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Late Holocene Occupation and Resource Use in the Sub-Coastal Moreton Region: The Open-Air Howard Creek Site, Southeast Queensland

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ABSTRACT

This paper reports archaeological investigations at the Howard Creek site, a Late Holocene open-air site in the sub-coastal Moreton region of southeast Queensland. The site adds to a regional record based largely on rockshelter excavations. Development-led salvage investigations included excavation, radiocarbon dating, lithic analysis, and use-wear and residue studies. Six radiocarbon determinations provide a broad chronological framework for site use during the last approximately 2000 years. The catalogued assemblage comprises 11,990 artefacts, of which 10,279 from two trenches were included in the lithic analysis. Artefact densities reach 2,016 per square metre within one excavation square. Chert constitutes 81.3% of the analysed assemblage and probably derives largely from the nearby Wongawallan Jasper Quarry. Cores and debitage indicate stone-working. Use-wear and residue analysis of eight selected artefacts provides evidence for plant processing and animal-tissue or bone processing. The assemblage suggests recurrent use of the locality for stone-working and other activities. Post-depositional mixing limits the chronological placement of particular artefacts and activities and the assessment of changes in occupation intensity. Howard Creek contributes further evidence for Late Holocene land use and activities beyond the rockshelter record.

RÉSUMÉ

Cet article présente les investigations archéologiques à Howard Creek, un site de plein air de l'Holocène récent dans la région sublittorale de Moreton, au sud-est du Queensland. Les fouilles préventives complètent un corpus régional principalement issu des abris sous roche. Elles comprennent des datations radiocarbone, une analyse lithique et des analyses tracéologiques et de résidus.

Six datations fournissent un cadre chronologique général couvrant les deux derniers millénaires. L'inventaire compte 11 990 artefacts, dont 10 279 provenant de deux tranchées ont été inclus dans l'analyse lithique. La densité atteint 2 016 artefacts par mètre carré dans une unité de fouille. Le chert représente 81,3 % de l'assemblage analysé et provient probablement en grande partie de la carrière voisine de Wongawallan Jasper Quarry. Les nucléus et les déchets de taille indiquent le travail de la pierre. L'analyse de huit artefacts sélectionnés révèle des traces de traitement de végétaux et de tissus animaux ou d'os.

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L'assemblage suggère une fréquentation répétée. Le remaniement des dépôts limite toutefois l'attribution chronologique des artefacts et des activités, ainsi que l'évaluation des changements d'intensité d'occupation. Howard Creek enrichit la documentation des activités de l'Holocène récent au-delà des abris sous roche.

1 | Introduction

This paper presents the results of archaeological investigations at the Howard Creek site, located in the Gold Coast suburb of Wongawallan, southeast Queensland. Much of the published archaeological evidence from the sub-coastal Moreton region comes from rockshelter excavations. The Howard Creek assemblage contributes to this regional record by providing evidence of Late Holocene activities in an open-air setting.

The investigations were undertaken as part of a development-led salvage program associated with the proposed upgrade of Tamborine–Oxenford Road. Although the excavation was confined to the proposed development area, the work generated a substantial archaeological dataset.

The aim of this study is to examine the use of the Howard Creek site during the Late Holocene. The radiocarbon determinations are considered together with evidence of site formation to assess the time span represented by the deposits. Since the deposits have been affected by post-depositional mixing, the interpretation also considers the extent to which particular artefacts and activities can be placed within this chronology.

The lithic assemblage and its spatial distribution are examined for evidence of stone-working. Use-wear and residue analysis provides further information on the activities represented by the selected artefacts. The results are then considered in relation to other open-air and rockshelter sites in the sub-coastal Moreton region and southeast Queensland more broadly.

2 | Archaeological Background

Southeast Queensland has seen more than six decades of sustained archaeological research. Early work included Ponosov's (1965) survey of southern Moreton Bay and Moreton Island, excavation of a shell midden near Caloundra (Tugby and Tugby 1965), and investigations at Broadbeach (Haglund 1968; Haglund-Calley and Quinnell 1973). Subsequent research has concentrated largely on coastal areas, while the sub-coastal Moreton region has received comparatively less attention (Hall 1999; Ulm 2002; Robins et al. 2015).

Open-air investigations have provided some of the earliest evidence for Aboriginal occupation in the wider region. Excavations at Wallen Wallen Creek on Minjerribah (North Stradbroke Island) established a Pleistocene occupation sequence (Neal and Stock 1986). More recent investigations place initial occupation at Wallen Wallen Creek between approximately 30 ± 6 and 49 ± 8 ka, and at Middle Canalpin Creek A (MCA20), on the same island, between 38 ± 8 and 41 ± 8 ka. Both sites also contain Holocene assemblages, including shell midden deposits (Adams et al. 2024). At Cobaki sand ridge in northern New South Wales, stone artefacts occur in sands dated to approximately 39 ka, although their chronological association remains uncertain. The upper deposits also contain a late Holocene shell midden (Robins et al. 2015). These localities are coastal today but were farther inland during periods of lower sea level (Adams et al. 2024; Robins et al. 2015). They provide a broader regional context for the open-air evidence from Howard Creek.

Much of the published archaeological record of the sub-coastal Moreton region comes from rockshelter excavations. The Moreton Region Archaeological Project (MRAP), launched by Jay Hall in 1976, contributed substantially to this record (Hall 1980). Between the 1970s and 1990s, eight sub-coastal rockshelter sites were investigated: Bushrangers Cave (Hall 1986; Hiscock and Hall 1988a; Kearney 1998); Brooyar Rockshelter (McNiven 1988); Maidenwell Shelter (Morwood 1986); Platypus Rockshelter (Hall et al. 1988; Hall and Hiscock 1988a; Hiscock and Hall 1988b); Gatton Rockshelter (Morwood 1986); Boonah Shelter (Burke 1988); Christmas Creek (Bonica 1992); and Bishop's Peak (Edmonds 1986) (Figure 1). Among these shelters, Bushrangers Cave has the earliest evidence of occupation, extending to around 10,000 cal BP (Kearney 1998; Williams and Ulm 2014). Other shelter sequences were established within the last approximately 6000 years. Increased cultural discard is evident at many sites after approximately 3000–2500 BP, although the timing and character of changes in site use vary between sequences (Hall 1999; Morwood 1986, 1987).

Lilley (1978) developed a model of sub-coastal subsistence and settlement based largely on historical sources and environmental information, at a time when archaeological evidence was limited. The model proposed seasonal aggregation along rivers in winter and dispersal into smaller upland camps in summer. Subsequent survey research examined site-location patterns and their relationship to environmental resources, providing an archaeological basis for assessing this proposed pattern of land use (Lilley 1982, 1984, 1985).

Development-led cultural heritage investigations have also generated substantial archaeological information for the region. Much of this evidence is documented in unpublished consultant reports, some of which have subsequently provided data for theses and published studies. McLaren's (2002) petrological study of Wongawallan jasper incorporated information from cultural heritage reports, while Clarkson and Bellas (2014) combined published and grey literature with data from museum and university collections to model regional lithic source zones. These studies demonstrate the extent of archaeological information available beyond the better-known excavated sequences.

Other work has addressed the organisation and comparative use of regional archaeological data through database design,

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FIGURE 1 | Location of the Howard Creek site and comparative sites in southeast Queensland and northern New South Wales. Site locations are approximate. Basemap: Esri Topo Maps.

classification and geographic information systems (GIS) (Smith 2000), and the compilation of radiocarbon and luminescence ages in AustArch (Williams and Ulm 2014; Williams et al. 2014). Nevertheless, detailed published accounts of individual sub-coastal open-air assemblages remain limited. Publication of the Howard Creek investigations makes a development-led excavation dataset available for comparison with regional open-air and rockshelter records and for further analysis of occupation and resource use.

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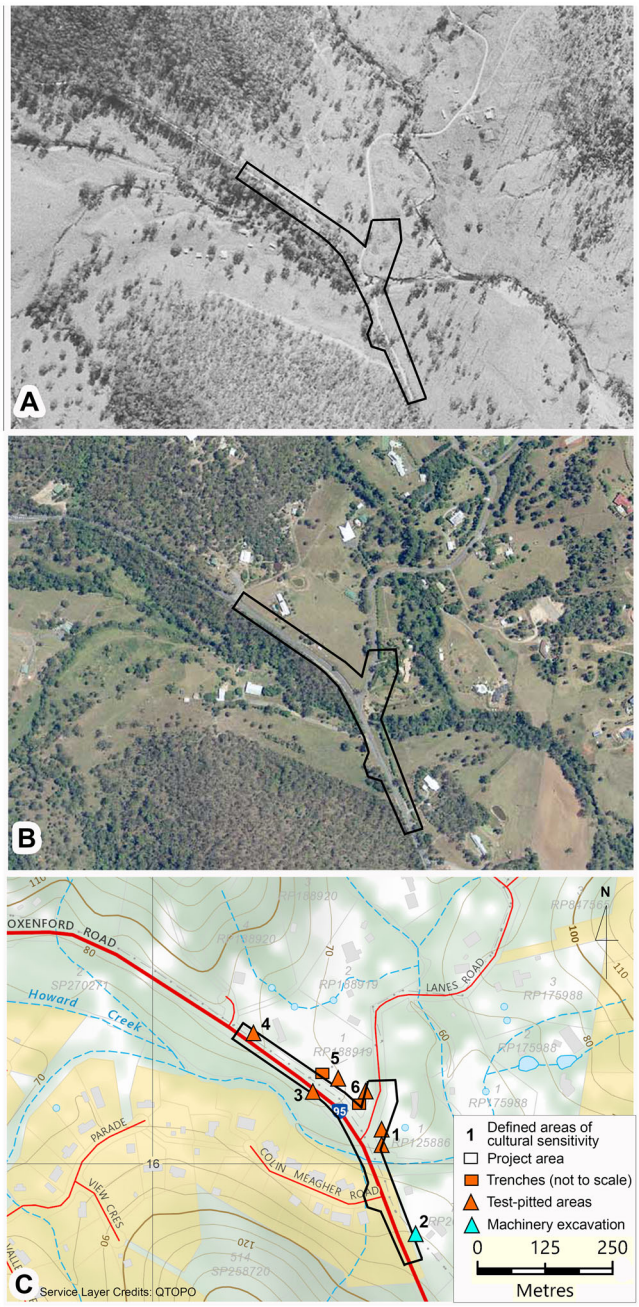


FIGURE 2 | Howard Creek project area in its landscape and topographic context. (A) Aerial photograph of Wongawallan, Queensland, 1955; (B) aerial photograph of Wongawallan, Queensland, 2002 (both photographs: Queensland Department of Natural Resources, Mines and Energy); (C) topographic map (*source*: QTopo, Queensland Government).

3 | Setting

The project area lies in the sub-coastal foothills of the Darlington Range, at the confluence of Howard and Wongawallan Creeks within the Coomera River catchment (Figures 1 and 2). The site occupies terraces of Howard Creek in a valley bordered by hills. Wongawallan Mountain, the location of the Wongawallan Jasper Quarry, lies to the northeast (Clarkson and Bellas 2014; McLaren 2002).

In the Moreton region, the present sea level was established after 3300 BP, while the modern El Niño–Southern Oscillation (ENSO) regime was established around 4500–3000 BP (McPhee 2017,8).

Landform units within the project area include creek floodplains, terraces and the adjoining foothills of the Darlington Range (Table 1; Figure 3). Excavations revealed alluvial deposits and evidence of recent disturbance, particularly associated with road construction.

4 | Methods

4.1 | Archaeological Investigation

The archaeological investigation aimed to recover as much information as possible before the proposed road upgrade, within the time and budget available. A total of 20.5 m^2 was excavated. Since the investigation was confined to the proposed development, the full extent of the Howard Creek site remains unknown.

Fieldwork was conducted in two stages. The exploratory stage covered the project area, with recovery methods adapted to the degree of contemporary disturbance (Figure 2C; Table 1). In Areas 1, 3, 4, 5 and 6, twenty-one 0.5 × 0.5 m test pits (TP) were excavated by hand to culturally sterile deposits. In Area 2, three 2 × 1 m trenches were machine-excavated, while surface material in Area 3 was recovered using a shovel, rake and sieve.

The second stage expanded selected test pits to investigate substantial artefact concentrations (Figure 2C). Trench 1, in Area 6, comprised eleven 0.5 × 0.5 m squares (2.75 m^2), including TP 7 and TP 11. Trench 2, in Area 5, comprised thirty 0.5 × 0.5 m squares (7.5 m^2), including TP 12 and TP 13, within a 2.5 × 3 m area.

During both stages, deposits were excavated in 5 cm spits and sieved through a 5 mm mesh. In situ artefacts were plotted on a plan. Gravel accumulations and charcoal concentrations were also mapped. Field recording included photographs, soil profile descriptions and drawings, and GPS locations. Recovered material was bagged and labelled for analysis, and test pits were backfilled after recording.

4.2 | Radiocarbon Dating

A total of 21 charcoal and bone samples were collected from deposits in Trenches 1 and 2 (Table 2). The bone samples were not submitted for dating because of their poor preservation. Six in situ charcoal samples were selected for accelerator mass spectrometry (AMS) radiocarbon dating, with three from different depths in each trench to provide a broad chronological framework. The remaining material was retained for possible future dating. No sufficiently large charcoal sample was available from the base of Trench 2, so its basal age could not be established.

The samples were submitted to the University of Waikato Radiocarbon Dating Laboratory, New Zealand. They were washed in hot HCl, rinsed and treated with repeated hot NaOH washes. The NaOH-insoluble fraction was then treated with hot HCl, filtered, rinsed and dried. Ages were calibrated using OxCal version 4.4.4

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TABLE 1 | Results of the exploratory stage of the archaeological investigation at the Howard Creek site.

LU	Description of landform unit	Feature	Chert	Silcrete	Quartzite	Quartz	Chalcedony	Complete flakes	Broken flakes	Cores	Other finds
A	Northern bank, creek floodplain—a low, flat area next to the creek bed, below 60 m a.s.l. Two test pits (Area 1, test pits 1 and 2), located 40 m north of the watercourse, had sediment composed of alluvial deposits that ranged from light to medium brown humic loams on top, becoming more yellow in the middle and eventually turning to clay at depths of 40 to 50 cm below the surface. The test pits did not show evidence for disturbance by contemporary development. Thus, in this environmentally dynamic area the apparent homogeneity of the Late Holocene unit may indicate taphonomic disturbance by the processes of post-depositional mixing and bioturbation.	TP1	19	1	0	0	3	7	13	2	2 ochre pieces, 1 bladelet
		TP2	5	0	0	0	0	1	3	0	1 ochre piece, 1 blade
B	Northern bank, first creek terrace—an area adjacent to a creek floodplain but slightly elevated (60–70 m a.s.l.). Nine test pits (Area 1, test pits 3–6, Area 6, test pits 7–11) and Trench 1 were excavated in this area. The deposits in these areas are of alluvial origin, but thinner than those found in the floodplain below. Characterised by brown and dark-brown loams on top, the deposits become lighter and more clay-rich towards the bottom. TP8, located close to Lanes Road which cuts through the terrace, showed disturbance by two possible cut-and-fill events. Contemporary material such as bottle glass and metal screws were found in the topsoil of some test pits, located 0–20 cm below the surface (TPs 3 and 6 in Area 1 and TPs 8 and 10 in Area 6).	TP3	20	4	0	0	0	2	21	0	1 bladelet
		TP4	25	1	0	0	1	2	23	2	
		TP5	32	3	1	0	0	6	30	0	
		TP6	8	0	2	0	0	1	8	1	
		TP8	22	4	0	0	0	3	23	0	
		TP9	24	0	0	0	0	5	19	0	
		TP10	10	0	0	0	0	3	7	0	
		Surface	22	1	0	0	1	8	14	2	

(Continues)

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TABLE 1 | (Continued)

LU	Description of landform unit	Feature	Chert	Silcrete	Quartzite	Quartz	Chalcedony	Complete flakes	Broken flakes	Cores	Other finds
C	Northern bank, second creek terrace—an area further elevated from the creek (70–80 m a.s.l.). Eight test pits (Area 5, test pits 12–15, Area 3, test pits 18–21) and Trench 2 were excavated on this terrace, which is crossed by Tamborine–Oxenford Road. Cultural material found on the western side of the road was defined as Area 3 and that found on the eastern side was defined as Area 5 (Figures 2 and 3). The deposits in each area slightly differ. Area 3 is located on a slope towards Howard Creek and covered with dense regrowth vegetation. The deposits consist of a mixture of alluvial materials, including grey-brown sandy loam at the top followed by dark grey-brown clay loams with small gravel inclusions, then turning to clay at a depth of 10–25 cm and becoming red-brown clay at 25–30 cm depth. Area 5 is located on a flat terrace elevated above Howard Creek, which probably was not subject to frequent flooding in the past. The soils in TPs 12 and 13 were undisturbed by contemporary development and composed of dark brown to brown humic loam becoming more yellow and clay-rich at 20–25 cm depth, and finally becoming red clay at 25–30 cm depth. TPs 14 and 15 were located 30 m southeast on the edge of the terrace and showed some disturbance. TP14 featured disturbance at a depth of 15–30 cm which was characterised by a mixture of dominant brown clay loam with underlying yellow clay loam. TP15 was located 1 m east of TP14 and reached culturally sterile red clay at a depth of just 10 cm. TP14 also contained a burnt tree stump in the northwest corner of the pit.	TP14	378	27	6	7	0	109	288	3	2 artefacts of unidentified material, 5 blades, 14 bladelets, 1 pebble tool
		TP15	5	0	0	0	0	1	4	0	
		TP18	50	7	4	0	0	19	39	1	1 blade, 1 bladelet
		TP19	29	5	0	0	0	14	19	1	
		TP20	39	7	1	0	1	19	24	2	1 blade, 2 bladelets
		TP21	42	5	2	0	1	7	34	3	1 basalt artefact, 1 blade, 6 bladelets
		Surface	50	2	0	1	0	7	44	1	1 bladelet
		Salvage	153	9	6	0	0	38	115	7	7 blades, 1 bladelet

(Continues)

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TABLE 1 | (Continued)

LU	Description of landform unit	Feature	Chert	Silcrete	Quartzite	Quartz	Chalcedony	Complete flakes	Broken flakes	Cores	Other finds
D	Northern bank, third creek terrace—the last flat area above the creeks, located right at the foothill of the Darlington Range (80–90 m a.s.l.). Two test pits (Area 4, test pits 16 and 17) were excavated in the seemingly undisturbed northwest corner of Lot 1RP188919. The deposits consisted of brown humic loams and reached a sandstone bedrock at a depth of 15–20 cm.	TP16	24	3	0	5	0	6	26	0	1 artefact of unidentified material, 1 blade
		TP17	22	4	1	0	0	2	23	0	2 blades
		Surface	175	13	2	2	4	30	141	15	8 blades, 2 bladelets
E	Southern bank, second creek terrace (70–80 m a.s.l.)—an area highly disturbed by current development. Machinery excavations in this area showed deposits consisting of grey-brown sandy loams on top and yellow clay with sandstone gravels below, at 15–25 cm depth.	Scrape 1	51	0	1	0	0	8	41	2	1 blade
		Scrape 2	103	11	1	0	1	9	101	2	3 blades, 1 bladelet
		Scrape 3	94	10	1	1	1	20	74	6	6 blades, 1 bladelet
		Surface	33	1	0	0	0	5	26	2	1 blade

*Note:*Blank count cells indicate zero. Test pits 7, 11, 12 and 13 are excluded because they were incorporated into the trenches. Raw-material and artefact-category columns are separate summaries and should not be added together. Blades and bladelets are listed in Other finds and are excluded from the complete- and broken-flake columns.LU = landform unit; TP = test pit; a.s.l. = above sea level.

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TABLE 2 | Radiocarbon dating results.

WK code	Material	Area	Square/ spit	Depth below surface (cm)	Context	AMS age (BP)	Calibrated intervals (95.4% probability)
53242	charcoal	6	C2/ 3	14	Brown humic clay loam with loosely dispersed small to medium concentrations of charcoal. Two artefacts in this square/spit, both recorded in situ; none from sieving.	160 ± 16	1680–1740 cal AD (26.8%) 1800–1900 cal AD (49.2%) from 1920 cal AD (19.4%)†
53243	charcoal	6	D3/ 5	25	Light-brown humic clay loam with loosely dispersed charcoal. Seven artefacts in this square/spit: two recorded in situ and five from sieving.	220 ± 15	1660–1690 cal AD (15.4%) 1730–1810 cal AD (80.1%)
53244	charcoal	6	C5/ 10	50	Yellow clay. The charcoal sample was collected beneath a stone at a depth of 50 cm in the northwest corner of Square C5. One chert angular fragment was recovered from sieving.	2067 ± 18	100–80 cal BC (1.7%) 70 cal BC–30 cal AD (93.8%)
53245	charcoal	5	B6/ 3	15	Brown clay loam with loosely dispersed small to medium concentrations of charcoal in the central part of the square. Twenty-nine artefacts in this square/spit: three recorded in situ and 26 from sieving.	356 ± 15	1500–1600 cal AD (81.5%) 1610–1640 cal AD (14.0%)
53246	charcoal	5	D2/ 4	17	Brown clay loam with large charcoal fragments and loosely dispersed small to medium concentrations of angular gravel. There were 269 artefacts in this square/spit: 123 recorded in situ and 146 from sieving.	1673 ± 16	360–480 cal AD (92.4%) 510–530 cal AD (3.0%)
53247	charcoal	5	E1/ 5	22	Light-brown to yellow clay loam. There were 115 artefacts in this square/spit: 24 recorded in situ and 91 from sieving. E1 was a partial square adjacent to TP12.	1530 ± 15	540–640 cal AD (95.4%)

*Note:*Artefact counts refer to all catalogued finds from the corresponding square and spit, rather than to closed associations with dated charcoal. † The youngest interval for Wk-53242 has no resolved upper endpoint in the reported calibration output.AMS = accelerator mass spectrometry; BP = before present (AD 1950); cal = calibrated; TP = test pit.

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FIGURE 3 | Location of Areas 1, 3, 5 and 6 in the landscape (Area 4 lies farther upslope from Area 5 and is not visible). View from Area 2 (southern bank of Howard Creek) (Photograph: Irina Ponomareva).

(Bronk Ramsey 2021) and SHCal20 (Hogg et al. 2020), at a 5-year calculation resolution. Calibrated intervals are reported at 95.4% probability in Table 2.

4.3 | Lithic Analysis

Given the large size of the recovered assemblage and the budget and time constraints typical of consulting archaeology projects, a basic artefact analysis was undertaken to characterise raw materials, artefact types, technological attributes and spatial distribution. Recorded attributes included find context, colour, raw material, category, type, completeness, retouch, length, cortex, pot lidding, burning and patina.

Category and type definitions followed Holdaway and Stern (2004,111–113, 163, 180, 212–274), with minor modifications. Distal and medial flakes were grouped together, while all broken flakes retaining a platform were classified as platform-bearing flakes, combining proximal and longitudinally split fragments. Flake length was measured along the percussion axis; maximum length was recorded for angular fragments. For cores, the length of the largest flake scar was measured, and for other artefacts, maximum length was recorded.

All finds were entered in the catalogue. The assemblage analysis used 10,279 artefacts recovered in situ or by sieving from the deposits of Trench 1 (n = 599) and Trench 2 (n = 9,680), including their incorporated test pits. Surface finds, clean-up and random collections, test pits outside the trenches, and five items classified as non-artefacts were excluded. The minimum number of flakes (MNF) was estimated by adding complete flakes to platform-bearing fragments (Holdaway and Stern 2004,115). Because the latter category combines proximal and longitudinally split fragments, the MNF is treated as an operational estimate.

Mean, median, minimum, maximum, range, variance and standard deviation were calculated for eight groups: complete flakes of chert, quartz, silcrete and quartzite, and cores of each of these four raw materials (Table 3). These groups comprise 2,455 complete flakes and 112 cores (n = 2,567). The flake statistics describe percussion-axis lengths, and the core statistics describe lengths of the largest flake scars. Fragmentary flakes and cores recorded as incomplete were excluded. Blades and bladelets were excluded from the flake summaries to avoid the influence of their elongated form on the length comparisons; core tools and pebble tools were also excluded. Mean lengths were also calculated for complete chalcedony flakes and for retouched and unretouched complete flakes within each raw-material group. Sample variance used $n - 1$, and standard deviation is its square root.

Mean lengths were compared among the four raw materials using Welch's one-way analysis of variance (ANOVA), with one analysis for complete flakes and another for the largest flake scars on cores. Welch's test allows unequal group sizes and variances. The median-centred Levene test indicated unequal flake variances ($F(3, 2451) = 3.804$, $p = 0.0098$). Descriptive effect sizes were expressed as η^2, calculated as the between-material sum of squares divided by the total sum of squares.

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TABLE 3 | Length statistics for flakes and cores from Trenches 1 and 2, by raw material.

Category	*n*	Mean (mm)	Median (mm)	Maximum (mm)	Minimum (mm)	Variance (mm^2)	Range (mm)	Standard deviation (mm)
Chert flakes	1977	17.7	14.6	62.3	4.3	103.1	58.0	10.2
Chert cores	95	31.3	28.9	122.4	10.5	186.7	111.9	13.7
Quartz flakes	246	15.6	13.3	84.8	4.3	91.3	80.5	9.6
Quartz cores	2	32.3	32.3	38.7	26.0	81.4	12.8	9.0
Silcrete flakes	179	18.1	15.2	56.1	4.9	110.4	51.2	10.5
Silcrete cores	9	35.8	28.5	65.3	21.8	212.1	43.5	14.6
Quartzite flakes	53	21.0	18.8	65.0	4.8	143.6	60.3	12.0
Quartzite cores	6	28.9	27.2	49.8	12.4	179.9	37.4	13.4

Note: Flake statistics include complete flakes, excluding blades and bladelets. Cores recorded as incomplete are excluded. Flake length is measured along the percussion axis; core length is the length of the largest flake scar. Variance and standard deviation are sample estimates ($n - 1$). n = number of artefacts measured.

The length–depth analyses included all raw materials, adding 19 complete chalcedony flakes and nine complete flakes of unidentified material to the Table 3 sample. This gave 2,483 complete flakes and 112 cores (n = 2,595; 25.2% of the analysed assemblage). Ordinary least-squares regressions were fitted separately for Trench 1 (n = 100) and Trench 2 (n = 2,495), with an intercept, recorded length as the response and spit number as the predictor. These regressions combined flake lengths and core flake-scar lengths, so they describe variation in recorded dimensions rather than a uniform measure of artefact size. Spit number was treated as an excavation-depth indicator rather than a chronological variable. Residual–fitted and normal Q–Q plots were inspected; residuals departed from normality, particularly in Trench 2. Spearman's rank correlation (ρ) provided a sensitivity check.

Raw-material proportions were compared among spits using separate contingency tables for Trench 1 (n = 588) and Trench 2 (n = 9,548). These tables included all artefact categories, including fragments, of the four principal raw materials. Pearson χ^2 statistics and Cramer's V were calculated. Because expected cell counts were frequently below five, p-values were obtained using 19,999 Monte Carlo resamples with a fixed seed of 20261016. Regression and correlation tests were two-sided, with $\alpha = 0.05$ for all tests. Artefacts may derive from overlapping reduction events, so independence cannot be assumed and the tests are interpreted as exploratory. Calculations used Python with NumPy 2.3.5 and SciPy 1.17.0.

4.4 | Use-Wear and Residue Analysis

Use-wear and residue analysis was conducted on fourteen specimens from the Howard Creek site assemblage as a targeted exploratory study (Stephenson 2021). The sample selection aimed to capture diversity in artefact types from well-recorded contexts, with potential surface modification and possible use-wear or residues also considered. Table 4 presents the detailed results for eight chert and silcrete artefacts: three scrapers, four backed artefacts, including Bondi points and preforms, and a longitudinally split flake. The remaining six specimens comprised four natural stones and two specimens with indeterminate utilisation.

Initial macroscopic examination was followed by examination using a portable hand-held digital microscope, Dino-Lite AM4815ZT, under varied lighting combinations (plane, cross-polarised and oblique) at magnifications of 30–230×. All margins and surfaces were examined for edge fractures, striations, polish, surface modification and adhering residues. Observed residues were identified using morphometric analogy, including internal and external structure, their behaviour in plane and polarised light, and residue reference collections for comparison. Soil controls and comparative samples of possum scats were examined to assess possible environmental contributions to the residues.

Targeted residue removal for staining and high-powered microscopy was performed on six specimens within the full fourteen-specimen study. The Dino-Lite was used to guide focused removal of specific residues with ultra-purified water and a pipette onto pre-cleaned microscope slides. On a further specimen, adhering material was tested by applying ultra-

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TABLE 4 | Results of use-wear and residue analysis of eight selected artefacts.

No.	Artefact code	Area/ square/ spit	Material	Description	Use-wear observations	Reported residues	Interpretation
1	HC06D4IN02	6/D4/4	Chert	Scraper	High density of overlapping bending flake scars and a steep margin, consistent with scraping.	Plant fibres, phytoliths and sclereids; no starch grains reported.	Plant processing; the specific activity is undetermined.
2	HC05A1SIS5134	5/A1/5	Chert	Bondi point preform	No evidence of hafting or damage along the chord; intact tip; no polish or striations.	No use-related residues identified.	No evidence of use identified.
3	HC05C3SIS336	5/C3/3	Chert	Backed artefact/Bondi point	A series of bending flake scars and occasional step scars; striations, polish, rounding, lances and a damaged tip.	Collagenous structures, amorphous collagen, collagen fibres, fibre bundles, folded collagen, periosteum, bone-like structures, lipid-like masses and parallel collagen fibre bundles.	Animal-tissue or bone contact/ processing; the specific activity is undetermined.
4	HC05B1IN59/1	5/B1/5	Chert	Scraper	A series of bending flake scars and step scars.	High density of parallel fibre-bundle masses/ trabecular bone-like structures with lacunae; vivianite. Starch granules, interpreted as environmental.	Bone contact/ processing; the specific operation is undetermined.
5	HC05A3SIS422	5/A3/4	Chert	Backed artefact/ preform	No use-wear identified.	No use-related residues identified.	No evidence of use identified.
6	HC05C5IN01	5/C5/2	Chert	Scraper	Step and bending flake scars.	Collagen fibres, woven collagen fibre fragments and parallel collagen fibre fragments.	Animal-tissue or bone contact/ processing; the specific operation is undetermined.
7	HC05D3SIS4131	5/D3/4	Silcrete	Bondi point	Backing flake scars along the backed margin; bending flake scars along the chord. The backing scars relate to manufacture.	No use-related residues identified.	Possible animal-tissue processing. Equivocal interpretation based on use-wear only.
8	HC05A3IN77	5/A3/4	Chert	Longitudinally split flake/ notched tool	Bending flake scars and occasional step scars, rounding and polish.	High density of collagenous residue. Amorphous cellulose and an isolated starch granule, interpreted as environmental.	Animal-tissue or bone contact/ processing; the specific activity is undetermined.

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FIGURE 4 | Area 6 Trench 1, general view at the end of excavations, facing north (Photograph: Irina Ponomareva).

purified water and gently agitating it with a pipette; the material dispersed and was identified as soil. To allow differentiation between morphologically similar plant and animal residues, a selective collagen stain, Picrosirius Red (PSR), was used. Identification of collagenous material considered morphology, staining response and enhanced birefringence under cross-polarised light. The stained extracts were examined using a Leitz Dialux 22 microscope at magnifications of 200–400×. A Tucsen ISH 500 camera was used to photograph lifted residues in plane, partially polarised and cross-polarised light at magnifications of 250× and 400×.

The combinations, densities and distribution of residues were considered in association with use-wear to determine broad processing activities. Unequivocal determinations of use were made only where use-related residues occurred with corresponding use-wear. Equivocal determinations were made where use-wear alone was present. Throughout its life, a tool may have been used for multiple purposes and retouched or altered. Surviving use-wear and residues therefore provide insights into tool use but do not necessarily represent its full history.

5 | Results

5.1 | AMS Radiocarbon Age Determinations

Six AMS radiocarbon determinations were obtained from charcoal samples collected in Trenches 1 and 2 (Table 2). In Trench 1 (Area 6; Figure 4), samples from depths of 14, 25 and 50 cm yielded ages of 160 ± 16, 220 ± 15 and 2067 ± 18 BP, respectively. The youngest sample came from unit A2, the intermediate sample from the A2/B boundary and the oldest sample from the lower part of unit B (Figure 5). These determinations span approximately 1900 radiocarbon years and provide a broad Late Holocene chronology for the deposits. The small number of dated samples and the potential movement of charcoal within the deposits limit the reconstruction of sediment accumulation rates.

In Trench 2 (Area 5), the charcoal samples yielded ages of 356 ± 15 BP at 15 cm in Square B6, 1673 ± 16 BP at 17 cm in Square D2, and 1530 ± 15 BP at 22 cm in Square E1 (Table 2). The determinations span approximately 1300 radiocarbon years. All three samples were collected from stratigraphic unit A2, which varies in thickness across the trench. The samples from D2 and E1 came from thicker parts of this unit, while the sample from B6 came from a thinner part. The variation in age among samples from similar depths in different squares does not provide a simple age–depth sequence. Differences in deposition and the redistribution of charcoal through flooding, topsoil erosion associated with land-use changes, or bioturbation may have contributed to this pattern (Graves et al. 2019). The determinations therefore provide a general chronological framework, within which particular artefacts cannot be assigned securely to dated episodes of use.

5.2 | Artefact Assemblage

Most artefacts were found on the northern bank of Howard Creek (Figure 2C), including the floodplain and the three terraces. The results of the exploratory phase are presented in Table 1, excluding test pits 7 and 11 in landform unit B and test pits 12 and 13 in landform unit C, which became part of Trench 1 and Trench 2, respectively. The following description and lithic analysis concern the 10,279 artefacts recovered from the deposits of these two trenches, representing 85.7% of the 11,990 catalogued artefacts. Surface finds and material from clean-up and random collection contexts are excluded from these analytical totals. Artefact density is exceptionally high, averaging more than 1,000 artefacts per square metre on the second creek terrace of the northern bank.

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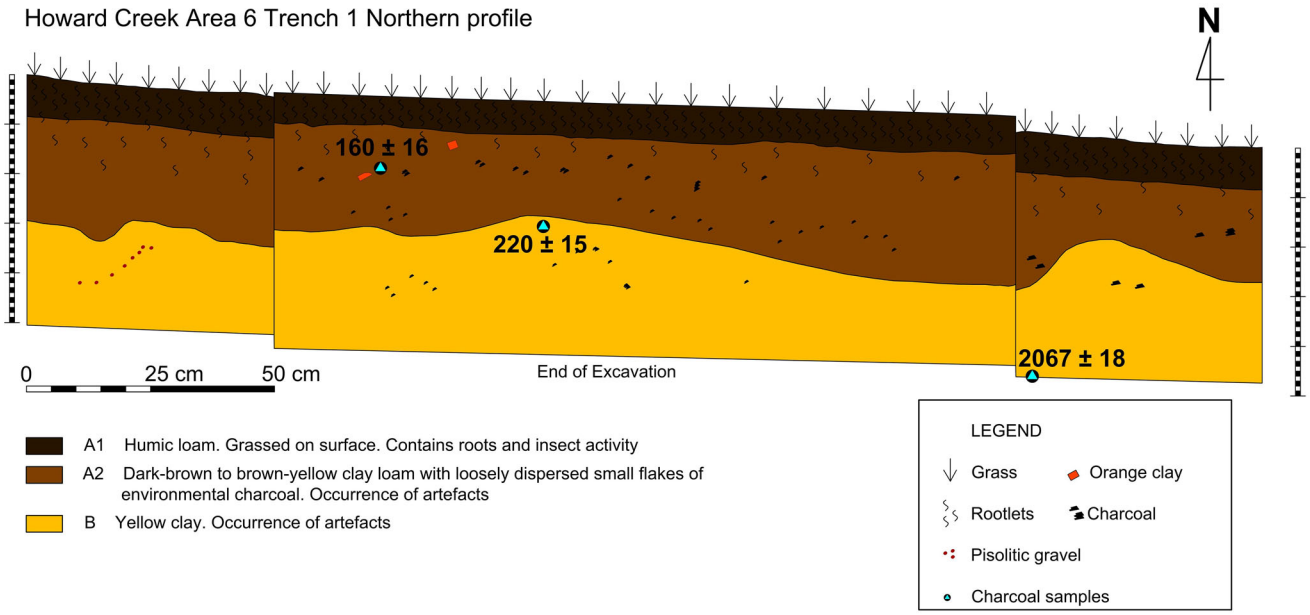


FIGURE 5 | Area 6, Trench 1. Combined northern profiles showing stratigraphic units and charcoal radiocarbon ages. Ages are conventional radiocarbon years BP (±1σ).

The stratigraphy of Trench 1 (northern bank, first creek terrace) is presented in Figure 5. Artefacts were discovered in Spits 2–10, with the highest concentration in Spits 4–8 (15–40 cm), mostly located in deposits of dark-brown and brown-yellow clay loam and the upper part of the yellow clay layer. In total, the trench yielded 599 artefacts from the excavated deposits.[1] In addition to stone artefacts, a large piece of red ochre was found in Square C2 and three pieces of yellow ochre in Squares B2 and D2, at depths of approximately 15 and 35–40 cm. The in situ information combined with sieve finds indicates that the concentration of artefacts stretches along the east–west axis across the middle of the trench (Figures 6 and 7). Square B4 contains the remains of a burnt stump and yielded relatively few artefacts. Possibly at the time of occupation there was a tree under which various camping activities took place. Charcoal accumulations recorded in Squares C2 and D2 may be the remains of a fireplace, or they could have come from the burning of the tree; no discrete hearth was identified. Other noteworthy observations include the high density of artefacts on the eastern side of the trench and the ochre finds in its western part.

The excavation of Trench 2 (northern bank, second creek terrace) is presented in Figure 8 and its stratigraphic composition in Figure 9. Artefacts were discovered throughout, with the highest concentration in Spits 3–5 (10–25 cm), mostly in deposits of dark-brown clay loam (Figure 10). The analysed assemblage from the trench comprises 9,680 artefacts,[2] the spatial distribution of which can be seen in Figures 11 and 12. The highest square count was 504 artefacts in Square B2, equivalent to 2,016 artefacts per m^2 for this 0.25 m^2 excavation unit. Another burnt tree stump was discovered at the southern edge of the trench.

Of the analysed assemblage from the two trenches, 81.3% was composed of chert (n = 8,356), 8.9% was quartz (n = 918), 5.4% was silcrete (n = 558), 3.0% was quartzite (n = 304), and 0.5% was chalcedony (n = 47). Other materials, represented by sandstone (n = 3) and basalt (n = 1), each account for less than 0.1%. Raw material was not identified for 92 artefacts (0.9%).

Using the total number of artefacts (n = 10,279), the assemblage consists of complete flakes, including complete blades and bladelets (26.4%, n = 2,710), broken flakes (72.4%, n = 7,438), cores (1.1%, n = 113), and core and pebble tools (0.2%, n = 18) (Holdaway and Stern 2004,243–244). The operational MNF is 4,192, calculated by adding 2,710 complete flakes to 1,482 platform-bearing fragments. Using MNF and the 113 cores as the basis for comparison (a combined total of 4,305), flakes account for 97.4% and cores for 2.6%.

A large proportion of the assemblage consists of medial/distal flakes (41.1%, n = 4,228), indicating a high degree of breakage that could have occurred during manufacture or through post-depositional processes such as trampling. Post-depositional breakage may be more likely, since medial/distal flakes would mostly include transversely snapped fragments. In contrast, the category of platform-bearing flakes (14.4%, n = 1,482) combines proximal and longitudinally split fragments, with longitudinal splitting being consistent with breakage during manufacture.

Mean lengths were compared among the four principal raw materials separately for complete flakes and cores (Table 3). Statistically significant differences were identified for flakes (Welch's ANOVA, $F(3, 186.91) = 4.931$, $p = 0.0026$). However, differences between material-group means accounted for only 0.6% of the total variation in flake length ($\eta^2 = 0.0063$). No statistically significant difference was detected among cores, for which the length of the largest flake scar was compared ($F(3, 4.14) = 0.259$, $p = 0.852$, $\eta^2 = 0.0102$). This comparison is limited by the small numbers of quartz, silcrete and quartzite cores.

In general, the knapping technology represented at Howard Creek produced small flakes. Mean lengths of complete flakes

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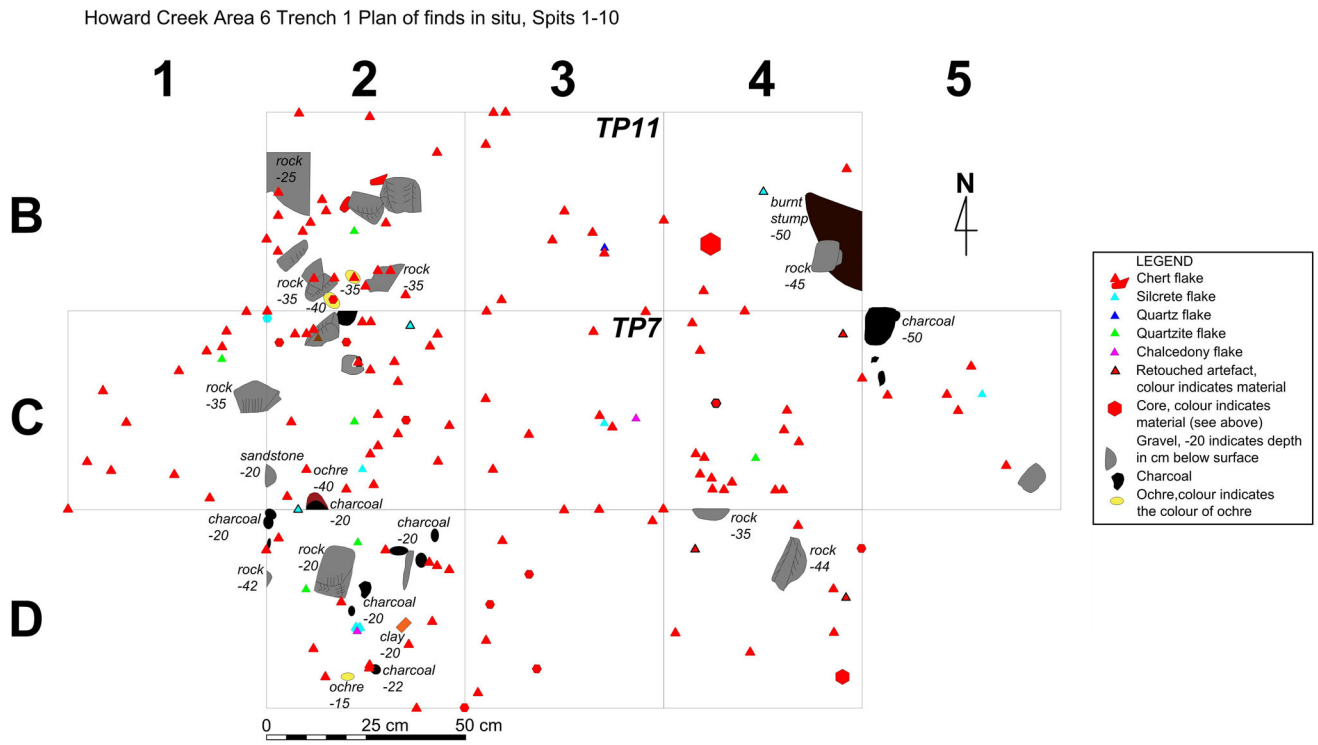


FIGURE 6 | Area 6, Trench 1. Plan of in situ finds from Spits 1–10.

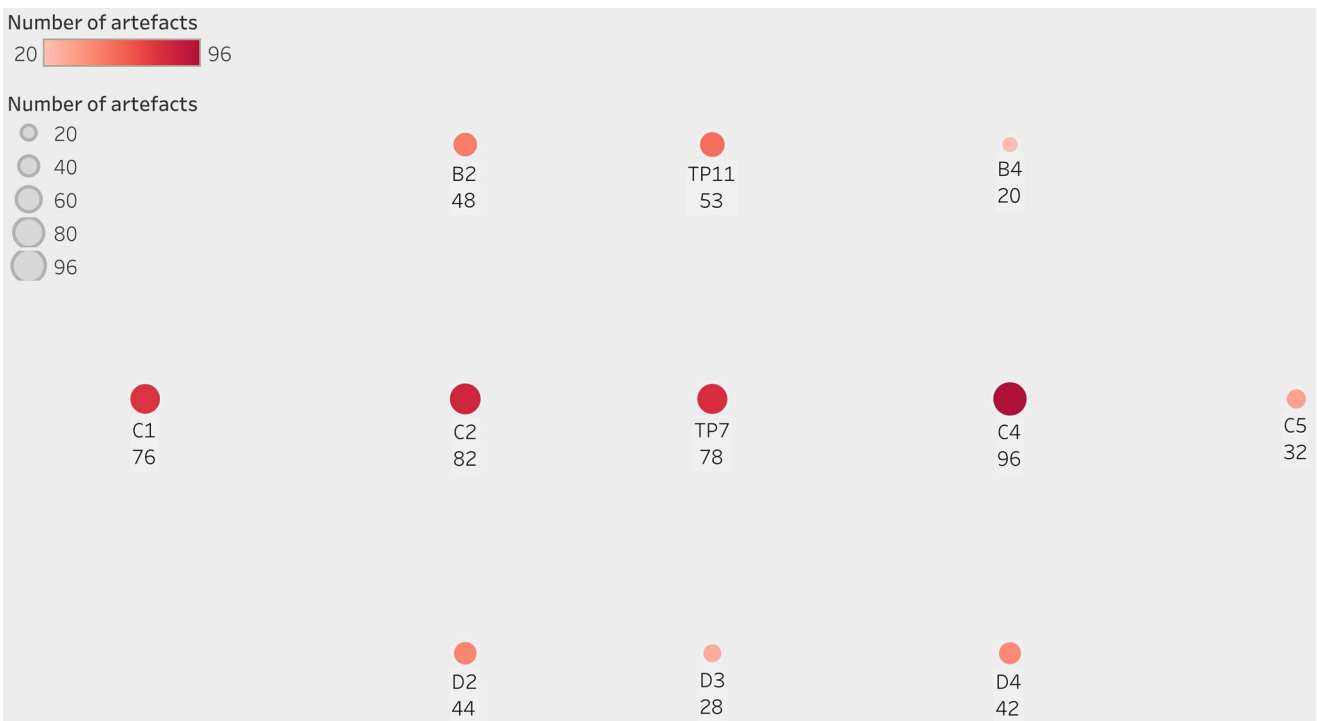


FIGURE 7 | Area 6, Trench 1. Distribution of artefacts across excavation units.

among the four principal raw materials range from 15.6 to 21.0 mm (blades and bladelets were excluded to prevent bias towards longer lengths). Chert and silcrete flakes have similar mean lengths of 17.7 mm and 18.1 mm, respectively, while quartz flakes are smaller, at 15.6 mm, and quartzite flakes are larger, at 21.0 mm. Complete chalcedony flakes, represented by 19 specimens, have a mean length of 17.3 mm. Neyland (2016, 275) suggested higher rates of raw-material conservation with imported materials,

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FIGURE 8 | Area 5 Trench 2. General view at the end of excavations, facing south (Photograph: Irina Ponomareva).

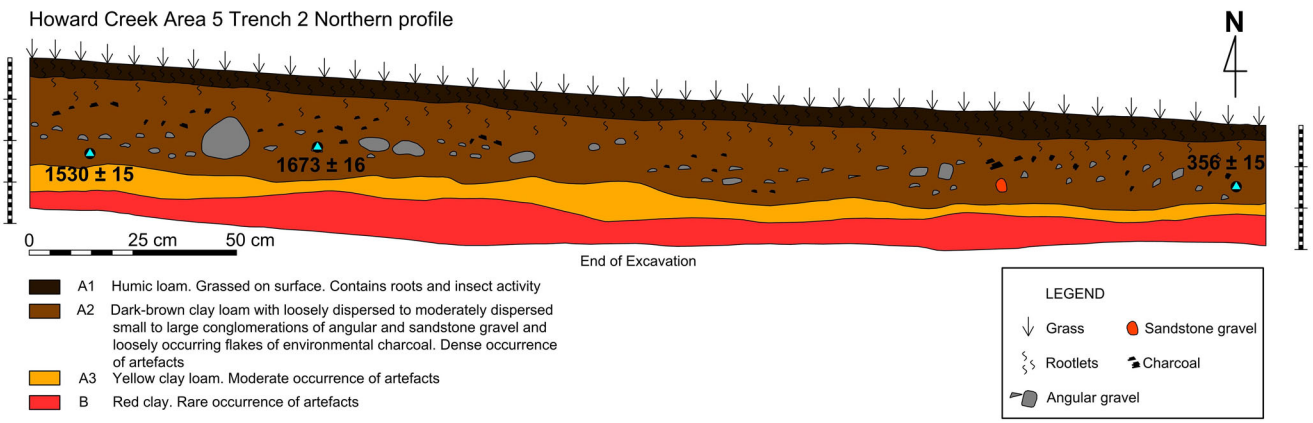


FIGURE 9 | Area 5, Trench 2. Northern profile showing stratigraphic units and charcoal radiocarbon ages. Ages are conventional radiocarbon years BP ($\pm 1\sigma$).

which would be more reduced. If chert at Howard Creek is considered locally available and silcrete imported, their similar mean flake lengths provide no clear indication of greater reduction of the presumed imported material. Of the 2,483 complete flakes included in the length analysis, 43 are retouched. Retouched chert flakes ($n = 38$) have a mean length of 35.3 mm, compared with 17.3 mm for unretouched chert flakes ($n = 1{,}939$). Retouched silcrete flakes ($n = 3$) have a mean length of 34.9 mm, compared with 17.8 mm for unretouched silcrete flakes ($n = 176$). Chert and silcrete therefore have similar mean lengths within both the retouched and unretouched groups. The larger mean lengths of retouched flakes in both materials are consistent with the selection of larger flakes for retouch. The single retouched chalcedony and quartzite flakes measure 31.9 mm and 25.2 mm, respectively. The small numbers of retouched specimens other than chert limit comparisons among materials.

Complete bladelets constitute 1.5% of the analysed assemblage ($n = 154$). In addition, 37 backed artefacts, including Bondi points, are present in the full catalogue, 31 of which were recovered from Spits 3–5 of Trench 2 (Figure 13). These include specimens made on bladelets, a blade and flake fragments, and were made from chert, silcrete, chalcedony and quartzite. The artefact assemblage includes a substantial number of scrapers, which feature various types of retouch, including flat, steep and notched (Figure 14). Some artefacts exhibit multiple forms of retouch. Retouch was recorded on 142 artefacts, comprising 140 flakes and flake fragments and two core tools. The retouched flakes and fragments make up 1.4% of the 10,148 flakes and broken flakes. Analysis of the retouched artefacts showed that retouch was mainly located on the left and right lateral margins. Retouch was also recorded on the distal end of 54 specimens (40.0% of the 135 artefacts with entries in the retouch-location field), sometimes in combination with lateral retouch. These finds indicate tool-making activity at Howard Creek, and use-wear and residue analysis provides an insight into what some of these tools were used for (see below).

The relationship between recorded length and spit number was negligible in Trench 1 ($n = 100$; slope = 0.07 mm per spit; $t(98)$

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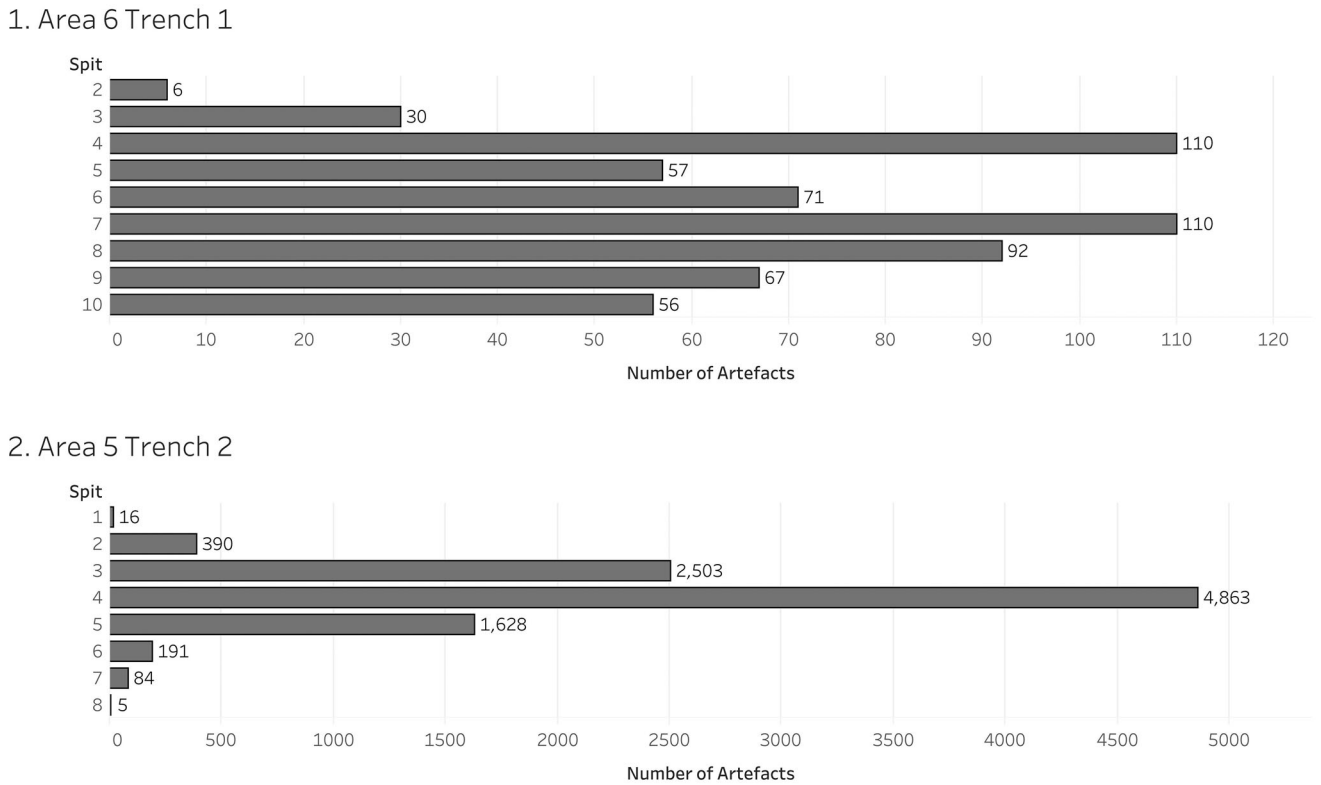


FIGURE 10 | Distribution of artefacts by 5 cm spit in Trench 1 (Area 6; $n = 599$) and Trench 2 (Area 5; $n = 9{,}680$).

= 0.117, $p = 0.907$, $R^2 = 0.00014$). In Trench 2, recorded length decreased slightly with increasing spit number ($n = 2{,}495$; slope = −0.56 mm per spit; $t(2493) = -2.125$, $p = 0.034$), but the model accounted for only 0.18% of the variation in length ($R^2 = 0.00181$). The Spearman rank correlation was also weak and not statistically significant ($\rho = -0.024$, $p = 0.224$). Comparisons of the proportions of chert, quartz, silcrete and quartzite among spits showed no statistically significant differences in Trench 1 ($n = 588$; $\chi^2(24) = 35.117$, Monte Carlo $p = 0.095$, Cramer's $V = 0.141$). Trench 2 showed statistically significant differences, although the association between raw material and spit was weak ($n = 9{,}548$; $\chi^2(21) = 86.882$, Monte Carlo $p < 0.001$, Cramer's V = 0.055). These exploratory results provide no clear evidence for systematic vertical size sorting in the analysed sample. They do not exclude post-depositional mixing or justify interpreting the spits as successive occupation phases.

5.3 | Use-Wear and Residue Analysis

The detailed results for eight selected artefacts are presented in Table 4. Use-related residues were identified on five specimens: #1, #3, #4, #6 and #8.

The chert scraper HC06D4IN02 (#1) yielded plant fibres, phytoliths and sclereids, while starch grains were not observed. These residues are consistent with plant processing, although the particular plant material and activity could not be determined. The backed artefact HC05C3SIS336 (#3), scrapers HC05B1IN59/1 (#4) and HC05C5IN01 (#6), and the longitudinally split flake HC05A3IN77 (#8) yielded collagenous or bone-like residues which, together with observed use-wear, are consistent with animal-tissue or bone contact or processing. The specific activities could not be determined. Starch granules were also recorded on #4 and #8, but these were interpreted in the specialist study as environmental rather than use-related.

Use-wear was recorded on the silcrete Bondi point HC05D3SIS4131 (#7), but no use-related residues were identified; its functional interpretation therefore remains equivocal. Evidence of use was not identified on HC05A1SIS5134 (#2) or HC05A3SIS422 (#5). The selected sample provides information on the use of particular artefacts, while its size and targeted selection limit the characterisation of activities across the assemblage as a whole.

6 | Discussion

The Howard Creek investigations provide new information on Late Holocene occupation in the sub-coastal Moreton region. As an open-air site, Howard Creek adds to a regional record largely based on rockshelter excavations. The discussion considers the chronology and use of the locality, its relationship to other regional sites, and the activities represented by the archaeological assemblage.

6.1 | Duration and Intensity of Occupation

In the regional context of other dated sites, Howard Creek falls within the most recent part of the Holocene record. Evidence for much earlier occupation in the wider Moreton region comes from open-air sites with sequences extending into the Pleistocene. At

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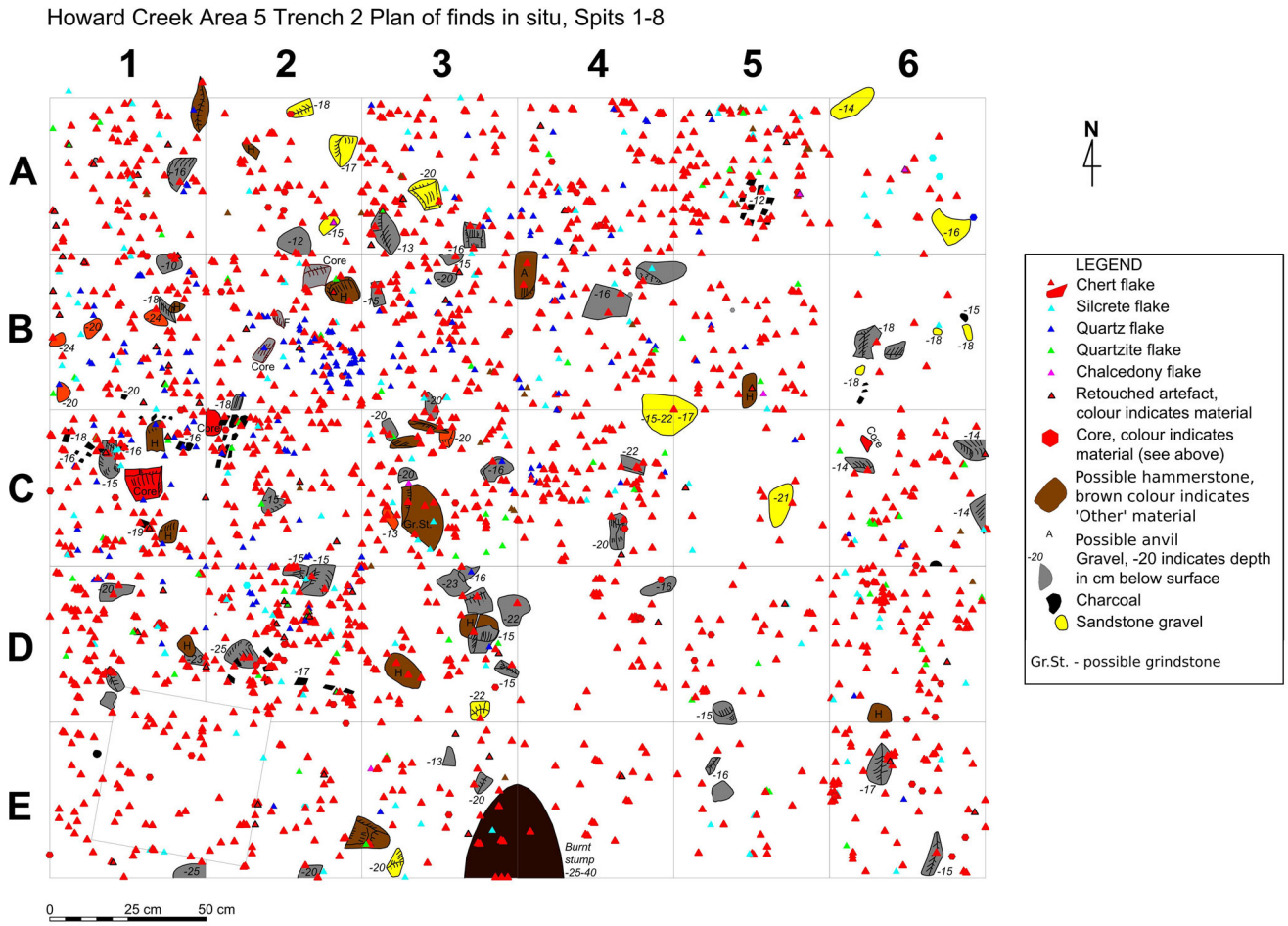


FIGURE 11 | Area 5, Trench 2. Plan of in situ finds from Spits 1–8.

Wallen Wallen Creek, on Minjerribah (North Stradbroke Island), the archaeological sequence extends from approximately 30–49 ka to recent times. Its upper Holocene Unit 1 dates from 8 ± 2 ka to recent, with increased artefact discard in the mid-Holocene followed by a decline in the late Holocene. At Middle Canalpin Creek A (MCA20), on the same island, dated archaeological contexts range from approximately 38–41 ka to 455–160 cal BP. The upper peak in stone artefact discard is bracketed by optically stimulated luminescence (OSL) ages of 6.2 ± 1.4 and 2.2 ± 0.6 ka (Adams et al. 2024). At Cobaki sand ridge in northern New South Wales, possible Pleistocene occupation has been reported from stone artefacts in sands dated to approximately 39 ka, alongside a late Holocene midden with shell dates ranging from 454–606 to 55–275 cal BP, although the chronological association between the dated materials and the stone artefacts remains uncertain (Robins et al. 2015).

The rockshelter sequences provide further evidence for the timing and intensity of occupation in the sub-coastal Moreton region (Hall 1999; Morwood 1987). Bushrangers Cave has dates of around 10,000 cal BP (Kearney 1998; Williams and Ulm 2014), with increased artefact and faunal discard documented in the rear of the shelter during the last 2500 years (Hiscock and Hall 1988a). Platypus Rockshelter, Maidenwell Shelter and Gatton Shelter yielded basal dates between approximately 6000 and 4000 BP (Hall et al. 1988; Hall and Hiscock 1988a; Morwood 1986). Hall (1999) describes increased use of Platypus Rockshelter between approximately 2500 and 2300 BP, followed by a decline associated with the collapse of the shelter floor. At Maidenwell and Gatton, stone artefact deposition was greatest between approximately 3000 and 1000 BP. At Gatton, however, faunal density and diversity increased after 1000 BP despite declining stone artefact deposition, a pattern interpreted as a change in subsistence and technology (Morwood 1986, 1987). Christmas Creek, Boonah Shelter, Brooyar Rockshelter and Bishop's Peak have basal dates between approximately 4000 and 2000 BP (Bonica 1992; Burke 1988; McNiven 1988; Edmonds 1986), with increased stone and bone discard at Bishop's Peak after approximately 2000 BP (Hall and Hiscock 1988b).

In his regional synthesis, Hall (1999) noted that increased cultural discard at many sub-coastal sites around 3000–2500 BP coincided with drier and cooler conditions and the expansion of open eucalypt woodland, which he suggested may have increased the availability of food resources. The Howard Creek radiocarbon determinations cover approximately the last two millennia, extending into the recent past (Table 2; Figure 15). They place the dated deposits within the later part of this regional history, although the available chronology does not establish when use of the locality began or whether its intensity changed through time.

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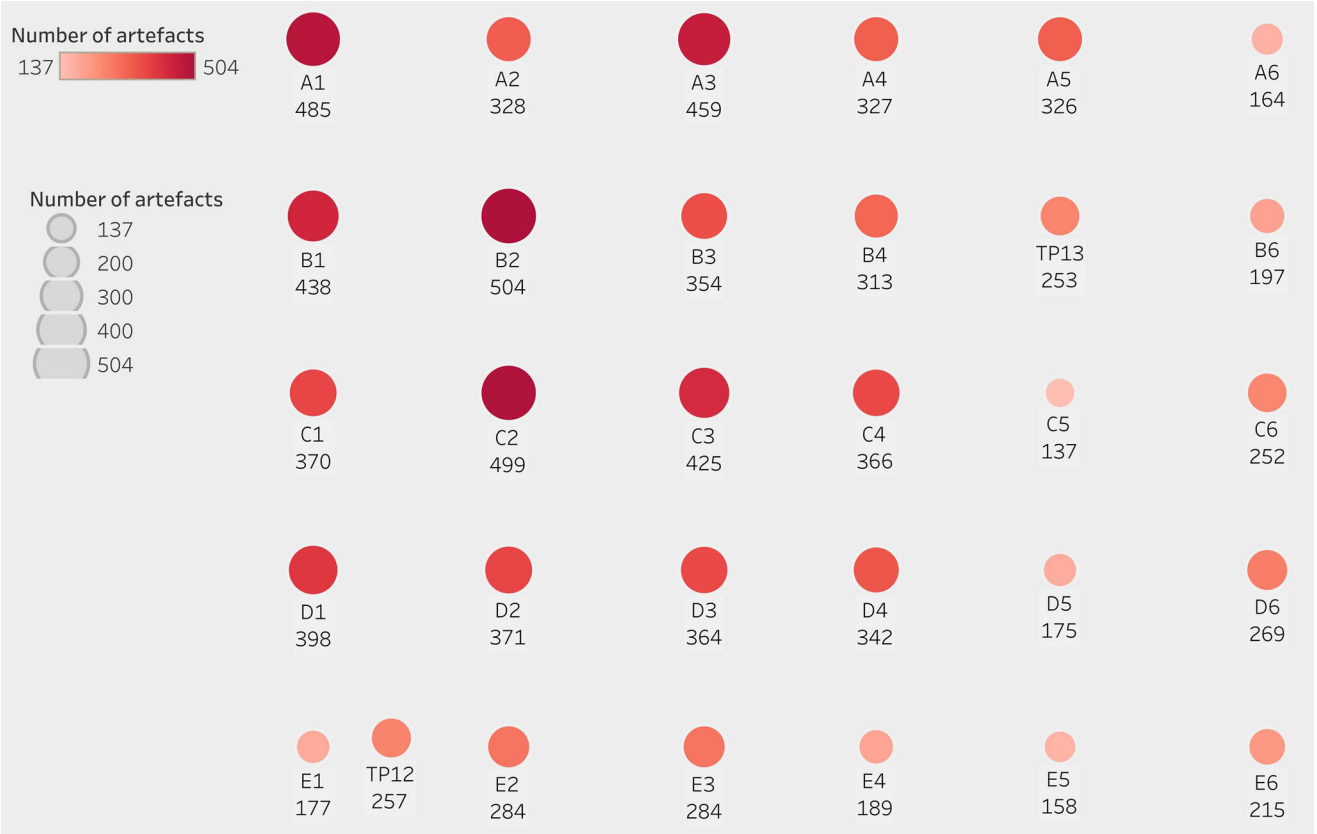


FIGURE 12 | Area 5, Trench 2. Distribution of artefacts across excavation units.

The chronological resolution of the Howard Creek deposits is limited by post-depositional mixing. The variation in radiocarbon ages within Trench 2 and the potential redistribution of material through flooding, erosion and bioturbation make it difficult to associate particular artefacts with dated episodes of use. Similar problems are recognised in other open-air deposits, although their depositional settings differ. At Cobaki sand ridge, a shell sample from a depth of 22 cm was dated to 454–606 cal BP, while sand sampled at 17–25 cm yielded a thermoluminescence (TL) age of 32.6 ± 3.5 ka. Robins et al. (2015) interpreted this contrast as younger midden material having moved into older dune sands, while the age of the stone artefacts remained uncertain. At Wallen Wallen Creek, the long Holocene depositional history described above is represented within a single upper unit extending to 80 cm (Adams et al. 2024).

The available Howard Creek dates provide a comparatively restricted Late Holocene framework for interpretation. Within this framework, the assemblage is considered as a palimpsest in which material from different episodes of use may have accumulated and been redistributed (Attenbrow 2006,30). The assemblage is consistent with recurrent use of the locality, but the duration and frequency of visits and changes in occupation intensity remain uncertain.

Late Holocene changes in occupation, technology and resource use have been interpreted in terms of socio-economic intensification (Lourandos 1997) and responses to environmental and resource pressures in the Red Queen model (Hiscock and Sterelny 2023). Recurrent use of Howard Creek, near stone and water sources, can be considered within these broader debates. However, the deposits do not resolve changes in occupation intensity, technology or resource use through time sufficiently to distinguish between the proposed processes.

6.2 | Regional Comparisons and Site Use

The Howard Creek site is located approximately 1 km west of the Wongawallan Jasper Quarry, an important source of chert in the Gold Coast region (Clarkson and Bellas 2014, McLaren 2002). Chert constitutes 81.3% of the analysed assemblage from the two trenches. McLaren (2002, 11) described the quarry as 'hundreds of overlapping jasper blocks' displaying a wide range of colours. Chert artefacts from Howard Creek exhibit the six macroscopic characteristics he identified: a generally vitreous appearance; quartz veins, healed joints and fractures; distinctive purple and red colouration; prominent banding; manganese patches; and a smooth texture (McLaren 2002,55). These characteristics and the proximity of the quarry suggest that much of the chert probably originated there, although geochemical comparison is required to confirm this attribution. Quartz veins within the chert may also have provided a source for some quartz artefacts. Only two quartz cores were recorded in Trench 2, and complete quartz flakes have a smaller mean length than chert or silcrete flakes (Table 3). Quartzite may have originated from the same locality, and some flakes consist of both chert and quartzite.

Chert, quartz and silcrete also occur in the Holocene assemblages from Wallen Wallen Creek and MCA20, although their relative

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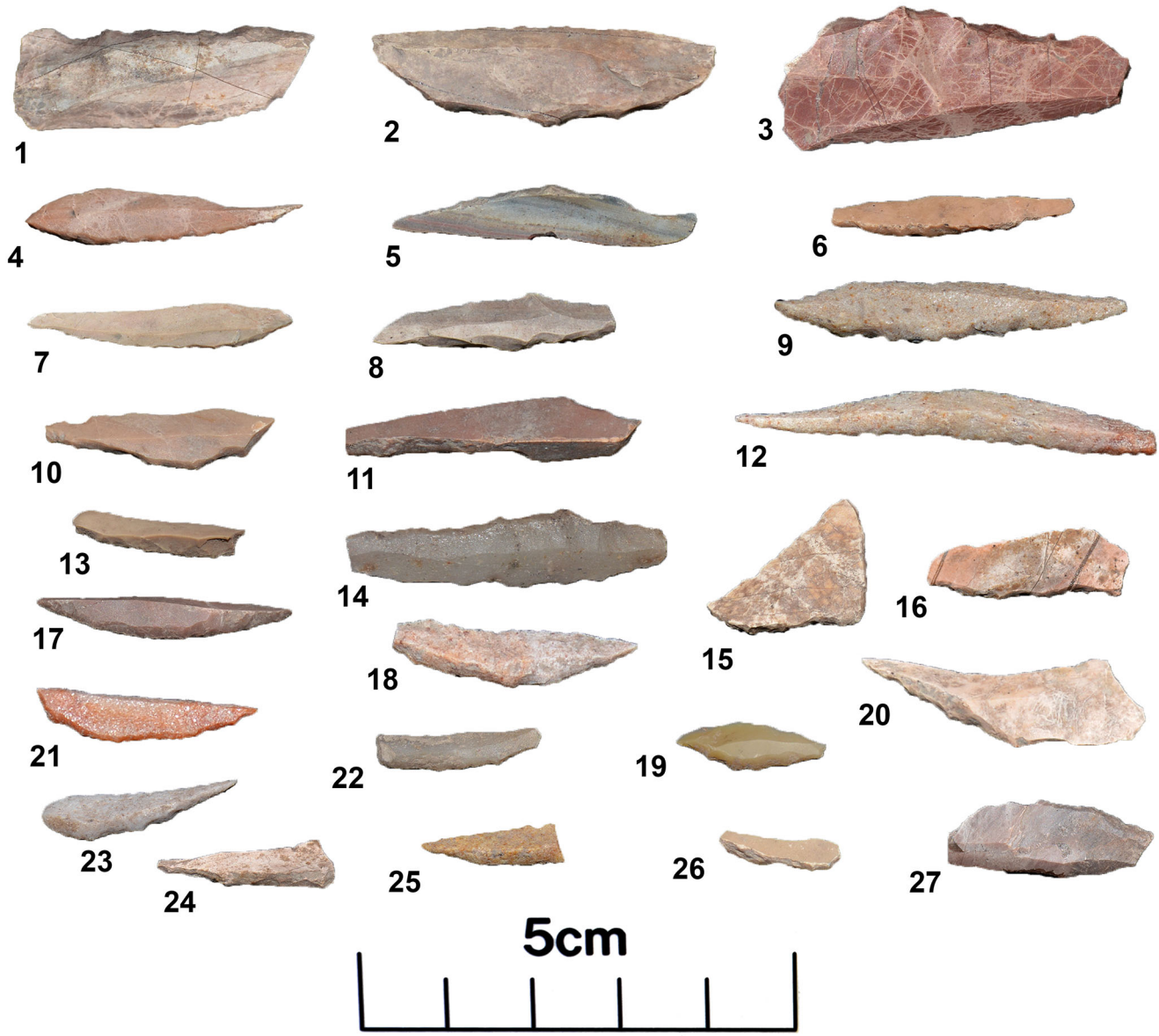


FIGURE 13 | Selected backed artefacts from Trench 2 Area 5, Howard Creek site. 1 – chert backed artefact (incomplete), 2 – chert Bondi point (complete), 3 – chert backed artefact (incomplete), 4 – chert Bondi point (complete), 5 – chert Bondi point (complete), 6 – chert backed artefact (complete), 7 – chert backed artefact (complete), 8 – chert backed artefact (complete), 9 – silcrete backed artefact (complete), 10 – chert backed artefact (complete), 11 – chert backed artefact (incomplete), 12 – silcrete Bondi point (complete), 13 – chert backed artefact (incomplete), 14 – quartzite backed artefact (complete), 15 – chert backed artefact (incomplete), 16 – chert backed artefact (complete), 17 – chert backed artefact (complete), 18 – silcrete Bondi point (complete), 19 – chalcedony backed artefact (incomplete), 20 – chert Bondi point (complete), 21 – silcrete Bondi point (complete), 22 – chert backed artefact (complete), 23 – silcrete Bondi point (complete), 24 – chert Bondi point (incomplete), 25 – silcrete backed artefact (incomplete), 26 – chert Bondi point (incomplete), 27 – chert backed artefact (complete) (Photographs: Irina Ponomareva).

representation differs from Howard Creek. Local quartz and non-local silcrete are prominent in the upper assemblage at Wallen Wallen Creek, while quartz is the dominant material at MCA20 (Adams et al. 2024). At Cobaki, the small stone assemblage recovered from the upper deposits containing the late Holocene midden comprises volcanic rocks, chert, silcrete and quartz. Its chronological association with the midden remains uncertain (Robins et al. 2015). The dominance of chert at Howard Creek may reflect ready access to the nearby Wongawallan source.

The numerous cores and debitage provide evidence for stone-working at Howard Creek (Figure 11). In Trench 2, artefact density was highest in the northwestern part of the trench, where many large cores were recovered (Figure 12). Quartz artefacts were most abundant in Square C2, with further concentrations in B2 and B4. Silcrete cores occurred in several squares, with the largest concentration in A6, while silcrete artefacts were distributed throughout the trench. Way's (2017) study of knapping floors in southeastern Australia recorded a mean diameter of 4 m and a mean density of 56 artefacts per m^2, while Neyland (2016) recorded an overall mean cluster radius of 0.64 m for the South Australian sites and features examined. The 9,680 artefacts recovered from the 7.5 m^2 of Trench 2 give an average density of approximately 1,291 artefacts per m^2. This cumulative assemblage

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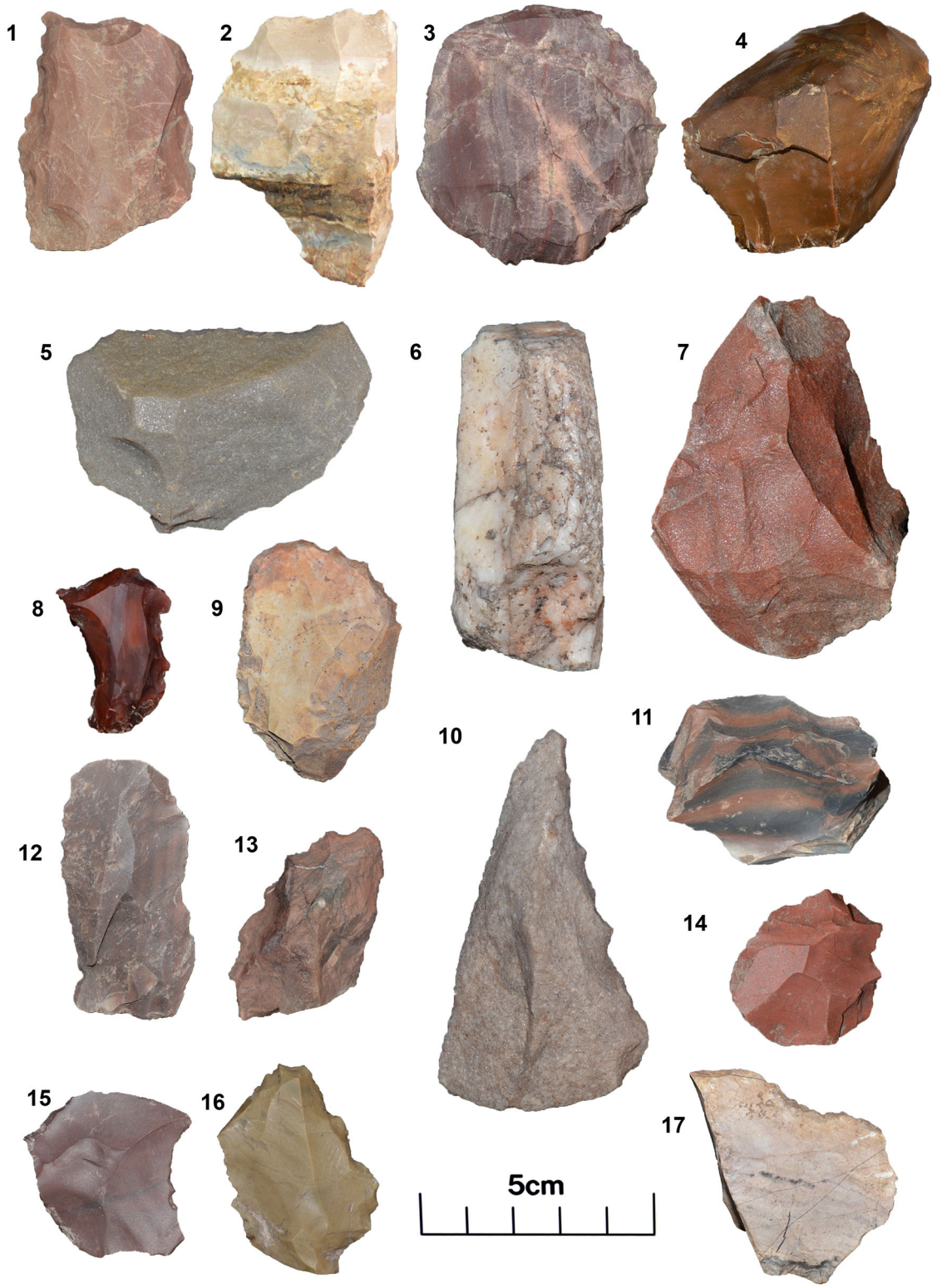


FIGURE 14 | Selected artefacts from the Howard Creek site. Area 6 Trench 1: 1 – chert drill/piercer, 2 – chert steep-edged scraper, 3 – chert round-edge scraper, 4 – chert multidirectional core, 5 – silcrete steep-edged scraper. Area 5 Trench 2: 6 – quartz multidirectional core, 7 – silcrete multidirectional core, 8 – chalcedony steep-edged scraper, 9 – chert notched artefact, 10 – silcrete flat-edged/steep-edged scraper, 11 – chert multidirectional core, 12 – chert complete blade, 13 – chert notched artefact, 14 – chert multidirectional core, 15 – chert flat-edged scraper, 16 – chert flat-edged/steep-edged scraper, 17 – chert longitudinally split flake (Photographs: Irina Ponomareva).

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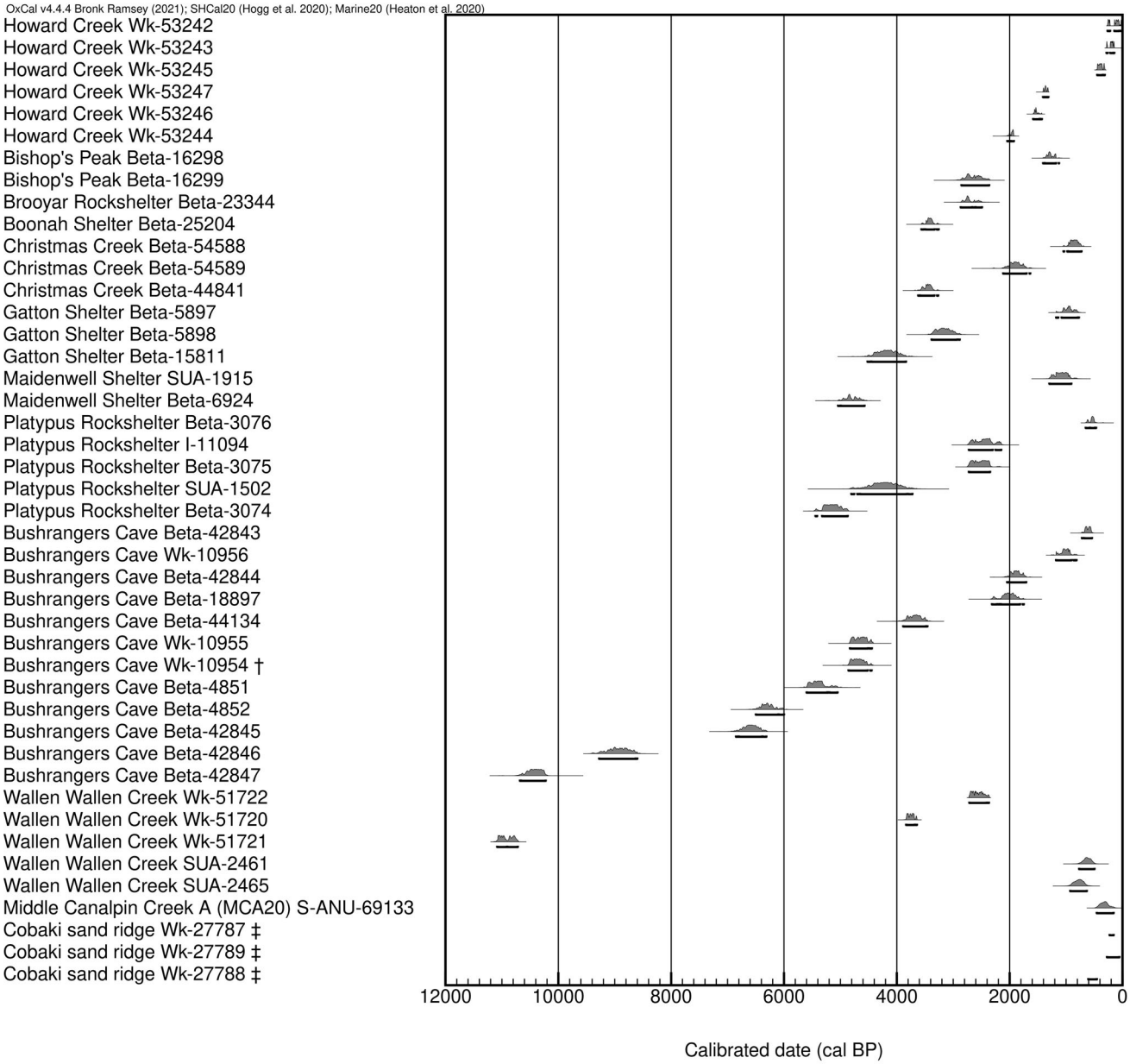


FIGURE 15 | Howard Creek age determinations in the context of Holocene radiocarbon dates from comparative sites in the Moreton region and northern New South Wales. Curves show calibrated probability distributions and bars show 95.4% intervals. Charcoal determinations were calibrated using OxCal 4.4.4 and SHCal20 (Hogg et al. 2020). Shell determinations from Wallen Wallen Creek and Middle Canalpin Creek A (MCA20) were calibrated using Marine20 (Heaton et al. 2020) and a ΔR of −156 ± 18 years, following Adams et al. (2024). Cobaki sand ridge is represented by published 95.4% calibrated shell ranges (Robins et al. 2015). Wk-10954 is flagged as anomalous in AustArch (Williams and Ulm 2014).

may represent multiple overlapping knapping episodes, with post-depositional movement also affecting the concentrations. Refitting could help distinguish individual reduction sequences and assess relationships between artefacts (Way et al. 2023). While such analysis was not feasible within this project, the spatial records collected for each in situ find provide a basis for future work.

Backed artefacts are well represented in mid-to-late Holocene assemblages across Australia (Hiscock 2002, 2008). At Bushrangers Cave they occur in deposits dated from approximately 5700 to 1550 BP (Hiscock and Hall 1988a), while their representation declines after approximately 1000 BP at Maidenwell and Gatton (Morwood 1986). Backed artefacts were also recovered from the upper deposits at Platypus Rockshelter, although their possible derivation from older sediments complicates the interpretation of their presence in the last millennium (Hiscock and Hall 1988b). A single backed artefact was reported from the upper midden assemblage at MCA20, together with bipolar artefacts and flakes from ground-edge axes. Scrapers, notched flakes, cores, bipolar artefacts and ground-edge axe flakes also occur in the Holocene assemblage

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at Wallen Wallen Creek (Adams et al. 2024). Howard Creek yielded 37 backed artefacts, including 31 from Spits 3–5 of Trench 2 (Figure 13). Mixing limits their chronological placement within the site's broad Late Holocene record.

Studies of use-wear and residues on backed artefacts have revealed their multiple functions and frequent incorporation into composite tools. Robertson et al. (2009) identified evidence for contact with wood, plants, bone, blood, skin and feathers. More recent work at Ngungara suggests that replacement of backed inserts during composite-tool repair contributed to variation in their form (Way et al. 2023). At Howard Creek, the use-wear and residue evidence indicates that some backed artefacts were used in activities involving animal tissue or bone, although the particular tasks and any hafting arrangements remain uncertain.

The animal-related residues on Howard Creek artefacts also suggest activities beyond lithic manufacture. There is a substantial record of bone tool manufacture in Australia, and bone points and hooks have played an important role in fishing for approximately 5000 years (Langley 2023). Although no osseous artefacts were identified at Howard Creek, Platypus Rockshelter yielded 20 bone artefacts distributed throughout the deposits. Francis' (2002) residue analysis suggested that one was probably used for skin working and several others for processing plant material, possibly to peel or cut *Typha* sp. The Howard Creek evidence concerns contact between stone tools and animal tissue or bone; it does not establish the manufacture of bone tools.

A chert scraper from Trench 1 provides evidence for plant processing, which Stephenson (2021) suggested could relate to fibrecraft or medicinal activities (Figure 14). Fibre objects include clothing, containers, string, personal adornments and fishing nets, but are often poorly preserved because of their organic composition. Ethnographic and rock art evidence from western Arnhem Land demonstrates their practical and ceremonial roles in Aboriginal societies (Miller 2021). The Howard Creek scraper may therefore represent an activity whose products have not survived. However, the absence of starch on this scraper does not exclude food preparation, and the surviving residues do not distinguish between fibrecraft, medicinal processing and other plant-working activities.

The red and yellow ochre recovered from Trench 1 provides another component for regional comparison. Ground ochre occurs in the upper midden assemblage at MCA20 (Adams et al. 2024), while Francis (2002) recorded ochre residues on bone artefacts from Platypus Rockshelter. These finds illustrate the presence of pigment in different material contexts, although the particular uses of the Howard Creek pieces remain unknown.

Skelton's (1996) study of Platypus Rockshelter provides a further comparison of plant processing. He examined 95 stone artefacts from stratigraphic units 2–6, with starch analysis undertaken on 63 specimens with sufficient surviving residue. All specimens tested for starch yielded starch grains. The starch and associated plant remains were interpreted as evidence for tuberous plant processing across the sampled sequence, with little variation in the resources represented through time. At Howard Creek, the starch recorded on other artefacts was interpreted as environmental rather than use-related (Stephenson 2021). Differences in sample selection and analytical approaches limit comparisons between the two studies and the inference of a distinct subsistence focus at Howard Creek.

Other regional sites provide more direct evidence of food resources. The Holocene middens at Wallen Wallen Creek and MCA20 contain shellfish remains (Adams et al. 2024), while the upper midden deposits at Cobaki yielded shellfish and small quantities of fish and terrestrial mammal bone (Robins et al. 2015). At Howard Creek, no hearths were identified and the bone collected from Trenches 1 and 2 was poorly preserved. Chemical leaching and other post-depositional processes may have contributed to poor bone preservation. Acidic conditions cannot be assessed directly because no soil pH measurements are reported. Differences in organic preservation further limit comparisons of food-related activities.

The investigations were confined to the proposed road development, and the full extent of Howard Creek remains unknown. Artefacts recovered from soil removed during construction of a shed on the adjoining property suggest that the site extends beyond the investigated corridor. Surviving deposits outside the excavated areas may provide opportunities to investigate the extent of the locality and the relationship between the concentrations documented here and broader patterns of site use.

7 | Conclusion

The Howard Creek site provides new evidence for Late Holocene occupation and resource use in an open-air setting in the sub-coastal Moreton region. Radiocarbon determinations provide a broad chronological framework covering approximately the last two millennia. The lithic assemblage indicates stone-working, with much of the dominant chert component probably derived from the nearby Wongawallan Jasper Quarry. Use-wear and residue analysis of selected artefacts provides additional evidence for plant processing and animal-tissue or bone processing.

The high artefact densities and evidence for several activities are consistent with recurrent use of the locality. The assemblage is interpreted as a palimpsest in which material accumulated through different episodes of use and was subsequently affected by post-depositional processes. Mixing limits the association of particular artefacts and activities with the radiocarbon determinations. The duration and frequency of visits, and changes in occupation intensity or technology through time, therefore remain uncertain.

The Howard Creek investigations demonstrate the contribution that development-led archaeology can make to a regional record largely based on rockshelter excavations. Publication of the excavation, dating and specialist results makes this assemblage available for regional comparison, while the detailed spatial records provide a basis for future refitting and further examination of artefact concentrations. Together with other open-air sites, Howard Creek broadens the evidence available for investigating Late Holocene land use in the sub-coastal Moreton region.

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Conflicts of Interest

The authors declare that they have no conflicts of interest to disclose that are directly related to the research presented in this paper. This research was conducted in accordance with ethical and professional standards, and no financial or personal interests have influenced the design, execution, analysis, or reporting of the findings. Our primary commitment is to the objective and impartial dissemination of archaeological knowledge, with due respect to the cultural heritage and contributions of the Indigenous communities involved in this study.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Endnotes

[1] The original catalogue count of 626 finds included 23 surface finds from Area 6 and four stones identified as natural during the use-wear and residue analysis. Excluding these items gives 599 artefacts from the excavated deposits.

[2] The original field report gives a total of 9,830 finds, but its category counts sum to 9,828, matching the catalogue. Excluding 53 surface finds, 87 finds from clean-up contexts, seven randomly collected finds and one item catalogued as a non-artefact leaves 9,680 artefacts from the excavated deposits.

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