The Bridge on the River Kraai

This article follows on the article "Cry the beloved railway" that appeared in the May 2013 edition of *Civil Engineering* (pages 40–45), and which was Highly Commended at the 2013 PiCA Awards in the category Non-Professional Writer of the Year.

Johannes Haarhoff
SAICE Fellow
johannes@haarhoff.org.za

William (Bill) James
Visitor to SAICE
bill@chiwater.com

Colonel Saito: "Do you know what will happen to me if the bridge is not built on time?"
Colonel Nicholson: "I haven't the foggiest."
Colonel Saito: "I'll have to kill myself. What would you do if you were me?"
Colonel Nicholson: "I suppose if I were you... I'd have to kill myself."
Colonel Nicholson (raising the glass of Scotch he previously declined): "Cheers!"
The Bridge on the River Kwai (1957)

INTRODUCTION

Of course, in that other storied bridge they had real men, prisoners of war, physical suffering, a commando raid, a rail bridge finally destroyed, and Alec Guinness.

In our story we also have real men, two earlier serious wars, physical suffering, seven rail bridges at the same spot (five systematically destroyed by floods in just over a year) and, yes, stubborn engineers.

We do note, however, that *their* bridge has become a popular tourist attraction, enriching the local economy, while ours yet languishes in defiant loneliness, snug in the Southern Drakensberg, a place well known to be lovely beyond any singing of it.

But now to our story of a bridge on the branch line from Aliwal North to Barkly East (see *Civil Engineering* May 2013) – railway construction was beset with technical and financial difficulties, which eventually resulted in an unusual, if not unique, set of eight reverses; a completed and never-used 70 m long tunnel; and a major bridge widely (and wildly) rumoured to have been lost at sea by enemy action. One of the delays during the long construction period, the tale of the destruction of rail bridges over the Kraai River by possibly the highest floods in recorded history, well illustrates the importance to small communities of rail access in the 1920s, of the difficulties of infrastructure construction in remote areas at the time, and the risks of inadequate hydrologic and hydraulics methods, then and now.

INITIAL CONSTRUCTION

Immediately on the conclusion of the South African War in May 1902, the Barkly East community stepped up its campaign for a branch line from Aliwal North, culminating in a public meeting on 11 October 1902 and a petition urging the government to construct a light railway from Aliwal North to Barkly East. Results soon followed – on 21 November 1902 Parliament authorised a line from Aliwal North, and thereafter progress was swift. Allan McDonald Campbell, Resident Engineer in charge of construction

of the line, received his instructions on 15 December 1902, and arrived in Aliwal North on 27 December 1902. Eleven short weeks, after petitioning to having parliamentary approval, for the construction engineer to be on site is impressive timing, especially given the slow communications of the day.

Campbell's first task, after close inspection and more surveying of the terrain, was to finalise the way. A number of routes had been suggested earlier by George Schele, who made a "flying survey" in 1899. By 21 January 1903, after less than two weeks on the job, Campbell had outlined the railway which, after a site visit, was supported by the Commissioner of Railways in February 1903, allowing start of a detailed survey. Construction, however, was delayed for two reasons: first, it had to await the "small and inexperienced staff" to complete their survey, and second, there was uncertainty over whether the line should be built to the standard Cape gauge of 3 ft 6 in (we use contemporary units here), or to a narrower gauge of 2 ft – at the time narrow, cheaper lines were being seriously considered for lightly-travelled branch lines. Debated at the highest level for more than a year, the proposed broader gauge, which became the South African standard, finally passed the third reading in the Legislative Council at the start of June 1904, but with no additional money voted for the project to cover the higher costs of the broader gauge (which was one reason why this phase of construction terminated at Lady Grey).

By June 1904 (the surveying and construction teams had been on site for 17 months) the entire line from Aliwal North to Barkly East was staked out, and quantities and estimates for both narrow and standard gauges were completed and submitted. Earthworks for the Aliwal North – Lady Grey section had been prepared for narrow gauge, and the changed gauge now necessitated the widening of cuttings and embankments, which would have to be done in conjunction with track-laying. At this time the Acting Engineer-in-Charge of construction was Arthur A Ashworth, assisted by one District Engineer, two Assistant Engineers and two field assistants. Construction started with 107 labourers, but the labour force increased to an average of 246 during the second half of 1904. Progress was considered to be good, and by the end of 1904, 28 miles (45 km) were completed. On 27 January 1905 the first train travelled the route to Lady Grey, 40 miles (64 km) distant.

Between Aliwal North and Lady Grey the railway line traversed relatively easy terrain, the most significant obstacle being the crossing of the Kraai River about 17 miles (27 km) from Aliwal North (see Figure 1). During construction, a temporary bridge (#1) was erected at a position which cannot

Figure 1: The Kraai River railway crossing at Kraaibrug lies between Aliwal North and Lady Grey, while the first six of the famous reverses (see *Civil Engineering* May 2013) are in the rectangle marked on the right (Map by Bruno Martin, published in *Tracks Across the Veld* by Boonzaaier, 2008, used with permission)

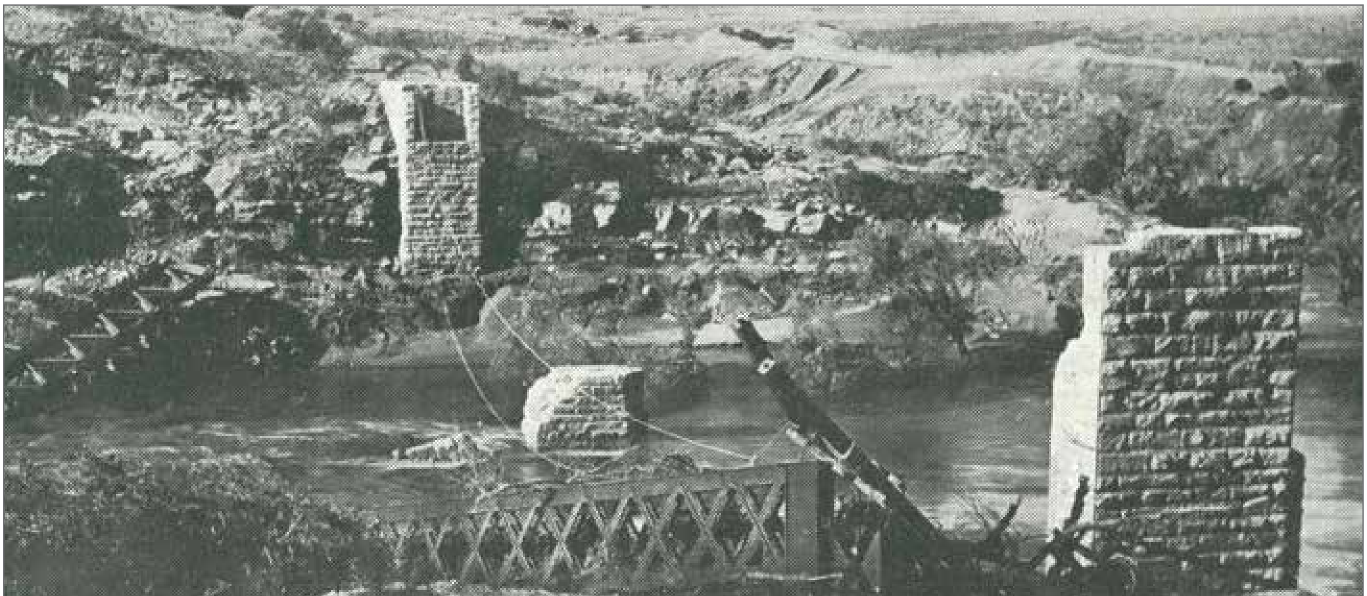

Figure 2: Kraai River Bridge (#2), shortly after being washed away on 23 March 1925, viewed from slightly downstream on the true left bank (*SA Railways and Harbours Magazine*, July 1925)

be confirmed at present, to allow construction trains to pass. Replacement of the temporary bridge by a permanent construction was interrupted by floods, and it was July 1905 before a substantial bridge (#2), consisting of eight spans (one of 100 ft, two of 75 ft and five of 15 ft), with a total length of 350 ft between abutments, was completed. Construction trains were opened for public goods on 19 June 1905, and on 2 November 1905 the line between Aliwal North and Lady Grey was officially opened.

EMERGENCY WORKS OF 1925 AND 1926

For twenty years the Kraai River Bridge served the branch line without problems. However, during March 1925 the catchment area of the Kraai River (roughly centred on Barkly East), and other parts of South Africa, experienced unusually heavy and continuous rains, resulting in historic flood flows. Situated at the downstream end of the river close to its confluence with the Orange River, the bridge was washed away on March 23, as shown in Figure 2. Evidently the river normally carried about

Figure 3: Engineer TCC Logan, the engineer responsible for restoring rail service to New England after the disastrous floods of 1925 in the Kraai River (*SA Railways and Harbours Magazine*, July 1935)

Figure 4: The permanent bridge position is marked yellow, the temporary bridge site red, and the approximate position of the deviation by a dashed line (Google Earth, annotated Johannes Haarhoff)

10 ft of "rather strong running water", but at the flood peak the water rose 5 ft above the top of the piers (the centre of the bridge was 71 ft above the river bed) and inundated the surrounding countryside, now appearing "like an inland sea".

Engineer Logan (Figure 3), responsible for local railway maintenance, was early on the scene of the failure and quickly made key decisions: At what elevation should the temporary bridge and causeway be built? Where should the temporary bridge be built, taking into account acceptable gradients and curvature? It was then the end of March, when seasonal rains tapered off, and rebuilding the main bridge was expected to take a relatively short time. Logan decided

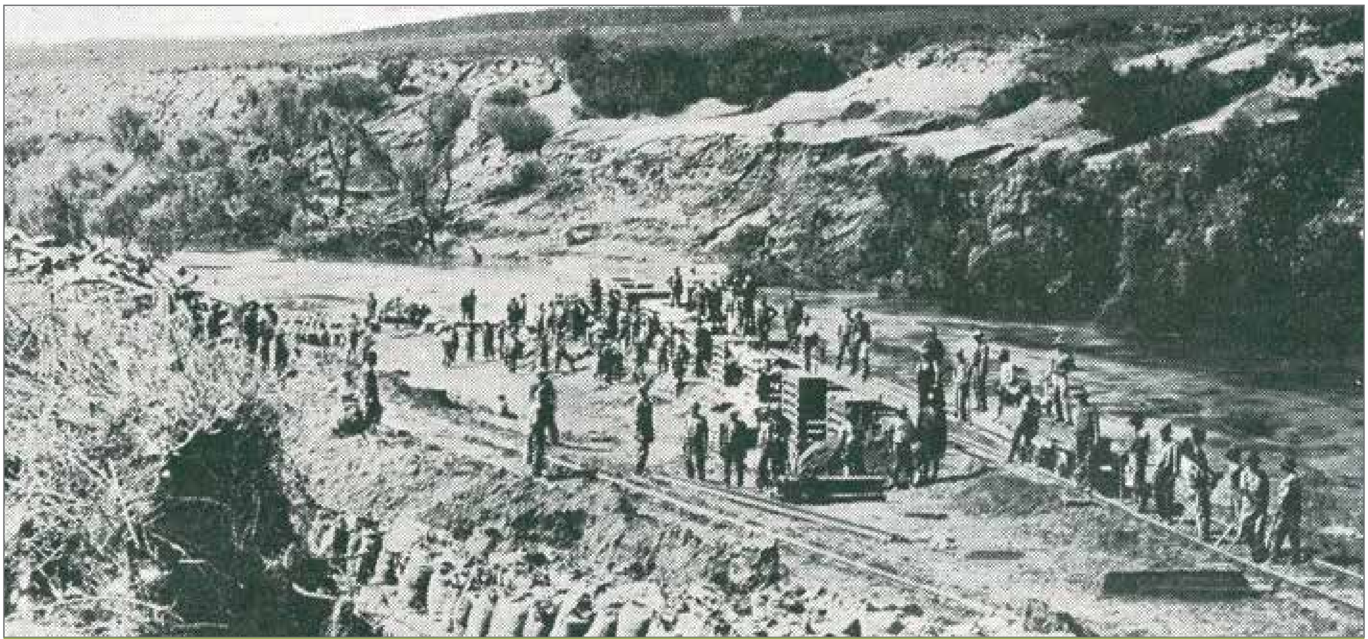

Figure 5: One of the temporary bridges (#3 or #4) being constructed during April 1925 as seen from the left bank (*SA Railways and Harbours Magazine*, July 1925)

to cross the river 275 m upstream of the wrecked bridge, as shown in Figure 4.

Men and materials were hurried to the site, but it was days before the floods subsided sufficiently to allow work to begin. It continued to rain, on and off, day after day, but eventually a 450 ft long temporary bridge was built at the position depicted in Figure 4. Because it was built at a much lower level, it was subject to a higher risk of erosion, and the railway line had to be connected to the bridge at a steep gradient of 1:30 on both sides. Piers were constructed using open timber cribs, stacking railway sleepers in "bird-cage" fashion, perhaps anchored by filling with rock. Track ran from pier to pier to form

Figure 6: Temporary bridge #6, completed 25 June 1925 until washed away early March 1926 (*SA Railways and Harbours Magazine*, August 1926)

Figure 7: The site of temporary bridges #3 to #6 as it appears in 2014, from roughly the same viewpoint as Figure 5 (Photo Bertus Bekker 2014)

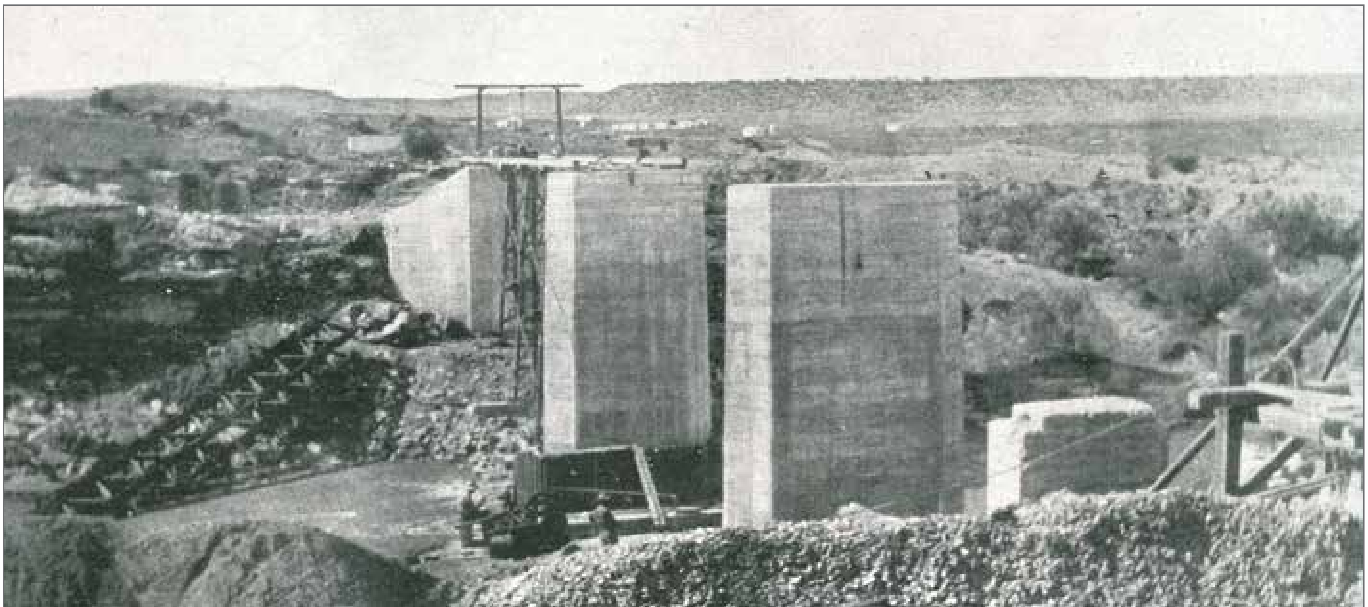

Figure 8: New permanent bridge under construction, 8 May 1926 (*SA Railways and Harbours Magazine*, August 1926)

Figure 9: New permanent bridge shortly before completion, 8 June 1926; view towards Lady Grey (*SA Railways and Harbours Magazine*, August 1926)

a rudimentary bridge deck, evident from Figure 5. Everything was proceeding well and arrangements were made to open the new temporary bridge (#3) on 14 April, but the river level rose again and carried bridge #3 away before the appointed day. A fresh start was made to rebuild another temporary bridge (#4), in dangerous conditions as the river level continued to rise and fall. A new opening date was set for 28 April, but the river rose again and destroyed bridge #4 as well.

Loss of the bridges was costly in materials and time. Nevertheless, because of the urgent needs of dependent communities, Logan made a fresh start, this time using a different approach. Timber cribs, it was now painfully obvious, could not stand up to the strong river current, and a pile driver was hurriedly despatched from East London to the scene of operations, to form sturdier piers on piles driven into the river bed.

Despite the hardships, everything now pointed to a successful resumption of traffic on 29 May, and the first train crossed the temporary bridge (#5) on 28 May. Incredibly, once again the river came down in spate on 30 May and washed away bridge #5 completely, together with all the material, boats and other equipment. Fortunately, two locomotives and a few carriages had safely passed over the bridge during the two days it was in operation. Undeterred, Logan made yet another attempt and finally succeeded with temporary bridge (#6). After a rail interruption of more than three months, and five bridges after the first wash-away, regular service to New England (the terminus at the time) was restored on 25 June.

Adverse hydrology persisted. Less than a year later, at the beginning of March 1926, the temporary bridge (#6) was itself washed away. This is not surprising, as bridge #6 was built at a low level, clearly as a stop-gap measure, while the permanent bridge #7 was rebuilt. Reporting coldly on 5 March 1926, the *Barkly East Reporter* wrote, "As everyone anticipated, the first flood has washed away the temporary railway bridge at Braamspruit." It is not clear when reconstruction of the second permanent bridge (#7) started, but it must have been soon after the completion of bridge #6, in order to exploit the low winter flows ahead of the next flood season. Figure 8, dated 8 May 1926, shows completed bridge piers, suggesting that construction started in 1925. It was completed by 30 July 1926, with the new permanent bridge deck slightly higher than before. Moreover, as seen in Figure 9, trusses were now placed above (a through truss bridge) rather than below the bridge deck (deck truss bridge), as was done on all the earlier bridges.

HYDROLOGICAL REFLECTIONS

Apropos design of the original bridge in 1905 and the replacements in 1925, the quality and quantity of rain and flow data available for waterway design would likely have been sparse, and in any case predated the concept of a "design storm". Contemporary engineering hydrology, if any, would have been a simplistic method like Mulvaney's rational method of 1851, and hydraulics would have been a steady-state application of Manning's (1890) or the Chézy formula (1775).

In fact, the engineers were handicapped not only by primitive engineering design methodology and sparse hydrologic data, but also by exceptional hydrological events – the slings and arrows of outrageous fortune. There were no river gauges on the Kraai at the time; the only nearby gauge, existing since 1920, was sited just downstream of the confluence with the Kraai at Aliwal North on the very much larger Orange River, and therefore of questionable relevance. Tertiary catchment D13 corresponds to the Kraai catchment, practically the same as the watershed for the bridge, as the crossing is only 33 km upstream (17 km in a straight line) of the confluence with the Orange River.

Monthly total flows in millions of cubic metres, from October 1920 to September 2006 (1 020 months or 85 years), were computed and the maximum five are listed in Table 2. Total flow in March 1925 was the highest of all monthly totals, with April 1925 also ranked in the top five. In the entire record, the

Table 1: History of seven bridges at the Kraai River rail crossing

Late 1904	Completion of temporary construction bridge #1	Probably a timber trestle bridge as was customary at the time
July 1905	Completion of permanent bridge #2	Steel trusses below bridge deck over five spans, supported on stone piers
23 March 1925	Permanent bridge #2 washed away	Water level 5 ft above top of piers
14 April 1925	Scheduled opening of temporary bridge #3	Rails placed on piers on timber cribs, but washed away before completion
28 April 1925	Scheduled opening of temporary bridge #4	Rails placed on piers on timber cribs, again washed away before completion
28 May 1925	Temporary bridge #5 completed	Piles driven into the river bed to provide sturdier piers
30 May 1925	Temporary bridge #5 washed away	In operation just long enough to allow locomotives to cross
25 June 1925	Temporary bridge #6 completed	Timber trestle bridge at higher level than previous temporary bridges
Early March 1926	Temporary bridge #6 washed away	See Figure 6 for details, and current remains in Figure 7
30 July 1926	Completion of permanent bridge #7	Three steel trusses above bridge deck, on concrete piers

highest three-month total was from March 1925 to May 1925, precisely when Logan was attempting to restore rail access across the Kraai. Of course, monthly flow totals do not necessarily correlate with peak instantaneous flow rates.

It is locally believed that bridge #2 was washed away because of a dam failure on the neighbouring farm Rietvlei, an event which would certainly have amplified flows at the bridge site. How many other upstream on- and off-channel structures, such as dams and bridges, failed during the extraordinary runoff of March 1925, releasing additional surges, is food for future thought.

Following the disastrous flood of March 1925, Logan probably gambled on smaller floods, if any, it being so close to the end of the rainy season.

Contemporary observations at the bridge site indicate a flow depth of 76 ft, an almost unbelievable rise in water surface elevation (WSEL) of about 66 ft. Figure 2, a photograph clearly taken from the true left bank just downstream of the crossing, confirms the great depth of flow. All four Brown trusses were toppled downstream. Abutment geometry confirms that the structure was indeed a deck truss bridge (trusses below railbed). Unusually, the central bridge pier remained somewhat intact, probably founded on solid rock, but the superstructure took a significant part of the top masonry (perhaps half the pier) with it. Overtopped (by 5 ft), these Brown trusses would have acted quite efficiently as debris traps – trees float near the surface and just below. Hinge supports on the centre span would likely not have been able to resist the high lateral forces induced by the flow on this particular type of truss with its trapped debris, and so the superstructure naturally folded horizontally at the centre towards downstream. Remnants of some of the original pier foundations are visible today, directly below the current bridge deck, as shown in Figure 10.

Obviously the bridge was constructed at a locally narrow part of the river channel, reducing the span and cost (steel had to imported), but the river banks do not appear to be particularly steep-to, so the hydrography downstream might also have contributed to the extraordinary WSEL, as readers might confirm from Google Earth (find: *Kraaibrug, South Africa*). Presumably contemporary backwater calculations would have

Table 2: Naturalised flows for tertiary catchment D13 from October 1920 to September 2006 (from WR2005)

Rank	Highest one-month flow (Mm³)		Highest three-month flow (Mm³)	
1	1047	March 1925	1958	March – May 1925
2	921	March 1975	1612	February – April 1975
3	858	February 1987	1590	January – March 1973
4	715	February 1971	1308	February – April 1987
5	704	April 1925	1120	January – March 1971
Mean	54	1920 – 2006	163	1920 – 2006

Figure 10: Some of the old pier foundation remnants of the first 1905 permanent bridge (#2) are still visible directly below the 1926 permanent bridge (#7) (Photo Bertus Bekker 2014)

Figure 11: An upstream view from the current bridge; notice the remains of the railway bench for the temporary deviation directly to the left of the river (Photo Johannes Haarhoff 2013)

been inaccurate, because even the standard step method, if used, would have been performed manually using slide rules, and the nearest control point, dicey at that, is evidently the confluence of the Orange River, a considerable distance downstream. Figure 11, taken October 2014, tends to confirm that local hydrography could be an issue in computing the flood WSEL, and also supports the contention that debris such as trees would likely have been a significant factor.

Admittedly, the temporary bridges were designed and constructed urgently, at lower elevations and therefore at lower cost, incurring higher risk. Nevertheless, with hindsight, the entire sad experience, namely six bridges in the same spot in little over a year, reminds engineers that the risks of river engineering are indeed high in times and places where local hydraulics and hydrology data are deficient; a lesson that applies equally well today (are you listening, budget officers?).

Of course, these are merely the opinions of the writers, who are professional water engineers. All kinds of alternative interpretations may apply, and various morals and homilies drawn in this endless struggle against the fluviology gods. In lieu of online reader commentary, readers are invited to insert their own personal, potentially legendary epigram here (e.g. *most bridge failures are caused by hydrologic rather than structural loads*) and e-mail them to us.

EFFECTS ON THE BARKLY EAST COMMUNITY

Initially the first wash-away disrupted only the postal services to Barkly East, but by 10 April 1925 there was no proper communication between Aliwal North and Barkly East. Soon, the effects became more serious as roads in the area became impassable because of the incessant rain. Further, at the time of the first wash-away, there were no locomotives or carriages on the Barkly East side of the break. As communities ran low on food and coal, emergency measures were devised, and an aerial cableway erected across the Kraai River at the bridge site. A fleet of dismantled motor trolleys was taken across the river, reassembled on the eastern side, and used to shuttle supplies (mostly coal and mealie meal) to Lady Grey and New England. Passengers crossed the river in a boat at their own risk, while goods were hauled across the river by suspension cable. Political pressure mounted, as Barkly East made "strong representations" to the Minister of Railways to protest their isolation. May month brought more rain, and the mountains were white with snow. Supplies of food, coal and paraffin ran very low in Barkly East, but the trolleys managed to bring a "considerable portion of goods" to the New England area. As shortages in Barkly East grew, a second aerial bridge across the raging river was completed. Temporary bridge #5 was in service just long enough to allow two locomotives and a few carriages to make it over the river by the end of May, which eased the logistics of moving goods to Barkly East.

In March 1926 CA Sephton, the local representative, raised in Parliament the matter of the five destroyed bridges, enquiring after the cost of the four temporary bridges that were washed away. Informed that the total financial loss amounted to £10 121, the local newspaper cried in exasperation: "The whole affair has been a glaring example of how not to do things!" – opportunist criticism that probably would not have been popular if made during the rush to re-establish supplies of staples and communications.

Well, hopefully the local newspaper, like Colonel Nicholson, may still be proven wrong. With luck, as in that famous bridge, leveraging all the stubborn hard work and all the suffering, someone might turn this six-bridges-in-a-year tale of empirical waterway structural hydraulics into a successful book, and even a popular film, starring a modern-day Alec Guinness, perhaps as the resolute engineer. Dreaming on, tourists could then ensue…our long-lived old railway bridge may yet become a famous film set!

May we suggest you visit the area before the crowds descend?

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SOURCES

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