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Nash Mills — *The Endless Web* Revisited

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A watermill is known to have existed on the river Gade since the 11th century on the site of Nash Mills, Hertfordshire, where a purpose-built paper mill was constructed in the late 18th century. In 1810 the mill was purchased by John Dickinson, one of the great innovators of the paper industry. The mill evolved significantly during the 19th and early 20th centuries as part of Dickinson's expanding business, which at one stage comprised five mills in the locality. Nash Mills remained in the ownership of John Dickinson and his successors until 1990, ceasing production in 2006, the last of Dickinson's mills to do so. Using documentary and building evidence, this article examines the development of the mill, emphasising the relationships between personalities, events, structures, processes, and changing business and technological influences.

Introduction

Nash Mills closed in 2006, after nearly 250 years of almost continuous paper and board production. It was the last of the Hertfordshire paper mills belonging to John Dickinson & Co., producers of the well-known 'Basildon Bond', 'Croxley' and 'Lion Brand' stationery ranges, to remain in operation, albeit under different ownership. The history of the mills to *c.* 1950 is documented in Joan Evans' book *The Endless Web*.[1] In response to redevelopment proposals for the site, Archaeological Services & Consultancy (ASC) was commissioned to undertake an archaeological desk-based impact assessment,[2] and a programme of historic building recording (drawn and photographic)[3] and building interpretation.[4] Onsite works were carried out in the summer of 2008.

Location

Nash Mills is located to the immediate south of Hemel Hempstead, Hertfordshire, in the floodplain of the river Gade (Figure 1). It occupies a roughly rectangular area of *c.* 4.75ha, centred on NGR TL 070044, and is bounded to the west by the Grand Union Canal, to the south by Red Lion Lane, to the east by Lower Road, and to the north by residential development.

The mill buildings cover most of the site, with yards to the east and north. The earliest parts of the mill (North Mill) are located in the north-west corner of the site, with more modern structures (South Mill) to the south and south-east. Near the centre of the site is 'Nash House', formerly the home of John Dickinson, latterly the company offices. At the north end, adjacent to the Lower Road entrance, is 'Stephenson's Cottage', a two-storey brick and flint building. The canal runs alongside the mill, falling through two locks. The millstream diverges from the canal in the north-west corner of the site and is culverted beneath the mill buildings, exiting the site at its south end and returning to the canal below the lower lock.

Papermaking

Papermaking appears to have originated in China, probably in the 2nd century BC, spreading to India and the Middle East after the defeat of the Chinese at the battle of Talas in AD 751. It was probably brought to Europe after the First Crusade in 1096, arriving in England some time after. The earliest recorded papermaking site in England was Sele Mill, on the river Beane at Hertford, established by John Tate and extant in 1495.[5] This and other early mills were not successful, probably owing to the ready availability of parchment, a lack of skill and raw materials, and cheap imports from Europe, especially Italy and France.

The first successful paper mill in England was established in 1588 by a German immigrant, John Spilman, at Dartford.[6] Spilman obtained a monopoly on papermaking, which he vigorously defended until the early 17th century. By the 1650s papermaking had taken root in Kent, Middlesex, Buckinghamshire, Hertfordshire, Surrey, Berkshire and Hampshire. Many of the earlier paper mills were converted from water-driven flour mills.[7]

The Gade valley has been favoured by the paper industry from the late 17th century onwards. This choice was dictated by the presence of plentiful, reliable supplies of clean water for the papermaking process. While soft water was preferred, the water available to the Gade valley mills, though hard, was clean and free from 'colour',[8] an essential consideration for making white paper. Water also provided power to the mills. The other principal ingredient of paper is fibrous material, typically vegetable fibres composed of cellulose. Today the most common source of this is wood pulp, though until the 19th century the most commonly used raw material in

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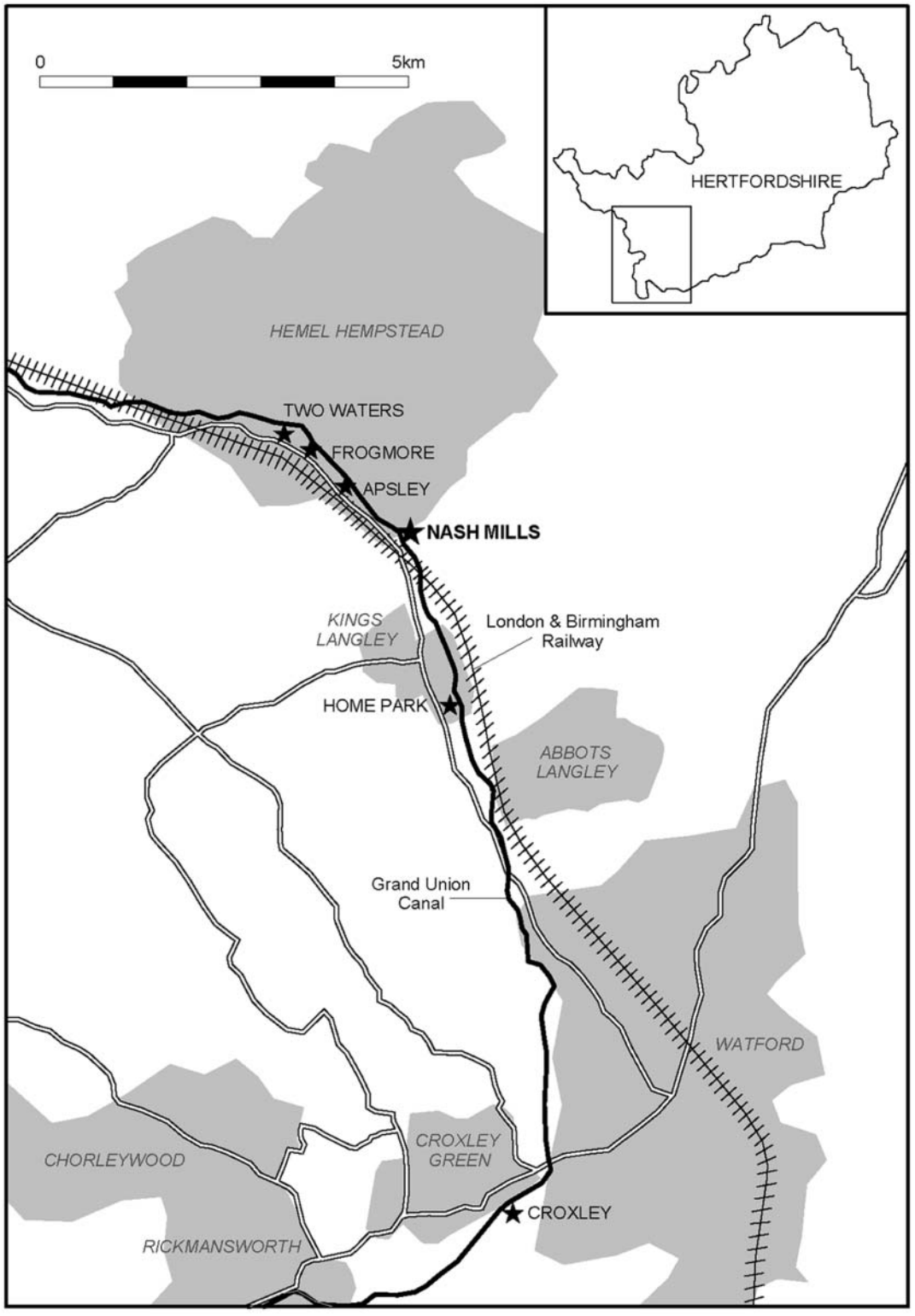

Figure 1.
Site location, showing places mentioned in text.

Britain was cotton and linen rags. These were sorted, had fastenings removed and seams unpicked and were washed, before being broken down by beating and boiling in a weak alkaline solution. The resultant pulp, known as stuff, could then be bleached or dyed.

Before mechanisation, a mould comprising a fine wire sieve in a wooden frame was dipped by hand into a vat of diluted stuff, picking up a thin layer of fibres, which formed a sheet of paper. Wet paper sheets taken from the moulds were pressed between layers of felt to expel moisture, after which the sheets were air-dried and any finishing processes, such as glazing, were applied, following which a second stage of drying may have been required. This method of manufacture was

slow, and the size of sheets was limited to the largest frame that could be held and shaken by hand.

By the end of the 18th century a shortage of labour for making paper, coupled with an increasing demand for the product, was causing problems for British papermakers. The solution came from France, where in 1799 Nicholas Louis Robert, an accountant at the French paper mill of Essonnes, patented a hand-operated machine for making paper in lengths of up to 12ft. Unable to get finance to develop his invention, he sold the patent rights to his employer Leger Didot, who in turn approached his brother-in-law, John Gamble, to take out an English patent and secure financial backing. Gamble used Robert's original French patent drawings to secure an English patent in October 1801, and obtained financial support from Henry and Sealy Fourdrinier, partners in the City stationery firm of Bloxham & Fourdrinier, in return for a one-third interest in the patent rights.

In 1802, the Fourdriniers appointed John Hall of Dartford to construct a working machine based on Robert's drawings and his working model. Progress was slow, until Hall's brother-in-law, Bryan Donkin, took charge of the project. The Fourdrinier brothers had a new engineering works built for Donkin in Bermondsey, and in 1803 leased Frogmore Mill in the Gade valley, where the first, improved Robert machine was installed later that year. In replication of the handmaking process, dilute stuff suspension was poured onto an endless fine wire mesh belt, from which water was drained as it travelled along to the press section, where it was transferred to a continuous felt blanket and pressed between rollers to make it dry enough to be rolled on a reel. Finally it would have been cut off the reel into sheets and loft-dried in the same way as handmade paper.

Supported by Gamble and the Fourdriniers, Donkin continued to refine the design of the machine. An improved machine was designed and engineered in Bermondsey and installed by the Fourdriniers at Two Waters Mill, adjoining Frogmore, in 1805. Further developments of both machines were made over the next two years and additional patents were acquired in 1803 and 1807, incorporating the advances that had been achieved in developing a machine that could produce good paper commercially. This process, with improvements, remains one of the dominant techniques for fine papermaking.

At the neighbouring Apsley Mill, John Dickinson installed and patented his 'cylinder mould' machine in 1809. This has a cylinder covered in fine wire mesh as the mould, partially submerged in a vat containing the stuff suspension. As the cylinder rotates, the mesh picks up a layer of fibres, and most of the water flows out of the cylinder. When the cylinder has rotated above the level of the pulp in the vat, more water is removed by vacuum suction. The sheet of paper thus formed is lifted from the cylinder by a couching roll, originally a brass cylinder but latterly felt-covered. This machine probably did not work well, but was turned into a successful machine by improvements patented in 1811. Dickinson's machine is used nowadays primarily for making heavy weight and security papers.

Dickinson subsequently developed and patented a number of improvements to his paper machine.[9] In 1811 he registered a device for making striped paper. In 1814 he patented an apparatus for removing knots or lumps of hard stuff from the paper. In 1817 he registered a process for making laminated paper for copperplate and letterpress printing. This patent was important for Dickinson's later attempts to produce thicker, multi-layered paper, which would become the basis for 'board' machines.[10] The 1817 patent also included modifications to his earlier patent for cutting paper with circular knives. In the same year Dickinson patented a paper-drying machine, in which damp paper was passed over a steam-heated roller, resulting in more even drying. In 1829 he registered a variant of the cylinder mould machine that introduced silk threads into the body of the paper for high security printing, the forerunner of the foil strip in modern bank notes. In 1832 he patented a strainer for removing impurities from dilute stuff. Most of these developments were constructed and tested at Apsley and Nash Mills. Dickinson took out 14 patents, perhaps the most of any papermaker.

Historical Background

Nash Mills is one of four Gade valley mills mentioned in the Domesday survey,[11] and one of 11 observed by Defoe in the early 18th century.[12] Some were initially corn or fulling mills, though many later converted to paper manufacture. Two Waters Mill was a fulling mill until the 17th century, when it reverted to corn milling. In 1763 it was both a corn and paper mill, and was later used by Fourdrinier as a paper mill. It was destroyed in an explosion in 1919.[13] Frogmore Mill is documented as early as 1540, when it was a corn mill. By 1774 it was producing paper, and was leased in 1803 by the Fourdriniers. Apsley Mill was also making paper by the end of the 18th century. It was purchased by John Dickinson in 1809 to exploit his newly patented papermaking machine.

The earliest cartographic evidence for Nash Mills is Seller's 1676 map of Hertfordshire, which shows the mill as being located on an island in the river. Beyond its appearance on

this and later county maps, little is known of the site before the late 18th century. It must have been making paper before 1769, as the *London Gazette* of 14 October of that year listed Zachariah House, papermaker of Nash Mills, as a bankrupt.[14] The next occupants appear to have been William and Ann Blackwell. William died in 1777, and Ann continued to run the mill for the next quarter century.[15] During this period she entered into partnership with Griffith Jones.[16] Apparently Ann was very much the senior partner, and played a prominent part in running the mill.[17]

In March 1796, Nash Mills was visited by John Gilpin, a Delaware paper manufacturer who toured the Hertfordshire paper mills at this time. Gilpin's account,[18] accompanied by sketches, provides a detailed picture of the mill. At this time, Nash Mills was still making paper by hand. The mill building, described as 'a complete new mill', housed a number of water-powered 'engines', presumably stamps for beating rags, and stuff chests and vats, with rag storage and processing on the upper floor. A second building housed the drying loft and 'salle' (finishing room). It is likely that Griffith Jones financed the construction of the new mill, and possibly also the building of Nash House on the site.[19]

In 1811 John Dickinson and George Longman bought Nash Mills, shortly after Dickinson's marriage to Anne Grover, and the newlyweds moved into Nash House.[21] On 26 October 1813, there was a serious fire that destroyed nearly all the mill, though the machine house survived. It is recorded that Nash House was saved from destruction 'by being hung with wet paper-felts'.[22] As paper felts were typically no more than *c*. 0.9m (3ft) square, it must be supposed that this tactic was used only on the more vulnerable parts of the building. Fortunately the mill was insured, and the insurance settlement of £8,000 made possible rapid rebuilding.

A near-contemporary development in the Gade valley, later to prove extremely significant for the area's paper mills, was the construction of the Grand Junction Canal. Its original course south of Hemel Hempstead, known as the 'Long Pound', opened in late 1798. This followed the east side of the valley for 2.5km, with a flight of four locks at its south end lowering the canal to the Kings Langley pound.[20] The Long Pound was criticised bitterly by both Jones and George Stafford of Apsley Mill, who contended that much of the river water was being diverted to the canal, thereby taking power from their water wheels. The case was initially heard before the Master of the Rolls, and a later stage, in which Thomas Telford was involved as arbitrator, was heard at Hertford Assizes.

The legal dispute between the mill owners and the canal company dragged on until 1818, when a bill was passed by Parliament allowing for abandonment of the Long Pound and construction of a canal along the Gade linking the mills, with three locks at Apsley and two at Nash Mills. Thomas Telford surveyed the diversion route and the canal company constructed the earthworks, but Dickinson contracted to build the locks, quays and other brickwork. The diversion opened in 1819, providing both mills with direct water transport and control over their water supply.[23] Telford's plan for the diversion (Figure 2) provides a reasonably detailed picture of the layout of the mill after the 1813 fire.[24]

The canal provided not only a link between Dickinson's mills and their markets, but also access to raw materials and fuel. The company owned a small fleet of narrowboats, painted in their own distinctive livery, which brought raw materials such as rags, waste paper and later china clay and esparto grass from Paddington and Brentford, returning with finished paper. Coal for the mills was brought from the Midlands coalfields, mostly by outside carriers. The coal traffic continued until 1962, when Nash Mills went over to oil firing.[25] In addition, the company maintained a fleet of shorter, wider boats for traffic between the mills.[26] Rail transport was also used for finished products, some going to Boxmoor Station (LNWR) and others to Hemel Hempstead Station (Midland Railway), where a transhipment shed was erected.

Dickinson was known as a forceful employer, who would stand no challenge to his authority and preferred to work with less experienced or younger staff. It was said that he 'could make a paper maker out of a hedge'.[27] One such employee was Philip Meadows Taylor, who was engaged as supervisor at Apsley in 1823. His notebook survives, containing a comprehensive guide to the management of the mills, the papermaking process, and its associated technical terminology.[28]

Despite Dickinson's fearsome reputation, his attitude to his workforce is best described as paternalistic. The mill workers were generally better paid than agricultural workers in the district, and Dickinson built cottages for them in Nash Mills, and also almshouses for retired workers. In this respect, Dickinson was similar to many of his contemporaries. One result of the owner's paternalism was the strong family tradition that existed at Nash and the company's other mills, where successive generations entered the mills, often in the same department.[29]

With Apsley and Nash Mills established and modernised, Dickinson set about expanding his business. In July 1826 Home Park Mill was opened at Kings Langley.[30] In 1830 Croxley Mill was opened at Cassio Bridge,

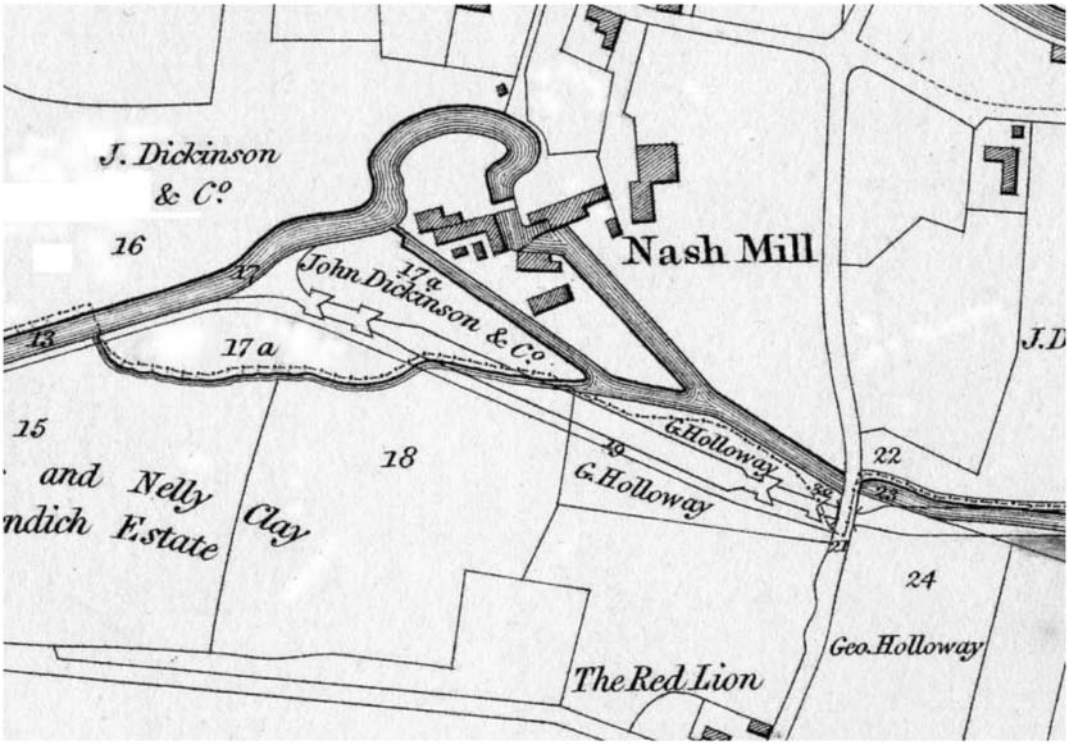

Figure 2. Extract from canal diversion plan, 1817 (Apsley Paper Trail 20582).

about 5 miles downstream from Home Park.[31] By 1818 Dickinson had taken on a paper mill at Batchworth, near Rickmansworth, and developed it for the production of half-stuff for use at Apsley and Nash Mills. Batchworth was remodelled in 1833, and a new wharf was built at Nash Mills.[32] Dickinson also continued to work on the development of machinery and processes for papermaking, mostly at Nash Mills. In 1839 he was awarded a contract to make high security paper for Exchequer bonds and other government documents, using the machine he had patented 10 years earlier. This paper was made at Nash Mills behind locked doors, on two machines guarded by Excise men. Two 'trustworthy women' were employed to repair the threads when they broke.[33]

In 1836 Dickinson began to build himself a new house, Abbot's Hill, on high ground to the east of Nash Mills. Before this was ready the family moved to London from Nash House in November 1834. They remained there until Abbot's Hill was completed in October 1837. In the spring of 1835, Charles Longman (nephew of George, John Dickinson's late partner) and his new bride moved into Nash House.[34] The Abbots Langley Tithe Map of 1839[35] provides details of the development of the layout of the mill in the two decades following the rebuild of 1813.

In 1840 Dickinson established the company's main engineering department at Nash Mills. In charge he placed Leonard Stephenson, who had been apprenticed in Darlington in the early days of the Shildon works and the Stockton and Darlington railway. Although there is no firm evidence that Leonard was involved with the more famous Stephensons, it is worth noting that papermaking machinery was one of the earliest products of Robert Stephenson and Co.'s Newcastle works. Leonard Stephenson's possible link with the firm therefore presents an intriguing possibility. Dickinson had a cottage built for Stephenson at Nash. Stephenson reorganised the engineering side of the mills, and in 1857–1858 the engineering department at Nash Mills built 10 horizontal twin cylinder steam engines for the company.[36] In 1843 a new wire shop was opened at Nash, to manufacture the bronze wire web used in the papermaking machines. Wire production continued until *c.* 1893.[37]

On 1 May 1840 John Evans, Dickinson's nephew, entered the accounts office at Nash. The son of Dickinson's sister Anne and Revd Arthur Evans, a schoolmaster, John Evans was well educated and successful. In 1850 he married Dickinson's youngest daughter, Harriet. The story of their relationship is told in detail elsewhere.[38] At the end of 1850 Dickinson admitted John Evans and Frederick Pratt Barlow, husband of his eldest daughter Fanny, into partnership in the business. In 1856 Dickinson, who was 74, retired. He died in 1869.[39]

After Dickinson's retirement, John Evans managed the entire manufacturing business. Like Dickinson, he was very much a man of his time. He became a member of the Institute of Civil Engineers in 1859, and President

of the Geological Society in 1874. His antiquarian pursuits with the Royal Society, the Society of Antiquaries and the Numismatic Society led to his being knighted in 1892. In 1872 he became Founder-President of the Paper Makers' Association, remaining in that position until his death in 1906.[40]

The development of the mill by the mid-19th century is comprehensively detailed in an insurance schedule and accompanying plan of 1856,[41] which not only records the layout of the mill buildings, but also their functions (Figure 3). A contemporary print of the mill also survives.

By 1861 the mill employed over 170 staff,[42] and was lit by gas from the company's own gasworks at Apsley.[43] During this period it manufactured higher-class writing and printing papers, and also specialised papers for reproducing maps and copperplate engravings. In 1879 the mill was largely rebuilt. The remaining water wheels were replaced with 'Hercules' water turbines. The Beater House was remodelled to bring all the beaters under one roof at one level, and a new machine-house was built. In 1881 Nash employed 69 staff in the mill, while the engineering department comprised 131 tradesmen, apprentices and labourers.[44] In 1883 the water frontage of the mill (Figure 4) was rebuilt.[45]

There were also significant changes in management. Frederick Pratt Barlow died suddenly in 1883, and in 1885 John Evans retired. The following year, John Dickinson & Co. was incorporated as a limited company. Evans remained at Nash House as the company's tenant, during which time he devoted himself to his numismatic and archaeological interests.[46] The new company board, which included John Evans's son Lewis, Frederick Pratt Barlow's sons Fred and Frank, and Charles Longman's son Arthur, made sweeping and innovative changes to the mills between 1887 and 1892. In 1887, the use of electric motors to drive paper machines was successfully tested at Nash Mills.[47] At this time, production was concentrated on fine rag paper, and on new Bouvier envelope-folding machines. However, the mill was not prospering. The engineering department at Nash declined in importance, and was transferred to Apsley by 1903. In 1897 a fire station was built at Apsley, and engines and equipment were transferred there from Nash.

In 1891 Nash Mills employed 56 hands on production (38 of them men) and 54 men and boys on maintenance. A former employee, J.W. Timberlake, recalled his impressions of the mill in the 1890s:

> The job I liked best was going around the mill watching the swirling stuff-chests, and the slow running of the high-grade plate papers; for Nash was then a very clean rag mill. Then the Salle, the sheeting room, for thick plate papers S and M qualities were sheeted most carefully for the least speck. Nash Mills plate papers were in high repute in those days, for Virtue and Co.'s publications and Whymper's prints of the Alps and such-like exacting work ... Special printing for book work was made, and a thin Bible paper which was largely exported to America ... Beater men and Machine men in those days always wore a paper cap, as a sort of trade insignia.[48]

From about 1903 onwards, Nash was developed as a mill for manufacturing pulp board.[49] In 1906, John Evans moved from

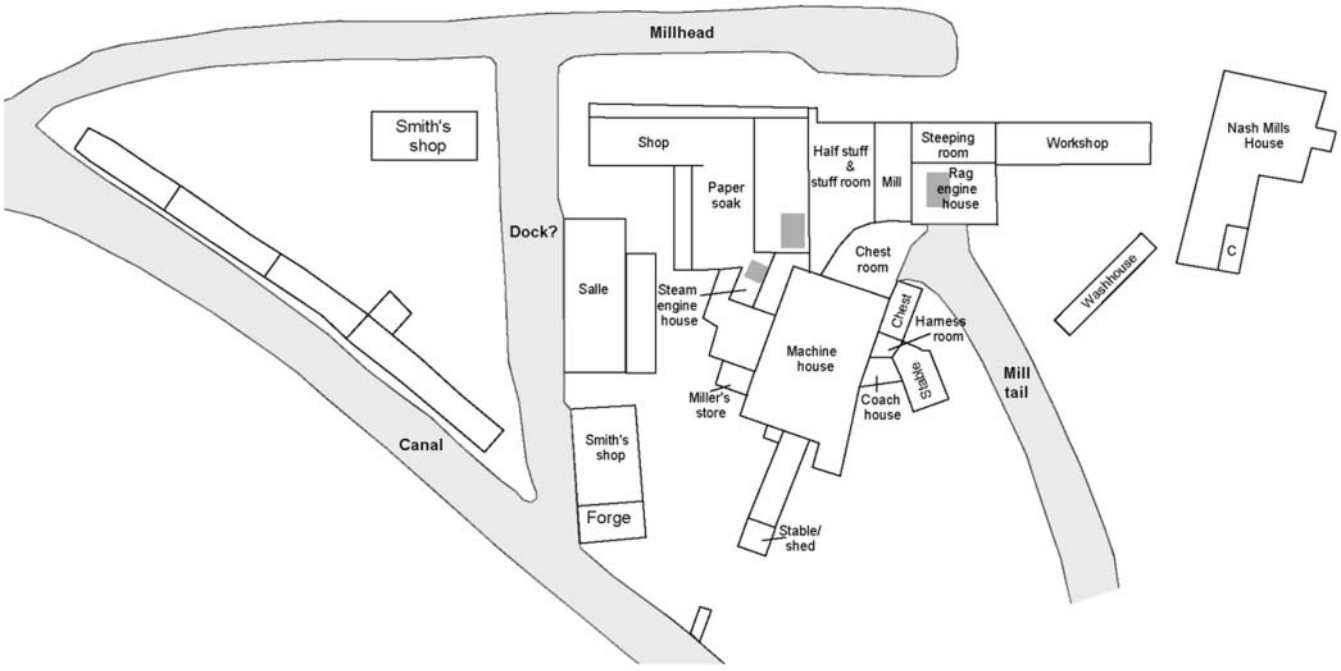

Figure 3. Insurance Plan of Nash Mill, 1856 (Apsley Paper Trail 2309.2).

Figure 4.
The millhead range from the east, c. 1896 (Apsley Paper Trail).

Nash House, which was then converted to offices. In 1908, construction of a new main engine house was begun. It was completed in 1909, with a Pollitt & Wigzell steam tandem compound horizontal condensing engine of 450hp, which drove all the machinery in the Beater House and Salle from an underfloor shaft. In 1909, as part of general improvements to fire precautions, an underground fire main was installed throughout the mill, fed from a water tower by a Shand Mason pump capable of delivering 2,500 gallons per hour.[50]

One week in 1911, the mill achieved a production record of 106 tons. At this time it was the largest maker of white and tinted pulp board in the country, and the only mill devoted entirely to its manufacture. In the same year, a coal wharf with a storage capacity of 3,000 tons was built alongside the canal. A travelling crane for unloading canal boats ran on rails from the wharf to the boiler house. In the same year a three-storey paper warehouse with an electric elevator and loading and unloading facilities was constructed in the centre of the mill, replacing two old buildings. Detailed written specifications and drawings for this building survive.[51] These are signed by W.A. Stephenson, great-nephew of Leonard Stephenson, who joined the mill as an apprentice in 1882, and eventually rose to the position formerly held by his great-uncle. In 1912 the mill was lit by electricity from its own generating plant.

With the outbreak of war in August 1914 many of the staff joined up, and the company was soon faced with a shortage of labour at all its mills. Overtime was worked at Nash, mostly by female staff, making trench bombs and small shells.[52] After the war, the mill was handicapped by insufficient room and inadequate plant in the Salle and finishing department, and was consistently receiving more orders than it could execute. In 1927, £75,000 was spent on new raw material stores to the north of the millhead, with a process bay for preparatory dusting, sorting and pulping (Figure 5). In 1928 the Beater House was remodelled with an additional storey, with new beaters, stuff chests and electric gear. A new Salle was built in 1934 'on the site of the old waste sheds'. In 1937 a new export packing room and canteen were constructed, and new cutting and drying machinery were put in.[53]

Dickinson's were better prepared for the outbreak of war in 1939. In 1936 an Air-Raid Precautions Committee had been formed with representatives from each mill, and ARP plans were ready by 1938. At Nash they cost £2,000 to implement.[54] From the first week of war, government controls were enforced on supplies of raw materials for papermaking, which became increasingly scarce as the war

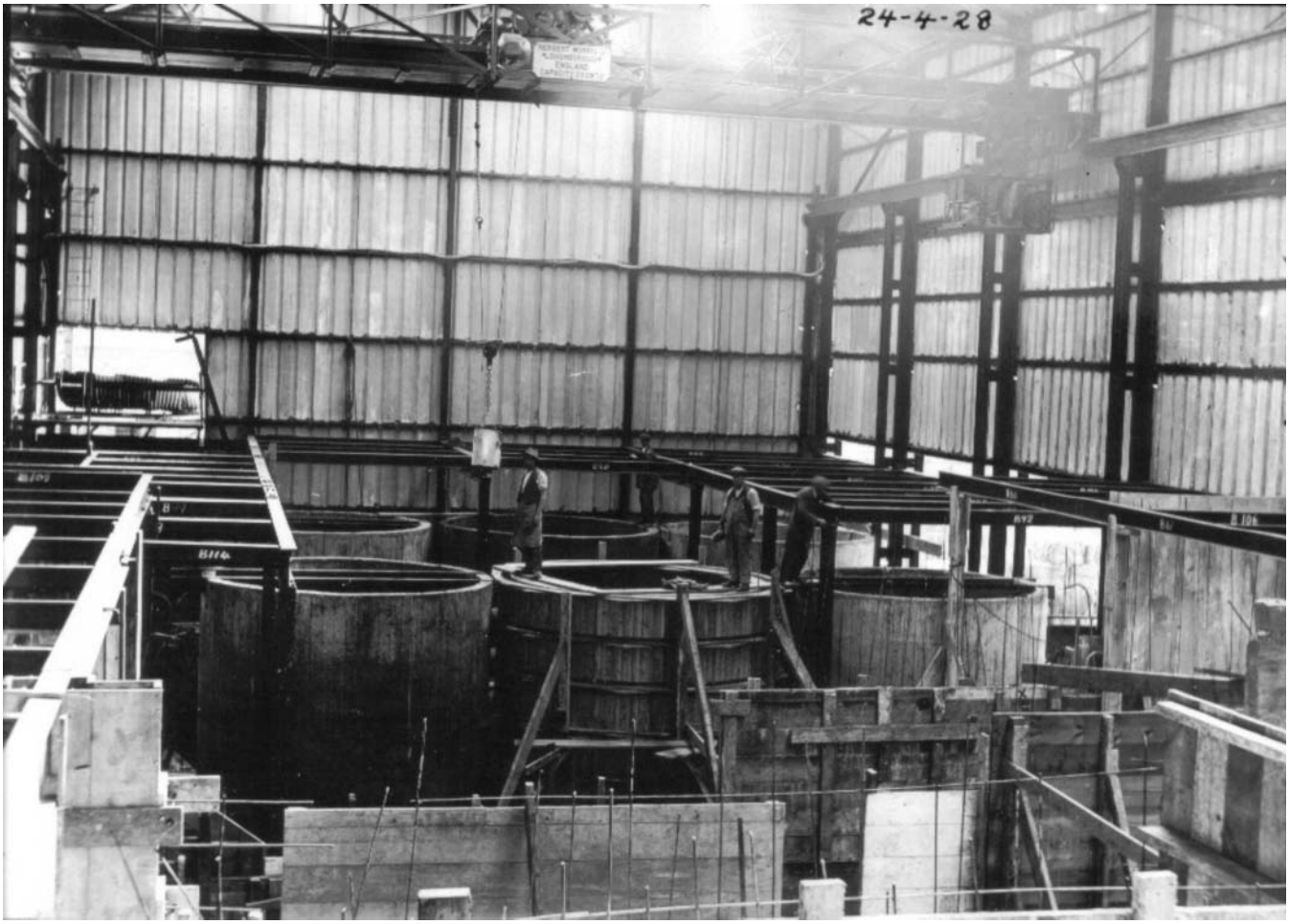

Figure 5.
Raw material store: fitting out the process bay, 1928 (Apsley Paper Trail).

progressed. In January 1941, after 1,500 of Dickinson's employees had joined the services, it was decided that the company should undertake as much war work as possible to achieve 'protected' status, for which they had to be doing 80% government work. This was achieved that year, and maintained throughout the war.

As business returned to normality after the end of the war, further expansion was planned at Nash Mills. One of the main obstacles to this was the millstream south of the mill, which lay between the existing mill buildings and the parkland south of Nash House. In 1948 two 3ft diameter pipes were laid along the bed of the millstream to take the flow, and covered with clinker from the adjacent ash pile, and hardcore from developments elsewhere on the site.[55] Major additions were made to the south of the mill between 1955 and 1957, including the Engineers' Shop, No. 4 Machine House, and a new boiler house.[56] Between 1963 and 1964 a new salle and warehouse were constructed, followed in 1964/5 by a new turbo-generating house. Three clarifiers and associated control and effluent pumping facilities were constructed in 1965.[57]

In 1966 John Dickinson & Co. became the Dickinson Robinson Group (DRG) Ltd. Through the 1970s and 1980s the business was restructured in response to changing market conditions. In 1982, three 'old' paper-making machines were removed from the machine house in the north mill,[58] after which the older mill buildings were converted to warehousing, or abandoned. After the closure of Croxley Mill in 1983, machinery and a number of steel-framed buildings were transferred to Nash. In 1992 the main boilers were moved into one of these buildings, and the previous boiler house alongside the canal was demolished. In 1990 Nash Mills was sold to the South African Pulp & Paper Industries (SAPPI) group, who produced a range of quality business papers and tinted paper and board there until 2006, when the mill was closed.[59] With the exception of Nash House, all buildings on site had been demolished by January 2010.

The Mill Buildings

Nash Mills comprises nearly 40 buildings of varied size, function and date (Figure 6). Excluding Nash House (in essence a

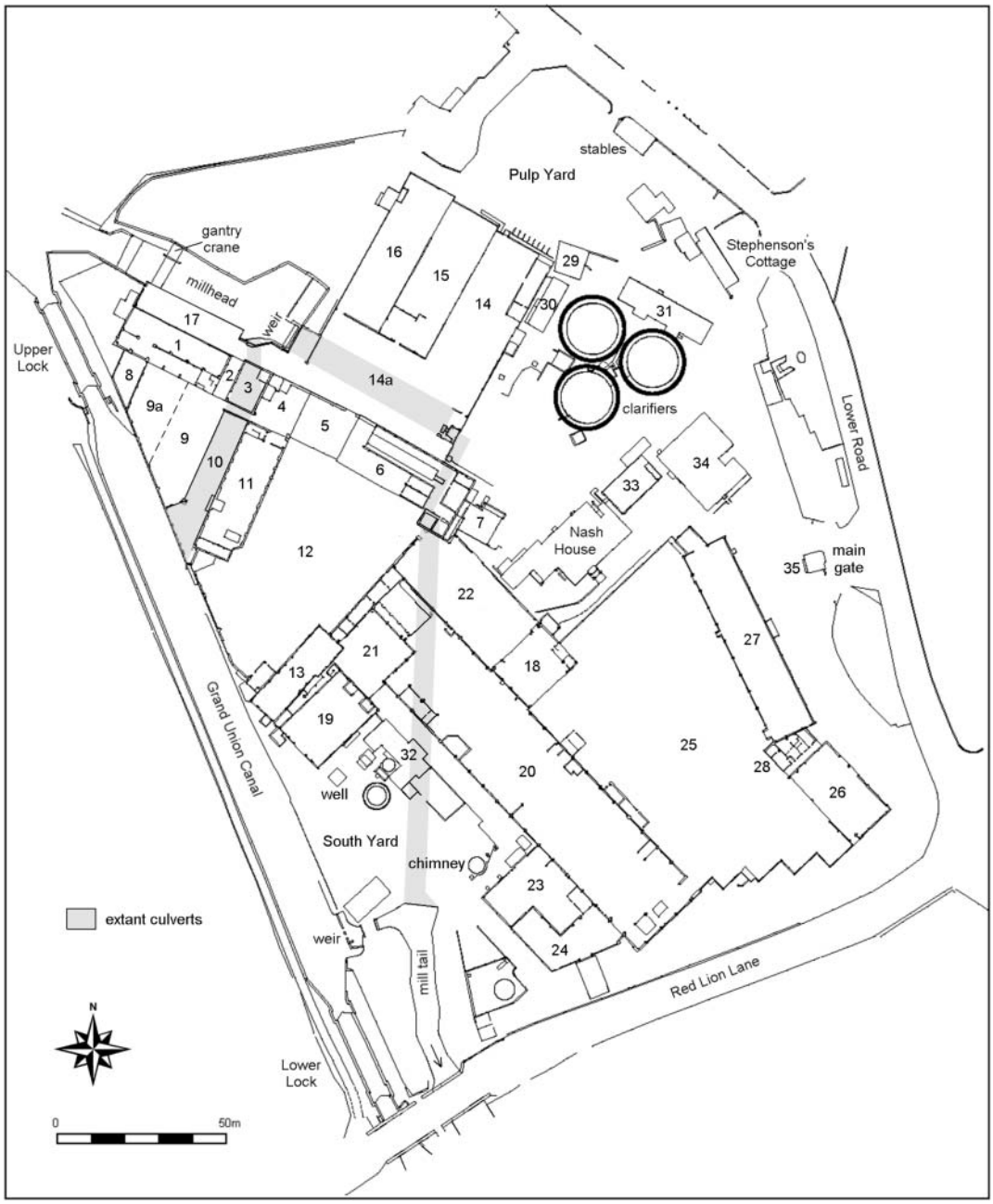

Figure 6.
Plan of the mill, showing structures referred to in text.

respectable Georgian dwelling) these fall into two groups: the North Mill, comprising mostly 19th- and early 20th-century structures (Buildings 1–17), and the South Mill, consisting of buildings of mid- to late 20th-century date (Buildings 18–36).

Considering the date range of the mill buildings, their construction details are remarkably consistent. Most buildings are of brick, allied with framing of iron or steel in the earlier buildings and reinforced concrete framing in more recent structures. Exceptions to this are Buildings 14, 15, 16, 21 and 22, which are steel framed with corrugated sheet cladding, and Buildings 23 and 24, which are steel framed, partly brick/block infill, partly clad. All floors are of reinforced concrete: upper floors have supporting iron or steel joists. Roofs are mostly iron or steel framed, clad in corrugated sheet, which evidently replaced slates on parts of the North Mill. Only Buildings 3 and 11 have timber-framed roofs. Building 25 has a distinctive arched concrete roof, cast *in situ*.

At the time of the survey virtually all machinery had been removed from the site, and some services had been stripped out. Where possible, machinery details were provided by former mill employees. Most buildings were equipped with electric lighting and power, and with the mill's comprehensive sprinkler system.

It is evident from the survey, and from conversations with former employees, that

Nash Mills was in a state of continuous evolution. Buildings were frequently extended (horizontally and vertically), partially or wholly rebuilt or remodelled, according to the requirements of the business. Building materials were frequently reused, and building styles did not change significantly, prior to the mid-20th century. Production machinery was moved around the site, and brought in from other mills in the group.

North Mill

The North Mill was the only area likely to contain any trace of the original 19th century structures. It occupied a triangular area between the millhead and the canal, with a later extension spanning the millhead to the north-east. Essentially the group consisted of a range fronting the millhead (Buildings 1–7, 17: Figures 6 and 7), a second range to the south-west of this (Buildings 8–13), and the third range to the north-east (Buildings 14–16). From the cartographic evidence it is apparent that there were buildings on the site of the millhead range by 1819, before the millhead was enlarged to its greatest extent and a wharfage over 100m in length was created. This was done between 1839 and 1856, bypassing a pronounced loop in the river to the north-east, which was then backfilled. The millhead range was rebuilt in 1879: its north elevation, reconstructed from photographs, is shown in Figure 7. Since that date the range has been almost totally rebuilt. The layout of structures to the rear of the millhead range has slightly later origins: buildings are first shown there on the 1839 Tithe map. The third group of buildings was much more recent, constructed in 1927/8 and linked to the millhead range in the 1950s.

From the historical evidence and the survey it was apparent that the primary manufacturing processes in the North Mill remained in the same locations on the site from at least 1856 to the end of production there in 1982, though the buildings containing them were frequently altered or rebuilt. It was therefore possible to identify the original and subsequent historical manufacturing process flow within the mill, though little physical evidence of manufacture remained.

Used rags were brought to the mill by canal, and are believed to have been stored and processed in the millhead range, where buttons and other fastenings were removed, seams were picked and the rags were washed. After 1856 the washhouse was located to the west of Nash House, south of the millhead range. Between 1909 and 1925 it was demolished and replaced by a larger building, constructed against the south wall of the water tower (Building 7). The interior tiling of the north end of this building survives on the south wall of the tower. This later washhouse was latterly used as an electrician's store and workshop, and was demolished in the 1980s.

After processing, the rags were sent to the Beater House to be turned into stuff. The Beater House (Building 6) was located at the east end of the millhead range. In 1856 the stuff production areas, namely the 'Steeping Room', 'Rag Engines' (i.e. beaters), 'Mill', 'Half Stuff and Stuff Room' appear to have been housed in several linked buildings at the east end of the millhead range. At this time the rag engines were still powered by a waterwheel. In 1879, as part of the general rebuild of the mill, the Beater House (Building 6) was constructed to bring all the beaters under one roof, at one level. In 1900, a battery of new beaters and stuff chests was installed. More beaters were added in 1910. In 1928 the Beater House was rebuilt in its present form, with the addition of a third storey. The upper floors contained the beaters and other machinery for stuff production. The ground floor housed two banks of stuff chests, from which stuff was piped as required to the paper machines in the adjoining Machine House (Building 12). The chests were installed in the early 1900s, and had gone out of use by 1975. One bank was removed in the 1980s: the other survived, and was recorded during the survey (Figure 8).

The surviving bank of seven chests was constructed in reinforced concrete, lined internally with ceramic tiles. Internally the chests each measured 2.78 × 2.99m, and *c.* 4.7m from floor to ceiling. The chests originally extended through the floor level above, and were open-topped. The bottom of each chest was semicircular in profile, to accommodate an agitator consisting of two large spoked iron wheels linked by paddles, chain-driven by an electric motor located above the passage between the banks of chests. Pipes above this passage fed in fresh stuff from the floors above.

On the north side of the surviving chests were passages on two levels. The lower passage provided access to the agitator bearings and the washout valves for each chest, which emptied into a drainage channel leading into the mill tailrace. The upper passage contained three tile-lined channels running its full length, truncated at the west end. Each chest had an iron valve box on its outer face above the channels, controlled by a worm gear and wheel. At the top of each revolution, the agitator paddles lifted stuff into the valve boxes, whence it passed into a sloping concrete tray crossing the channels. In the tray above each channel was a tapered hole.

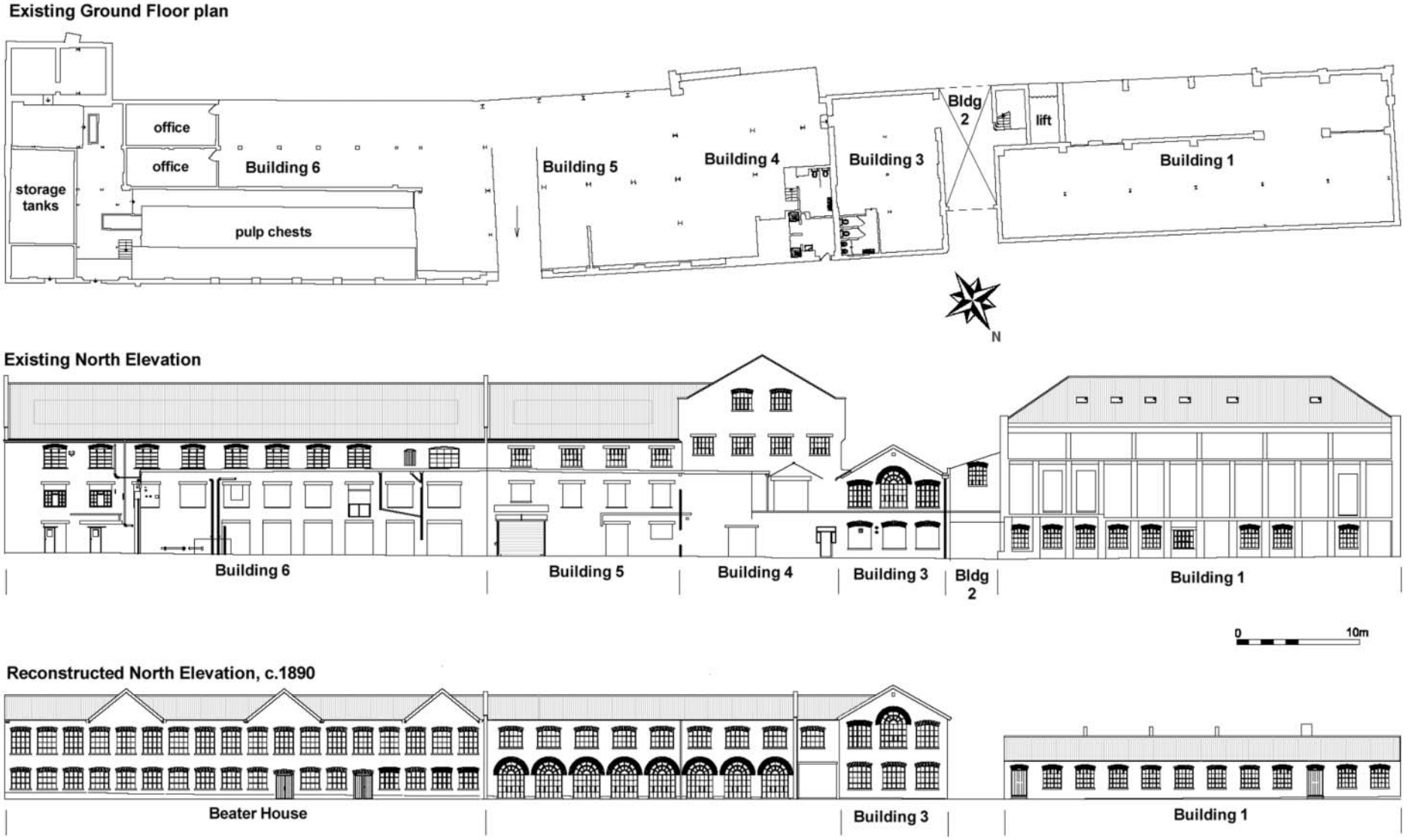

Figure 7.
The millhead range (Buildings 1–6), plan and elevations (2008), and reconstruction of elevation, c. *1890.*

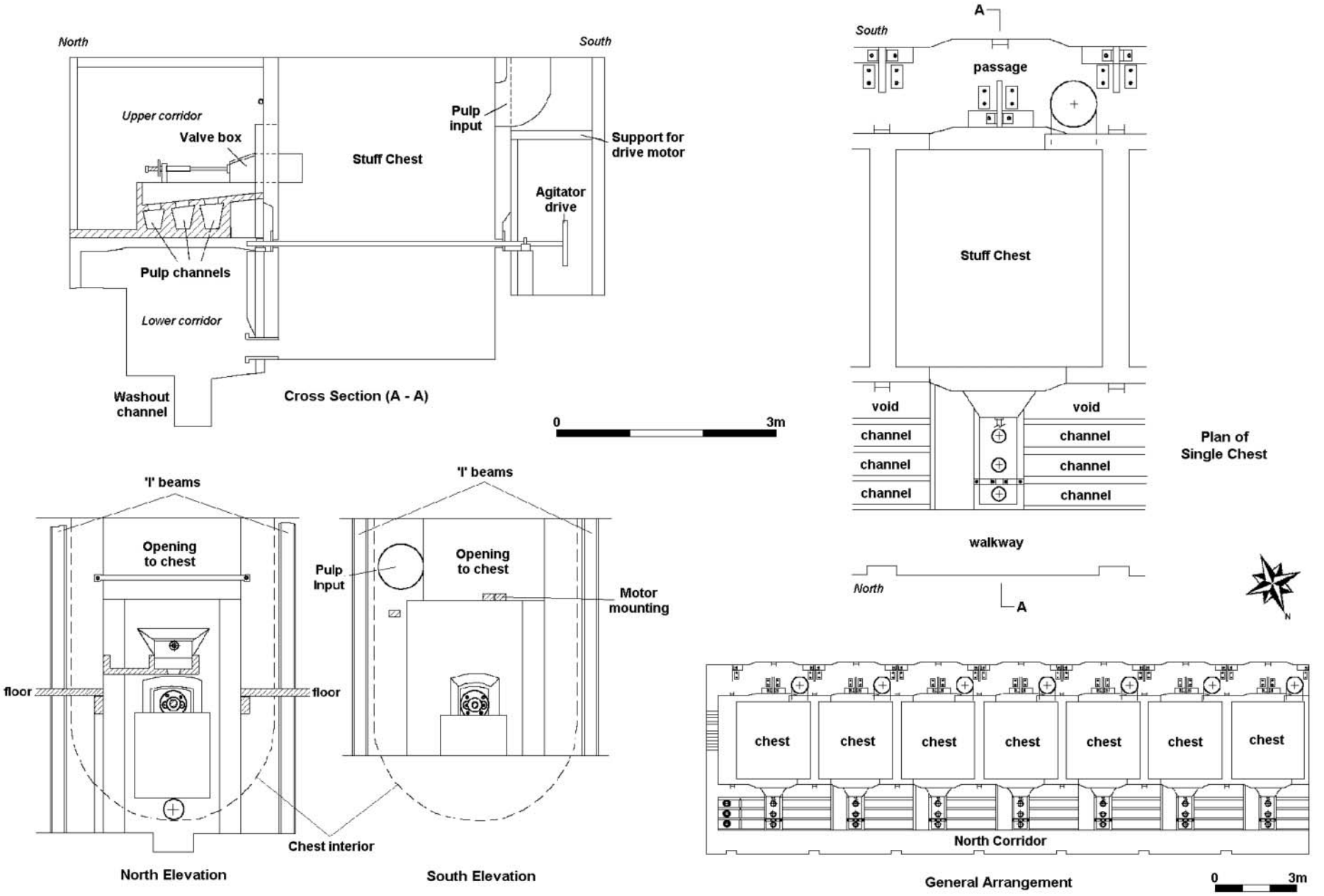

Figure 8.
Beater House, Building 6: stuff chests.

The evidence suggests that it was possible to select the desired channel by inserting or removing plugs from these holes, though none survived *in situ*. Each channel delivered stuff to a duplex or triplex pump, which in turn fed it to the paper machine chests.[60]

The Machine House, where the papermaking machines operated (Building 12) was located to the south of the Beater House. From the cartographic evidence, it is apparent that the Machine House was certainly in this location in 1856, possibly since at least 1839. It was rebuilt in 1879, and lengthened in 1900, by which time it housed two machines. It was further extended to the south-east, probably in 1933, when a third machine was installed.

Building 12 was the largest structure in the North Mill, with maximum dimensions of 68.7 × 47.8m, rising to a height of 15.6m. It was lit by clerestory windows and rooflights above the central aisle, and also originally by a very large window, now bricked up, in the south wall. Its cathedral-like interior comprised three aisles, each of which originally housed a papermaking machine. The western and central aisles each had rails for a travelling crane down their length: only the crane in the western aisle remained. In the roof spaces were pipes for a ventilation system, and the clerestory windows above the central aisle contained a number of large extractor fans. The floor had been re-laid when the building was converted for warehousing in the 1980s; no trace of machine beds, drains or services remained. Cartographic evidence suggests that a machine house was established here following the 1813 fire, and that the building was successively lengthened and widened to accommodate additional and larger papermaking machines. The structure examined in the survey probably dates from 1879, and was extended in length in 1900. It was widened to the west after 1911, and its east aisle was added to accommodate the No. 3 board machine installed in 1933.

On the south-east side of the Machine House was the Compressor House (Building 13), a two-storey structure comprising a reinforced concrete frame with brick infill. The central part of this building appears to have been erected before 1925, and has been tentatively identified as the structure built in 1909 to house the engine that drove the machinery in the Beater House and Salle. The building was later extended to the north-east and south-west, and prior to closure housed two compressors and their power source. The only machinery remaining by the time of survey comprised three 5-ton travelling cranes.

From the Machine House, the rolls of paper were taken to the Salle (Buildings 8, 9, 9a: hereinafter referred to as the 'Old Salle') for cutting to size, finishing and packing. This area of the North Mill, originally a triangular island separated from the rest of the site, was largely undeveloped in 1856, containing only the smith's shop and a row of sheds used for storing waste paper. At that time a building referred to as the 'Old Salle' was to the east of the bypass channel. Documentary evidence revealed that the earliest structure on the site of Building 9 was a freestanding open-sided, iron-framed shed with a curving roof, *in situ* by 1898. The Old Salle observed on site during the survey was built in 1934 and probably comprised Buildings 9 and 9a and possibly Building 8, which was the management office for the finishing department. As recorded, Building 9 was a two-storey structure, with distinctive rooflights of the 'Northern Lights' type. Its upper floor was accessed from Building 1, and at one stage it was linked by a bridge to the first floor of Building 11.

In 1911, a three-storey warehouse for paper storage (Building 11) replaced two buildings in the centre of the mill. From the 1856 plan it is evident that the demolished buildings were the original salle and the adjoining smith's shop and forge, both probably dating from the 1813 rebuild. The warehouse was originally a freestanding building of 12 bays, with an enclosed stairwell at its north-west corner, and an elevator linking all floors on its east side. From the ground and first floors, electric travelling hoists spanned the adjoining canal dock. After 1934, the upper hoist was extended into the first floor of Building 9.

Building 4, to the immediate north of Building 11, appears to have been built as an extension to the latter. To provide access to all four floors of the extension, a new elevator rising to the attic of Building 11 was installed on the north-west side, and the earlier elevator was removed. This later elevator carries the date '1949', providing an indication of the likely date of Building 4.

Until the advent of modern road transport, most finished paper products left the North Mill by canal. Building 10, which formed the northern part of the Old Salle at the time of the survey, was originally an open canal dock, fed at its northern end by an overflow sluice from the millhead. It is first shown on the 1839 Tithe map, and appears to have replaced an earlier channel connecting the millhead and mill tailrace. The dock was partially covered by a glazed roof in the 1920s, removed by 1938 (Figure 9). It appears that the dock had gone out of use by 1963, when the present roof was put in, and concrete piles were inserted into the dock to support a reinforced concrete floor. The dock survived as a bypass channel, the flow of water being controlled by a sluice on the millhead.

Figure 9.
The millhead range, c. *1930, from the north-west (Apsley Paper Trail).*

Building 1, at the west end of the millhead range, was probably the earliest surviving structure in the mill. Its northern half occupied the same footprint as the Smith's Shop shown on the 1856 plan, and its northern ground-floor elevation resembled the single-storey building shown in a photograph of the 1890s. It was subsequently extended in width and given an upper floor with a windowless north elevation, carrying the date '1913'. In the 1960s it was widened a second time by means of an inserted, concrete-framed structure (Building 17), and another floor was added. Access to the upper floors was by an enclosed stairway and an elevator, both in the south corner. The building was last used in the 1980s as the export warehouse.

The water tower (Building 7) at the east end of the millhead range was built in 1909, on the site of a two-storey cottage shown on late 19th-century plans and photographs. As previously noted, the tower fed an underground fire main, installed at the same time throughout the North Mill. The tank had a potential capacity of 160,000 litres (35,000 gallons). At the time of the survey, the ground floor of the tower housed the building maintenance department; on the first floor were a mess room and electrical store, connected to the Beater House by a covered bridge.

In 1927/8, new raw material stores were constructed to the north of the millhead, with a process bay for preparatory dusting, sorting and pulping (Buildings 14, 15, 16). These structures were steel framed, clad with corrugated sheeting. The westernmost (Building 16) was the store, with a travelling crane for moving materials. Adjoining this was the process bay (Building 15), which had two floors housing a pulper, vats, etc. Pipes from the upper floor were carried to the Beater House on a high level bridge. When surveyed, the easternmost part (Building 14) contained the rails for a travelling crane, but no other fixtures.

As built, the roofs of these buildings extended above the millhead, forming a covered dock for unloading raw materials brought by canal. With the decline of canal carrying in the 1950s, the east end of the millhead was culverted, and the roof and outer walls were extended to link with the Beater House, forming an enclosed loading area for lorries (Building 14a).

South Mill

The whole of the South Mill was constructed on a greenfield site between 1955 and 1984. Details of structure and use are available in the full report on the site, a copy of which is held in the Hertfordshire CC Historic Environment Record. Briefly, the buildings comprised: the Engineer's Shop (Building 18); the No 4 Machine Shop (Building 20); the Stock Preparation Room (Building 21), housing the steel tanks which superseded the stuff chests in 1983; the complex consisting of the

Figure 10. New Salle, Building 25: under construction, 1963 (Apsley Paper Trail)

New Salle (Building 25 — Figure 10), Goods Reception (Building 26), Reel Store (Building 27) and Surgery (Building 28); and a variety of smaller buildings related to power provision, provision of process water, effluent treatment, welfare and office space.

CONCLUSION

Papermaking was carried out at Nash Mills from the mid- to late 18th century. The first purpose-built paper mill at Nash was constructed in the 1790s, manufacturing paper by hand. Although the survey indicated that no process structures of this period remained on site, a detailed description survives of the buildings and their uses. This mill was destroyed in the fire of 1813, and was rebuilt to take advantage of the papermaking machinery invented and developed by the new owner John Dickinson. Although no surviving parts of this phase of the mill were identified, it is likely that its layout, and the location of the various papermaking processes within it, influenced the subsequent development of the North Mill.

The archaeological survey confirmed that buildings at Nash Mills were frequently extended, both horizontally and vertically, and were often partially or wholly rebuilt or remodelled. These alterations seem to have been largely due to changing production requirements, although damage caused by the stresses and strains of use may have been a factor. Building materials (*eg* bricks, window frames) were often reused on the site, and building styles did not change significantly prior to the mid-20th century. Machinery was both moved around the site as production needs dictated, and brought in from other mills in the group. Consequently, precise dating of many of the buildings in the North Mill was difficult, and might have proved impossible without reference to the significant amount of historical and photographic evidence available.

By the time of the survey, all machinery relating to the papermaking process had been removed from the mill, mostly for reuse elsewhere. The only machinery remaining had been tailor-made for the site (*eg* elevators, travelling cranes, tanks and silos), and was presumably uneconomic to dismantle and relocate. Most fixtures were relatively modern, and did not appear to be of any significance beyond their relationship to the building in which they were located, or the function they performed. One group of early 20th-century stuff chests in the ground floor of the Beater House was recorded as part of the project. It is interesting to note that No. 4 Machine House, built in 1964, contained stuff chests that appeared to be of the same design and construction.

Nash Mills was the last of John Dickinson's paper mills in the Gade valley to close,

marking the end of a prominent local industry. In 2009 only Frogmore Mill, now the home of the Apsley Paper trail, remains standing. Research undertaken for this project indicates that 19th-century paper mills are an obsolete, poorly documented and fast-disappearing class of building. As with every class of structure, comparative study is the real key to understanding; other paper mills of this period also require detailed recording and analysis, before the opportunity is lost.

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