reputation began to wane as serious faults were becoming apparent in some of his other engineering projects.¹ Nevertheless, Broadmead's recommendation that the Parrett Navigation promoters should engage a 'first rate' engineer was turned down and he was directed instead to engage Joseph Jones who turned out to be, at best, only second rate.

Jones' simplistic and poorly thought-out first draft report in November 1835 clearly did not satisfy Broadmead, who substantially altered it. There are strong indications that Jones was retained as the promoters' Engineer principally to give some technical gravitas and credibility to proposals that had been devised, or at least adapted, by Broadmead. Two important concepts that were to play a major part in the fortunes of the PNC originated before Brunel arrived on the scene. The concept of the 'self acting weir' appeared in Jones' earliest report, before Broadmead incorporated his own alterations and additions. In contrast, the earliest mention of the second concept – that of making the land drainage and irrigation independent of the navigation by cutting collateral drains to carry the run-off to a point downstream of the next lock – appeared in the agreement made between Broadmead and Walter Long's agent on 3 December 1835; this was three weeks after Jones' report had been adopted by the promoters and it implies that it was Broadmead, and not Jones, who was responsible for including these drains in the scheme.

Brunel said he visited the Langport area several times between mid-December 1835 and the end of January 1836, accompanied by 'only one principal assistant.' In view of Gravatt's later role in the PNC it seems possible, on the face of it, that Gravatt himself was that 'principal assistant.' However, Gravatt later stated that he had nothing to do with the project before August 1836, in which case Brunel's own involvement in the Parrett Navigation project had ended before Gravatt's began. In the event, Brunel made few

¹ George A.B., *op.cit.*, pp.104-142 *passim*.

alterations to the overall scheme; his most important contribution was to approve the principles already adopted. However, his advice on two particular measures was to have far-reaching and expensive repercussions for the PNC. Firstly, he endorsed and extended the principle of cutting collateral drains wherever practicable. Secondly, he gave his approval to the 'Bridgwater Clauses,' which regulated the times and conditions under which the locks and self-acting floodgates would be operated. Both measures were sound, practical and effective techniques for improving the navigation and for protecting other interests, but in both cases Brunel badly underestimated the scale and expense of the work involved, with very nearly ruinous financial consequences for the PNC. Other than reaffirming his estimates and advising the promoters that Gravatt was 'perfectly competent' to undertake the design of the works, he played no further part after the Bill was passed in July 1836.

Gravatt was engaged by the PNC as 'Engineer to the Company,' although his role was actually that of a consultant brought in whenever the PNC Committee felt that the technical difficulty was beyond the capabilities of their own staff. It was of course inevitable that, for Gravatt, the B&ER should take precedence over the PNC and this must have been clear to Broadmead and the PNC Management Committee when they engaged him. Indeed, in their report to the Annual Meeting in August 1838 the Committee used Gravatt's pre-occupation with 'the greater concern of the Bristol and Exeter Railroad' as some sort of justification for any of the PNC's works that had not been constructed properly or expeditiously.

Gravatt later stressed that he was merely acting upon a scheme that had already been prepared; he had seen none of the designs and estimates on which the parliamentary plan and Bill had been based, and all his own designs were made in accordance with the requirements laid down in the parliamentary plan and the Act. He was not asked to make, so did not make, a complete plan or estimate of the whole works. Instead he made his designs and estimates in a piecemeal way, and he emphasised that it was the PNC Committee who decided the order in which works were to be designed, contracted for and carried out. The PNC's acute financial difficulties, which they discovered at about the time Charles Hodgkinson was engaged as Resident Engineer, were primarily due to the naivety of the proprietors themselves, who later claimed they had been deceived by the estimates of Jones and Brunel. But they never considered asking Gravatt or Hodgkinson to make an estimate of the complete scheme, in which case the enormity of the disparity would have been identified sooner.

Gravatt was one of two signatories to the parliamentary plan that was deposited in November 1836 for extending the navigation up the Yeo by constructing a lock a mile above Load Bridge. This scheme seems to have been at best no more than a half-hearted speculation and at worst one of the devious tactics, employed by Nicholas Broadmead and his brother Philip, which were aimed at taking control of the old Ilchester Navigation Company.¹ The scheme would not have worked effectively, as Broadmead himself later reported that:

The Parrett Navigation Company's locks pound the waters of the Yeo up to and above Bicknell Bridge ... and in an imperfect way the river is always navigable so high up as Load Bridge, but beyond that point is only navigable by means of flood waters after rains.²

In view of the complex river control arrangements that were considered to be necessary in all the eighteenth century proposals for improving the Yeo, one must wonder why Gravatt felt able to sign up to such a simplistic scheme.

Gravatt was certainly accountable for the designs, drawings and specifications for virtually all of the bridges, culverts, locks, flood-gates and other structures; by contrast, the collateral cuts and other earthworks were generally planned and contracted for by the PNC's own staff. The day-to-day management of the construction of all the works was effectively left to the PNC's staff, and Hodgkinson in particular seems to have generally proved himself competent with little or no direct technical support from Gravatt, albeit he had frequent planning discussions with Broadmead. Noticeably, Gravatt was not present when the Stanmoor locks and flood-gates were first tested, or when experiments were made to determine whether sufficient depth of water could be gained between Langport and Stanmoor by operating the paddles in Langport lock, or when the effectiveness of the works along the West Moor canal were tested for the first time at its opening, or when experiments were made to determine the optimum operational criteria for opening and closing the locks and flood-gates. It seems that both Gravatt and the PNC Committee were content to leave the supervision of these seemingly momentous activities to Hodgkinson.

Langport Bridge and most of the West Moor canal bridges are still extant and operational, as is Midelney Bridge although the masonry in the elevations of this bridge has been rebuilt. The river-control structures that were built in the Parrett generally seem

¹ For details of the Broadmeads' attempts to acquire shares in the old company see: Body G. & Gallop R., *op.cit.*, pp.33-34.

² Messrs Gregory & Co. [for Broadmead] to Mr. Rogers, 14 Sep 1843: SRO D/RA 3/3/21, 'Case regarding river Yeo Navigation for the opinion of Mr. Rogers.'

to have operated successfully, at the outset at least, and it is regrettable that no original drawings of them have been found. The lock chambers at Langport and Middelney are still extant; the remains of the last surviving 'self-acting' floodgates or weir, at Langport, were demolished only recently, although they had not operated as originally intended since the early 1870s.¹

The first objective of this study was to establish the particular roles of Brunel and Gravatt in the various projects in which they were jointly involved. In summary, the findings have established that the working relationship between Brunel and Gravatt on both the Thames Tunnel and the B&ER was essentially that of a principal and an assistant, albeit an assistant with pretensions. The scant evidence that has been found relating to the extent of Gravatt's role on the GWR suggests that he acted in a similar subordinate role – firstly preparing estimates in the run up to the first GWR Bill proceedings in 1834, and secondly, in Brunel's words, to 'superintend under me the making the designs and drawings' of works that were subsequently carried out on the GWR, including most of the 'standard' bridges and some of the long-span bridges. By contrast, when it came to designing the Parrett Navigation works Gravatt actually had the chance to be his own man, out of Brunel's shadow although he was working on a project which had been endorsed in principle by Brunel. As a result, the personality clashes and consequent conflicts that arose on the B&ER had no parallels, and thus no direct impact, on the Parrett project.

The study's second objective was to explore the circumstances that led to the break-down in their relationships. In Brunel's view, by July 1840 they disagreed over 'important engineering questions,' whereas Gravatt is reported to have said that the quarrel between them that led to Brunel dismissing him originated when he urged Brunel to 'make correct estimates,' and that his dismissal would not have occurred if the GWR had not now been completed, 'Mr. Brunel now possessing time to attend to the Bristol and Exeter.' On the basis of a review and evaluation of the available evidence it is reasonable to infer that the topics on which they disagreed were the projected traffic figures and the consequential estimated working costs of the line. These were essentially professional differences which may well have contributed towards a breakdown in their professional association, but there were also the underlying stresses within their personal relationship that had existed since the Thames Tunnel days.

¹ Greenfield D.J., 'The Flood-Gates near Langport Lock, River Parrett,' unpublished discussion document (2004).

Gravatt's faults were compensated to a degree by an outstanding mathematical ability which was appreciated by his associates in the Royal Society and at technical discussions at ICE meetings, and which he put to good practical use in developing optical instruments and, later, Scheutz's 'calculation engine.' His low-profile laminated timber bridges on the C&HN showed exceptional mathematical and technical proficiency, if the condensed version of John Waterhouse's description in Gravatt's ICE obituary ICE is to be believed. However, it does not appear that the principle of their design and construction was used again, which suggests that there were disadvantages to its adoption. Brunel exploited Gravatt's talents to design bridges on the GWR and the B&ER – the flying bridges on the B&ER were a manifestly successful innovation and if Gravatt carried out the routine calculations for some long-span bridges on the GWR such as the Maidenhead bridge, as appears probable from the results of the investigation of relevant primary material documented in Appendix 2 to this study, then his contribution to Brunel's engineering reputation was considerable. These points are interesting for two reasons. Firstly, apart from a passing mention in his ICE obituary Gravatt's engagement in the design of GWR bridges does not appear to have been noted before. Secondly, the conclusions apparently contradict the conventional view of Brunel's management style, typified by George Clark who had been an assistant engineer under Frere at the Bristol end of the GWR:

Everything for which [Brunel] was responsible he insisted upon doing for himself. I doubt whether he ever signed a professional report that was not entirely of his own composition; and every structure upon the Great Western, from the smallest culvert up to the Brent viaduct and Maidenhead bridge, was entirely, in all its details, from his own designs.¹

Brunel was prepared not only to exploit Gravatt's talents but also to call him a friend, albeit he did once refer to Gravatt with some justification as:

... a younger friend, whom I had frequently protected & withdrawn, by my advice & assistance, from difficulties into which his temper has betrayed him.

By July 1840 Brunel was aware that Gravatt was acting subversively, but it was another 11 months before he told Gravatt:

I cannot allow old feelings of friendship so entirely to supersede all sense of prudence or duty to others as to induce me [to] continue such a state of things ... you must consider that you cease from this day to be in the service of the Bristol & Exeter Railway Company.

¹ Quoted in Brunel I., *op.cit.*, p.94.

These 'old feelings of friendship' may well have contributed to his reluctance to dismiss Gravatt sooner, but another contributory factor would have been the practical problem of replacing him, during a critical period of the works and at a time when Brunel already had his hands full elsewhere. Now, with the GWR opened and 'Mr. Brunel now possessing time to attend to the Bristol and Exeter,' Gravatt's dismissal was inevitable.

It was not unusual for Brunel to be at odds with other engineers over 'important engineering questions': Angus Buchanan has cited several examples of Brunel quarrelling with, or at least having major differences with, his peers and close colleagues, and has concluded that: 'These professional brushes ... did nothing to bruise their cordial friendship.'¹ Clearly his disagreement with Gravatt was in a different class, with its added dimension of a long and 'intimate' association. Another factor was their relative positions as 'principal and assistant,' which raises the topic of the third objective of this study – aspects of Brunel's leadership qualities which may be gleaned from evidence relating to his relationship with Gravatt. Three facets come to mind.

Firstly, up until April 1839 Brunel permitted Gravatt a degree of autonomy that was some way beyond the restrictive limits that were cited by I. Brunel:

From the complete personal supervision Mr. Brunel sought to maintain over all his works, his assistants had not perhaps so many opportunities of independent action as they might otherwise have obtained.²

Angus Buchanan has justifiably described I. Brunel's work as 'an act of filial piety,'³ in which case a more impartial view is provided by Francis Conder, who added a qualification to his assessment of Brunel's style which may apply in the case of Gravatt; Conder wrote that Brunel's Resident Engineers:

... no more ventured to act without his direct authorization, ad hoc, than did any inspector on the line. Of course there would be differences due to the greater or less distance from town, or the greater or less personal acquaintance with the Chief, possessed by his former pupils, or by any others who held office under him.⁴

Brunel would have appointed Gravatt in the knowledge of his faults and foibles, and presumably on the basis of that knowledge he considered him to be a safe pair of hands.

¹ Buchanan R.A., Brunel, pp. 10, 143, 166-167; BDCE2, p.741.

² Brunel I., op.cit., p.92.

³ Buchanan R.A., Brunel, p.xvii.

⁴ Conder F.R., op.cit., p.118.

Secondly, there is a persistent impression that Brunel's desire to maintain 'complete personal supervision,' denoting an inability to delegate, resulted in his being overwhelmed by all his projects.

Thirdly, there is the intriguing, but currently unresolved, matter of the extent of Charles Fripp's influence on Brunel. Fripp's appointment as Managing Director of the B&ER was a defining moment as he immediately set to work zealously, 'inspecting the Works, superintending the Affairs & constantly communicating with the Board on the General Business of the Company'. Regrettably it has not been possible to clarify to what degree Brunel's engineering decisions were moderated by Fripp's views or, for that matter, whether the appointment of a Managing Director in such a pro-active role was unique to the B&ER.

Evidence in the primary sources has substantiated much of the character assessment in Gravatt's remarkably frank ICE obituary: notably his pride, his social inadequacy and a readiness to resort to subterfuge which, in combination, tended to alienate him from his colleagues and superiors. Indeed, there are all the ingredients of a veiled allusion to the fateful proceedings on the B&ER within a passage in the obituary:

Capable of the warmest and most persistent friendship, Mr. Gravatt was also susceptible of strong resentment. This was, for the most part, based on a perception of wrong, as such, and expressed his strong and clear disapprobation of wrong doing. It was also sometimes tinged with personal feelings, and ... as a natural consequence, it was at such times often unjust ... The art of engineering men ... he possessed in an eminent degree, and had he been endowed with the same faculty when he was brought into contact with men in general and with directors of public companies in particular, he would have attained success in life, in proportion to his capacity in engineering matters.

Intentionally or otherwise, he precipitated his own downfall; in essence, the fundamental cause leading to the failure of his relationship with Brunel was succinctly stated by Gravatt's obituarist: 'He could not, or would not, conform to the ordinary ways of the men among whom his lot was cast.'