# The Bourke Lock and Weir.

By Mr. A. E. AMPHLETT, B.E., Assoc. M. Inst., C.E.

*(A Paper read before the Sydney University Engineering Society on December 8th, 1897).*

# The Locking of the Darling River.

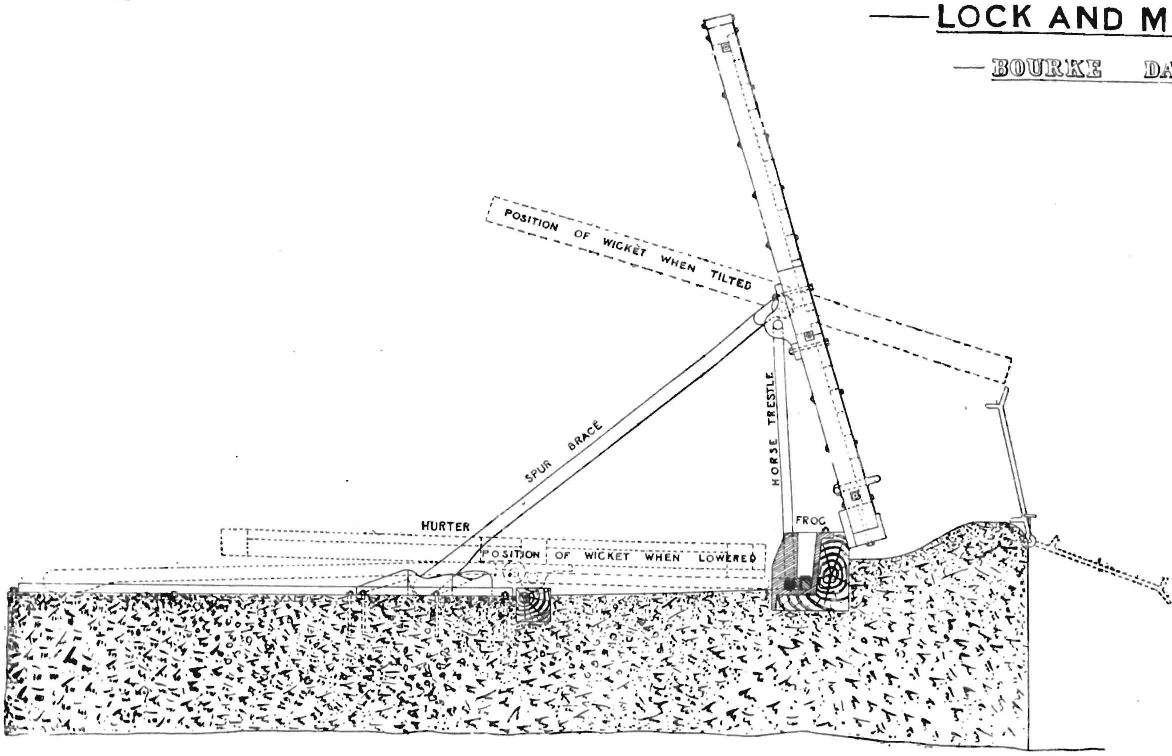
## A BRIEF REVIEW.

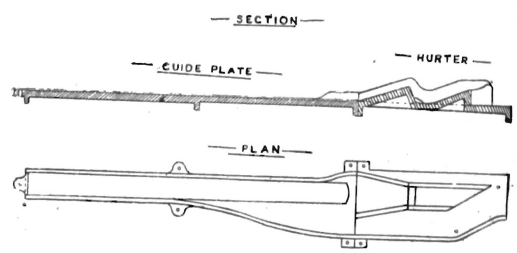
By Mr. WILLIAM POOLE, Jun., Assoc. M. Inst., C.E.

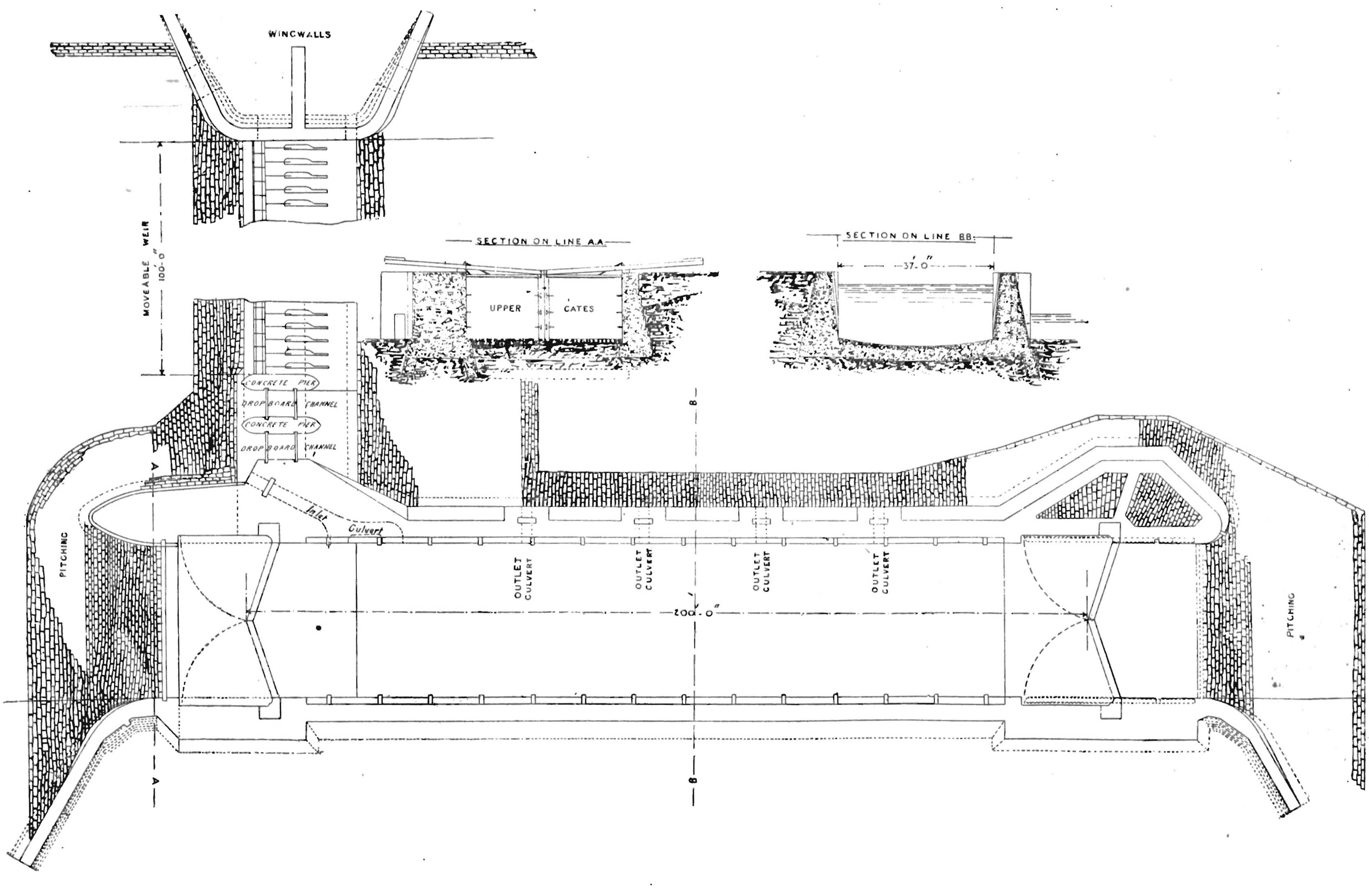
*(A Paper read before the Sydney University Engineering Society on December 8th, 1897.)*

# LOCK AND MOVEABLE WEIR

## BOURKE DARLING RIVER



# THE BOURKE LOCK AND WEIR.

By E. A. Amphlett, B.E., Assoc. M., Inst. C.E.

*(A Paper read before the Sydney University Engineering Society, Dec. 8th, 1897.)*

The locking of the Darling is a scheme the importance of which has long been recognised by the Governments of the Eastern Colonies.

At the recent Federal Convention a motion was passed by virtue of which this Colony is to retain the ownership of the Darling River and tributaries within its borders. The importance of maintaining a safe navigable river has recently been shown by the famine prices to which such necessaries as flour, potatoes, and forage have risen. And the Government of this Colony, recognising the extent to which the settlers and townspeople on the Darling are dependent upon an open river, have a snagging steamer at work at the present time. There is no doubt that, with a locked and permanently navigable river, a great impetus and development would take place in the western portions of the Colony. If, however, the whole course of the river was canalized, trade would be diverted to Adelaide. The Railway Commissioners are understood to favour the locking of the river between Walgett and Wilcannia, when the terminus of the Western Line (Bourke) would become the trade centre for the commerce of this length of river, at least during such periods as the steamers could not run between Wilcannia and Morgan, a South Australian rail terminus on the Lower Murray, 100 miles from Adelaide. In initiating a scheme for the locking of the Darling, it was found that the most important condition to be fulfilled was that no silting of the river-bed should take place above the weir. In a navigable river this is best obtained with a movable weir, and on this account the Chanoine balanced type was adopted. The average fall per mile in the Darling is about 3″, and the current is consequently sluggish, and, moreover, carries a large percentage of mud in suspension. The site for the first lock and weir was chosen at a point on the river four miles below Bourke, where the bed of the river was found to be composed of soft rock overlying a strata of indurated shale, suitable as a foundation for masses of concrete. The cross sectional area of the river was deep and narrow, and has since been increased to allow for the permanent obstruction caused by piers and lockwalls. It was intended at that time to lock the river between Walgett and Bourke. As the cost of each lock and weir was estimated to exceed £20,000, the proposal was reported upon by the Public Works Committee of this Colony, and rejected on the grounds of the great expense, and that the prospective advantages were not such as to justify the construction of the works at the present time. The lock and weir, in its present completed state, differs from the original design. 1st. The lock is altered from a 6 to a 7-feet lift. This necessitated the addition of an extra foot of concrete to the lockwalls and abutment, also the raising of the weir-crest by 1 foot. 2nd. The substitution of the Hurter system for raising and lowering the weir, instead of the tripping mechanism.

*Concrete Lock.*—The dimensions of the concrete lock, as originally designed are : Length, 200 feet between apices of mitre sills, overall length 242 feet over sills, mean breadth 37 feet, and depth 18′ from top of lockwalls to invert. It has been designed to accommodate a steamer and barge together. The walls are 4 feet wide on top, battered 1 in 10 on the inner face, and 1 in 5 on the stream face. The land wall is carried into the river-bank at each end by curved abutment walls, and the river wall is terminated on the up-stream end by a cutwater head, and by a round head on the down-stream end. An apron wall 3 feet thick is carried down to reduced level 290.50, extending from up-stream abutment wall in front of lock sill round cutwater head ; thence the whole length of weir sill to the abutment on the left bank, returning to river wall of lock under concrete apron of weir ; thence under the whole length of the wall and sill to down-stream abutment wall. The outer and inner round head walls are connected by a partition wall 2′ 6″ thick on top, and the intervening spaces filled in, and the surface pitched with 9″ pitchers. The filling culvert is placed in the upper pier-head, the opening being 6′ x 3′, branching into two openings 5′ x 2′, which discharge the water into the lock. The penstock chamber in connection therewith is 4′ 6″ x 1′ 6″, fitted with a timber penstock 6′ 6″ x 3′ 0″, working in timber guides, and is raised and lowered by means of a $2\frac{1}{2}$″ capstan-headed screw. The dimensions of the four outlet culverts are 2′ 6″ x 4′ 0″. They are spaced at regular intervals in the river wall, and are regulated by penstocks in the same manner as the inlet culvert. The penstock chambers are covered by chequered foot plates fastened to copings by short lewis bolts. It was originally specified that the lock walls and piers were to be covered with stone copings ; this portion of the work was omitted. The walls of lock and pier-heads are protected with fixed ironbark fenders, 12′ x 4″ x 6″. The lock gates are constructed of ironbark timber throughout, framed together, and fastened with wrought-iron straps, plates, and bolts. Heel and mitre posts are bolted together with three horizontal stay bolts $1\frac{1}{4}$″ in diameter. Each gate is fitted with a balance beam 41′ long x 15″ x 15″, morticed to fit on the heads of mitre and heel posts, and connected to mitre posts by bridle straps bolted through with $\frac{7}{8}''$ screw bolts and nuts, and to heel posts by 1" screw bolts and nuts, and also by short straps on each side, bolted through from side to side. A cast-iron balance weight of 1 ton is fixed on top of the outer end of each balance beam, and the gates are supported and prevented from drooping by wrought-iron truss bolts $1\frac{1}{2}''$ diameter. Each gate is pivoted on a cast-iron pintle bedded in the concrete. The pintles fit into cast-iron sockets fixed to the lower end of heel post. The centre of heel post pivot is fixed about an inch further from the sill meeting face than the central axis of the heel post; this gives the sill post an eccentric motion in closing, and ensures a close joint against the meeting face on quoins. The hollow quoins are made of best Bowral trachyte, dressed to the proper form with the greatest accuracy, each stone being set in cement, and the back joints breaking about 12", so as to effect a bond with concrete. A wrought-iron welded ring is shrunk on the head of the heel post, the outer face of which is turned true, and a wrought-iron strap fits on the outer half-circumference of the ring. Each end is prolonged, and passes through a cast-iron crosshead, which is secured to the hollow quoins by means of jagged iron bolts leaded into stone. The iron strap is secured by two wrought-iron wedges passing through slotted holes in strap, and bearing against back and front of crosshead. The heel posts of lock gates can be adjusted at any time by means of the wedges, and the stress due to weight of gate is taken by two anchor bolts bolted to either end of crosshead, joggled 9" at the ends, and leaded into the stone. Chases are cut in the stone in order to allow these attachments to be flush with cope level. The gates are sheathed with 2" planking, secured to beams by 4" spikes; the joints are caulked with oakum and pitch. A gangway is formed across the lock at each end by bolting a widening strip on the inside of balance beam. It is, of course, only available when the gates are shut. An iron handrail, supported by stanchions fixed to balance beams, is also provided. Two regulating passages 6 feet wide are formed between the lock and weir by means of boat-shaped concrete piers 19 feet long x 4 feet wide. Each passage is provided with two sets of drop-boards, 7' 0" x 6" x 4", which work in grooves formed in the piers. Boards are provided with an eye-bolt near each end, sunk in the timber; they are raised and lowered with long-handled iron hooks. The weir sill, apron, and footings are of concrete of the form shown on drawings. The over-all width between up-stream edge of concrete sill and edge of apron is 27 feet. Curtain walls 3' thick and 6' deep are provided under weir sill and down-stream edge of weir apron. They are carried down to reduced level 291.50, are bonded to lock wall, and continued into 6′ bank to form an abutment and gear chamber for the operating gear.

*Movable Weir.*—The movable weir is built on the Chanoine principle, and consists of 30 balanced timber wickets 10′ 6″ high by 3′ 3″ wide, each being supported on a wrought-iron horse-trestle, and sustained against water-pressure by a wrought-iron spur brace. The foot of each spur brace rests against a cast-iron check plate when the wicket is holding up a head of water. The wickets are set in a straight line throughout the entire length of weir at right angles to the direction of current, and spaces of 1″ and 2″ are left between bottom and top halves of each wicket, in order to allow a proportion of the water to pass down the river. The position of bearings for horse trestle in respect to the hydraulic centre of pressure on the wickets is so situated that when the water overflows the crest of weir to a depth of 15″ the wickets tilt automatically at an angle of about 21°. A cast iron weight is placed on the lower end of each wicket to bring it back to the original position when the river falls. The lower ends of the wickets rest against a timber sill 27″ x 18″, the back upper edge of which is checked out to receive cast iron frogs on the bottom bearing blocks of trestles. The horse trestles are solid forgings with a turned gudgeon at each of the four corners of the frame; these fit into a gun metal bushed wrought iron bearing block bolted to wicket on top and into castings called frogs, bolted to the timber sill. The horse trestle is fastened in the frog by means of cast iron wedges and angle irons. The bearing blocks are provided with projecting stop pieces to regulate the angle at which the wickets open. A wrought iron bow, 1″ dia., is fixed in front and to lower end of each wicket for lifting the weir. A bearer 12″ x 8″ is fixed at the back of the timber sill to which the tripping bar bearing blocks are bolted. The wickets are lowered by means of a horizontal sliding bar of $1\frac{3}{4}''$ square wrought iron, extending across the river channel on gun metal roller-bearing fixed to concrete floor in front of check plates or hurters. It is fitted at equidistant spaces with wrought iron triggers; one to engage the foot of each spur brace, the triggers being so spaced on the tripping bar that one half of the wickets can be lowered, two at a time, and the remainder four at a time. The tripping bar is carried through the concrete abutment wall into the gear chamber by means of a stuffing box and gland. On the last 4′ of tripping bar a $2\frac{1}{2}''$ dia. square threaded screw $\frac{3}{4}''$ pitch is turned, which works in a gun metal nut fixed in the axis of a cast iron bevel wheel. The operating gear consists of two sets of bevel wheels fixed on vertical and transverse shafts and tripping bar. The power is transmitted through a handle worked by one man. The gear chamber is fitted with ladder, trap door, and 6″ dia. single faced sluice valve, connecting to 6″ cast iron pipe extending through the outer wall of chamber at such a level as to drain off water to river channel.

*Alteration in Design of Lock and Weir.*—We now come to the alterations introduced, with a view of giving greater utility to the lock, and better facilities in raising and lowering the moveable wickets of the weir. As before mentioned, the lock walls were made one foot higher, so that the lock is now available for a maximum lift of seven feet. This necessitated raising the crest of moveable weir through the same height. The introduction of the Hurter system for raising and lowering the wickets dispenses with the tripping bar and its controlling mechanism, thus making each wicket independent, whereas, in the event of an accident to the tripping gear, as originally designed, the whole weir would be thrown out of control. The hurter is a separate casting, fixed to fit close to the end of guide plate It consists of an inclined plane 13″ long, having a rise of 4″, and shaped as shown on the plan. When the spur brace is acting as a strut to maintain the wicket against a head of water, the toe rests against the check plate provided at the end of guide plate, and also on the foot of the hurter. In lowering, each wicket is pulled far enough forward, in an upstream direction, for the toe of the spur brace to reach the end of the inclined plane on the hurter, where it drops into the guide plate. The weight of the wicket and the pressure of water combined then brings the wicket into a horizontal position on the floor of the concrete apron. It will be seen from the shape of the guide that when the wicket is in this position the spur brace concides with the centre line of the check plate and hurter. The wicket is raised by a pull in the same direction as was required in lowering, the spur brace rising up another small inclined plane at the end of the guide plate, and then falling down against the check face and on to the hurter. The raising and lowering can be carried out by one man, who is stationed on a punt fixed to a wire stretched across the river, parallel and at a suitable distance upstream of weir, and fixed to a pile driven in each bank. The man employs a long hooked shaft, which engages the wrought iron bow placed on the lower end of each wicket. Each of the thirty wickets is thus raised or lowered in succession. The punt is fitted with a crab winch, so that by attaching a hook handle the power is increased by working the winch. Moveable W. I. rests, fixed to the concrete sill, have also been introduced for the fifteen wickets comprising the left half of weir, with the object of keeping this portion tilted, in order to prevent undue concentration of current when the last wickets are being raised. The whole of the ironwork was coated with Dr. Angus Smith's composition.

*Construction of Work.*—It is now proposed to briefly describe the manner in which the work was carried out. A contract was let in July, 1895, to Messrs. Kerle & Kerle to complete the whole of the works, according to the original design, for the sum of £18,868. Work was commenced at once, the river being exceptionally low. By the 18th of November, 1895, part of the excavations for the improvement of the existing river channel had been carried out. Two thousand cubic yards of concrete had also been deposited in the lock walls and floor. A temporary low level bridge was being used for the conveyance of plant and materials from the left to the right bank of the river. The river by this time had risen and become navigable, but on the above date all work was suspended by the contractor, for the reason that the above-mentioned bridge was cut away by the master of a trading steamer, as it blocked the river to navigation. The whole of the river work was shortly afterwards submerged. Owing to subsequent complications which arose out of the action of the steamboat master, the contract was cancelled, and the contractor's plant seized. The department then decided to complete the work by day labour, and to introduce the Hurter system for raising and lowering the weir wickets, an arrangement having, in point of simplicity, a great advantage over the tripping gear. Work was resumed under this system in June, 1896, and it was found convenient to erect an overhead wire tramway for the conveyance of material required in the construction of the lock. The elevation of the wires above the water level of the river was regulated so that they caused no obstruction to the navigation of the river, and they were located to command the weir. The tramway consisted of two lengths of $1\frac{3}{4}''$ dia. steel wire cable, supported on each bank by a timber trestle, making a clear span of 325 feet. The ends of cables were securely fastened to pile anchorages. Each cable was provided with a wrought iron carrier suspended, and running on two cast iron sheaves. The carriers were connected to an endless hauling wire passing through snatch blocks, and drawn by a horse on the left bank of the river. The broken metal was conveyed in skips holding about a ton, fitted with a hinged false bottom, and trigger catch for opening and closing. The heaviest weights taken across the river were the $2\frac{1}{2}$ ton blocks of Bowral trachyte for the hollow quoins. The skips were filled at the crusher head and lifted on to the carriers by means of a 4 h.p. vertical hoisting engine. All the timber and iron work, including the wickets, which were first framed and fitted together on the bank, were also transferred to their positions. The erection of the weir was therefore greatly expedited by means of the wire tramway. A three-ton hand crane was used for setting the hollow quoins, and also in the erection of the lock gates. The excavation for the lock was kept unwatered by means of a bag dam 8′ 6″ high, reinforced on the outside with excavated material, which surrounded this portion of the work on the river side. The upstream portion or head of the dam was protected from erosion by a series of groynes, made of fallen trees. A $3\frac{1}{2}''$ M'Comas water-lifter, worked by hand, was sufficient to keep the leakage under while the river remained low; and the maximum inflow was pumped out with a 6″ centrifugal and a No. 5 Pulsometer, working together. On three occasions the workings were flooded. The concrete timbering was composed of 6″ x $1\frac{1}{2}''$ Oregon, nailed to 6″ x 4″ Oregon posts and studding. As it was necessary to keep the river open to navigation, the weir had to be constructed in two sections, and a commencement was made with the right half. The unwatering in each case was effected by a coffer dam designed to hold out a head of 10 feet of water, and composed of 9″ x 4″ grooved sheet piling, kept watertight with W.I. galvanized hoop iron acting as a tongue in the sawn grooves. The sheeting was driven between 9″ x 4″ walings, bolted to ironbark piles spaced 10′ apart. Owing to the hard nature of the river bottom, it became necessary to first bore a hole $10\frac{1}{2}''$ in diameter for each pile. The piles were then driven with a 7 cwt. monkey, the boring and pile-driving gear being fixed to a punt moored in the required position. When the last wicket comprising this half of the weir had been fixed, the midstream side of the second half of the coffer dam was built, while the finished half of weir still remained unwatered. This was done by driving a pile at the edges of the concrete sill and apron. A large pine log was then bolted to these corner piles, the top face being adzed flat. A second log, running parallel at a distance of about 2 feet, and on the same level as the other, was supported on stump piles resting on the concrete apron. The last wicket was then boxed off from its neighbour with 1″ deal lagging, carefully jointed and fitted to the intervening space, the ends resting and making a close joint with the concrete floor. The top of the box was made of the same material, secured with nails to the adzed surfaces of the girders. The 9″ x 4″ sheet piling then rested on the lagging, the weight being taken by the transverse girder, and the sheeting was kept in position by upper and lower walings; the latter, resting on lagging, made the whole secure. The end bays of each side of the old coffer dam were also connected by two wings of sheeting. Before commencing the left section of coffer dam, the remaining central portion of the old dam was removed. By the end of 1896 the whole of the lock and right half of weir had been completed. The works remained flooded till the end of March, when the river fell sufficiently low to enable operations to be again resumed. On the completion of the coffer dam it was pumped out with the No. 5 Pulsometer. The concrete apron, pitching, and timbering for abutment were completed by working day and night shifts, but at this stage operations had again to be suspended owing to another fresh in the river, which flooded out the coffer dam. By the beginning of May it was once more possible to resume work. The coffer dam was unwatered, the abutment walls completed, and wickets erected and tested. The work was finally completed and opened by the Minister for Mines on the 5th July, 1897, when a steamer was passed through the upstream gates into the lock, where she was lowered and raised, afterwards passing out and steaming back to Bourke.

*Materials.*—The stone used for the concrete and pitchers was a heavily-silicated variety of desert sandstone, obtained from a quarry 10 miles distant, on the left bank of river. It was broken to the required gauges by a Baxter stone crusher, driven by a 10 h.p. engine. Owing to the extreme hardness of the stone, the cost of breaking was considerably increased by the frequent renewals of crusher jaws which were required. The sand was drawn from a deposit, also on the left river bank, distant one mile below the site. It was too dirty to be used for concrete in its natural state, and had, therefore to be washed. The washing apparatus consisted of two wooden boxes, containing about ½ a cubic yard of sand each. They were provided with false bottoms of perforated sheet iron. Water under a head of 10 feet was introduced under the sheet iron; the sand was worked about while the water was running. The supply of water was obtained by pumping from the river into two 400-gallon tanks, elevated on stands. 4″ galvanized iron piping, fitted with stop cocks, was used to conduct water to the sand boxes. The pump was a 1½″ double-acting plunger pump, worked off the fly-wheel of a 3 h.p. "Capitaine Oil Engine." The oil engine proved very economical and satisfactory in every way. The proportions of concrete were as follows:—No. 1: One of cement, 1½ sand, 4 stone broken to 1½″ gauge, and consisting of ⅓ shivers; this made 22 cub. ft. of concrete to the cask of cement. No. 2: One of cement, 2 sand, 6 of stone, broken 2½″ gauge, and consisting of ⅓ shivers; this made 27 cub. ft. of concrete to the cask of cement. The materials were measured in boxes, and spread on a timber platform as close as possible to where the concrete was to be used. The sand and cement were first mixed, and then spread over the stone. The whole of the dry materials were turned twice, water being then slowly added through a rose-headed can, and again turned over twice. The concrete was carefully deposited in place, and well packed and rammed in layers not more than 18″ thick. All exposed concrete faces were faced 12″ with No. 1 concrete, the outer face being worked smooth on removal of the timbering.

The actual detailed cost of a cubic yard of the two descriptions of concrete is as follows :—

| Description. | No. 1 Concrete. 4 : $1\frac{1}{2}$ : 1 Cost per c. yd. £ s. d. | No. 2 Concrete. 6 : 2 : 1 Cost per c. yd. £ s d. |
|---|---|---|
| 1. Stone getting ... ... ... | 0 6 3·868 | 0 7 4·536 |
| 2. Stone-breaking ... ... | 0 4 1·680 | 0 4 10·480 |
| 3. Conveying material across river on wire tramway ... ... | 0 2 4·279 | 0 2 4·279 |
| 4. Mixing and putting in position, including tools and lights ... | 0 5 4·340 | 0 5 4·340 |
| 5. Supply and delivery of cement ... | 1 3 10·728 | 0 18 7·000 |
| 6. Timbering ... ... ... | 0 2 8·740 | 0 2 8·740 |
| 7. Sandwashing and carting ... | 0 0 9·948 | 0 1 1·254 |
| Total cost per cubic yard | £2 5 7·583 | £2 2 4·429 |

| | £ s. d. |
|---|---|
| Cost of quarrying stone amounted to ... ... | 0 2 11·20 |
| Cost of carting stone amounted to ... ... ... | 0 4 8·668 |
| Cost of breaking stone amounted to . ... | 0 5 0·216 |
| Total cost per cubic yard ... ... | £0 12 8·084 |

| | £ s. d. |
|---|---|
| Cost of sandwashing ... ... ... ... | 0 2 4·58 |
| Cost of carting sand ... ... ... ... | 0 1 0·74 |
| Total cost per cubic yard .. ... ... | 0 3 5·32 |

*Working of Weir.*—Since its completion, the lock and weir have been submerged three times, and the experience gained in raising and lowering the wickets has, so far, gone to prove that they are easily worked, and are automatic in tilting when the river overflows the crest of the weir. The following tabulated record shows that the wickets have fulfilled the requirements for which they were designed :—

| Date. | Reading of Gauge above Weir. | Reading of Gauge below Weir. | Remarks. |
|---|---|---|---|
| Oct. 9. | 13′ 10″ | 5′ 8″ | Heavy rain. |
| „ 10. | 14′ 3″ | 8′ 2″ | At 11 a.m. one wicket tilted. |
| „ 11. | 13′ 9″ | 8′ 7″ | During night one wicket tilted. |
| „ 12. | 13′ 3″ | 10′ 0″ | Five more tilted between 6 a.m. and 12 p.m., and one at 2.30 p.m. |

The level of the top of weir is 13 ft. on the gauge.

It will be seen that the fresh was due to heavy local rain, and it was, therefore, unnecessary to lower the whole weir.

In conclusion, the author begs to acknowledge the kindness of Mr. H. G. McKinney, Principal Assistant Engineer for Water Conservation, Irrigation and Drainage, Public Works Department, in allowing the use of plans and model exhibited. His thanks are also due to Mr. L. A. B. Wade, Assistant Engineer, for much of the information contained in this paper.