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Power Hall and
Decarbonisation

Science and Industry
Museum

26th July 2021
Gutter Design Principles

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1 Introduction:

The note has been prepared by Carmody Groarke, with input from the design team and Donald Insall Associates, on behalf of the Science and Industry Museum in relation to the proposals for the roof to the Power Hall. This forms part of the wider Power Hall + Decarbonisation project at the Museum to restore and refurbish the Power Hall, in relation to defects to the integrity of the roof drainage and overall roof condition, and to substantially improve energy efficiency and lower carbon emissions across this globally significant site.

The roof of the building is characterised by two double pitched roofs (at approximately 33 degrees) connected via a central valley gutter, with perimeter gutters contained by parapet walls on all four sides.

The client brief for the roof refurbishment works is to deliver watertight construction that responds to the heritage significance of the building, with improved detailing that meets current regulations and best practice guidance and responds to anticipated climate change needs with regards to rainfall. The gutter design is key to ensuring that watertight construction can be achieved and this note provides details of the existing gutter conditions and drainage principles, some of the options considered and the preferred approach.

2 Existing Gutter Condition

2.1 Context and Significance:

Significance - Donald Insall Architects:

The roof was substantially refurbished in 1979 - the roof structure was strengthened, with metal plates fitted to the trusses and the roof was re-slatted using a combination of reused and reclaimed slates, incorporating new glazing and plasterboard insulation. The gutters in the central valley were replaced with aluminium box gutters, with lead flashings. The outer parapet gutters were lead-lined, with lead flashings. Since then, they have been patch repaired in multiple locations using felt and bitumen.

Central Valley Gutter

This gutter is of no evidential, historical and aesthetic value – given its recent date and it makes no contribution to the character of the roof, indeed its felt flashings and repairs detract. No significance.

Parapet Gutters

These are of no evidential or historical value given their recent date. They are however of lead, which as a traditional roofing material makes some aesthetic contribution to the character of the roofscape – however this is only experienced when in very close proximity (only possible on scaffold) and so their contribution is limited.

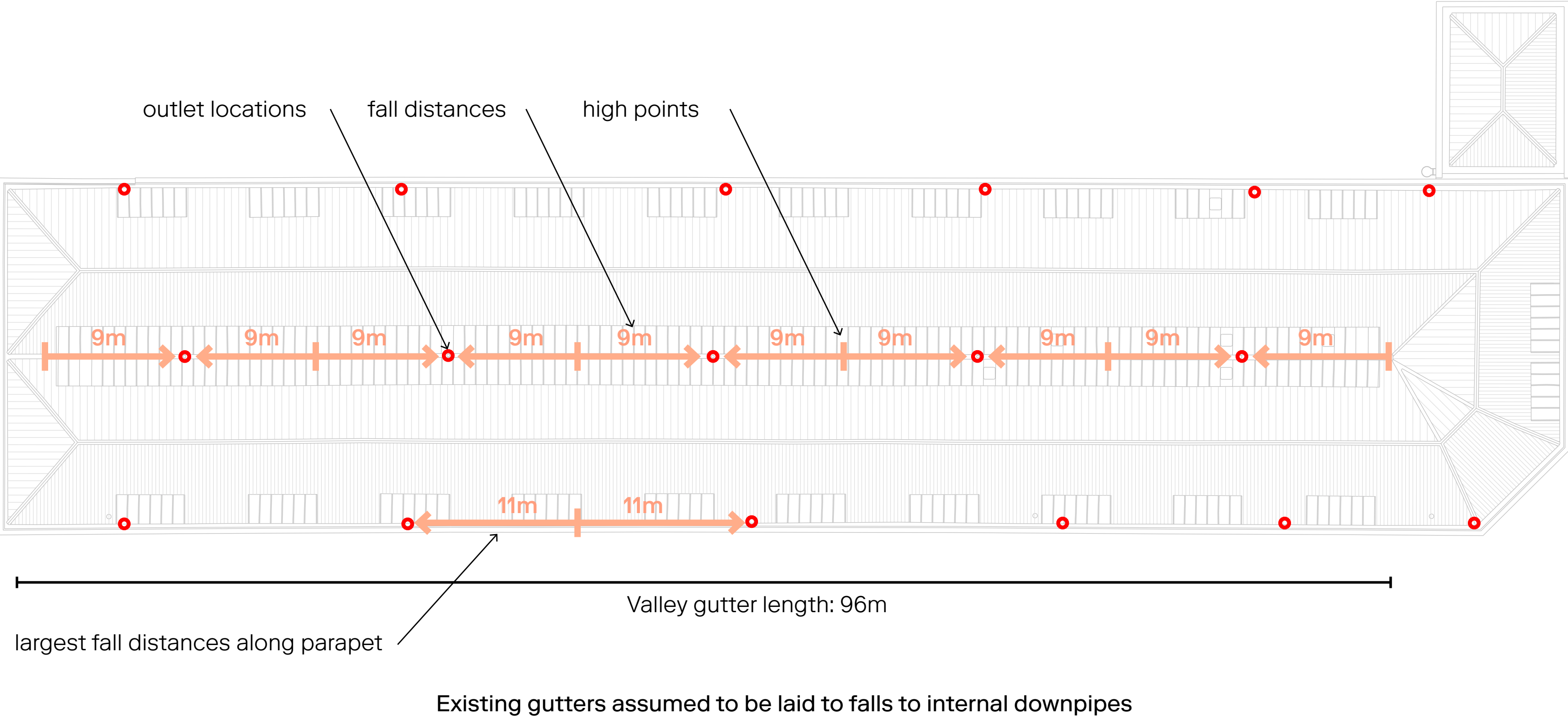
They are of low significance overall and the inappropriate repairs detract.

2.1 Context and Significance:

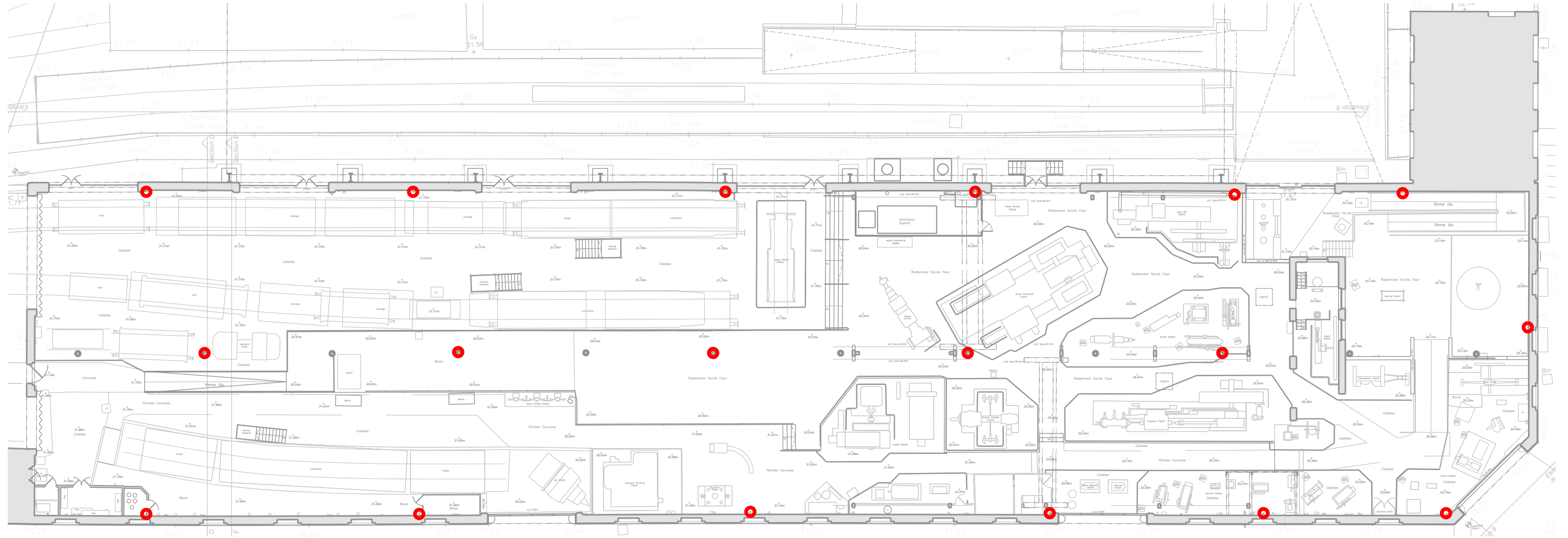
Recent context

- The building was closed in 2018 due to damage from water ingress as a result of inadequate drainage system. Currently enclosed in protective scaffolding to prevent further damage to the historic timber structure.
- Damage to structure as a result of water ingress is to be repaired where required as part of the proposed works.
- The client brief is to create robust drainage detail to ensure that the historic building fabric is better protected to eliminate the risk of water ingress so that the building can be enjoyed in perpetuity.

2.2 Existing Drainage Principles

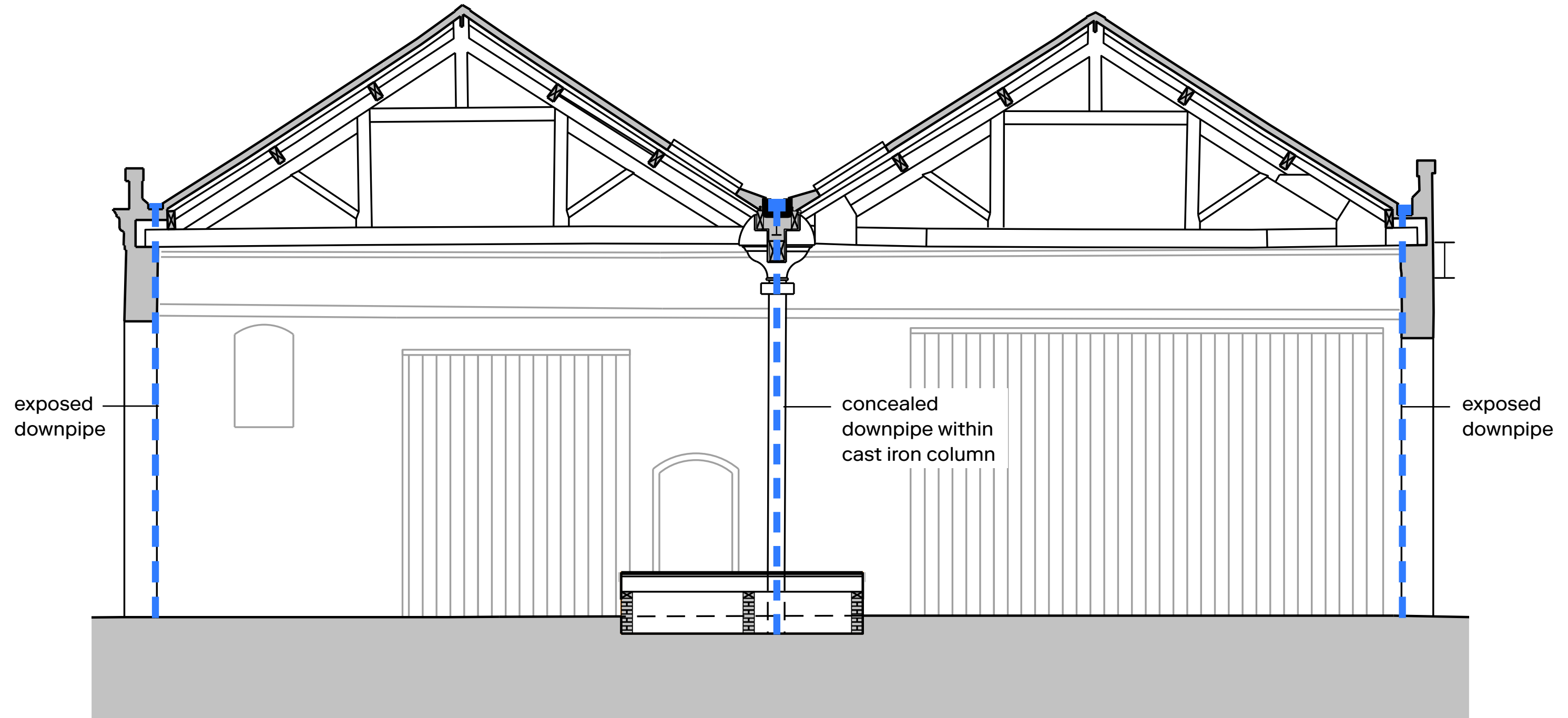


2.2 Existing Drainage Principles



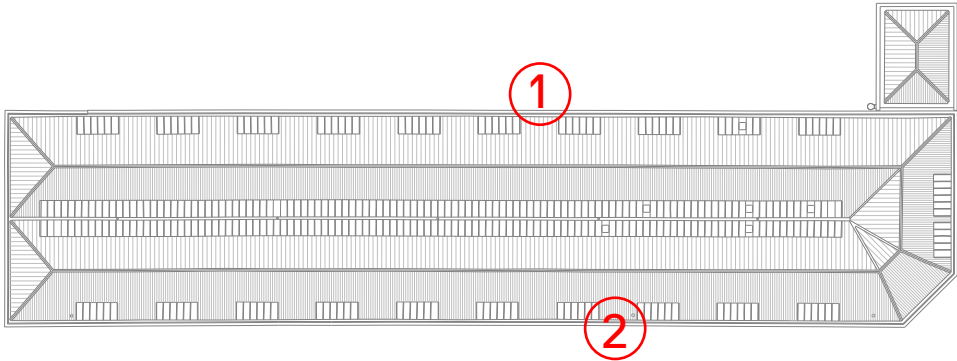
Existing downpipe locations

2.2 Existing Drainage Principles



Traditional gravity drainage system

2.3 Existing Gutter Condition



1

Tide mark from past water levels
Patch repairs with roofing felt
Lead Flashing

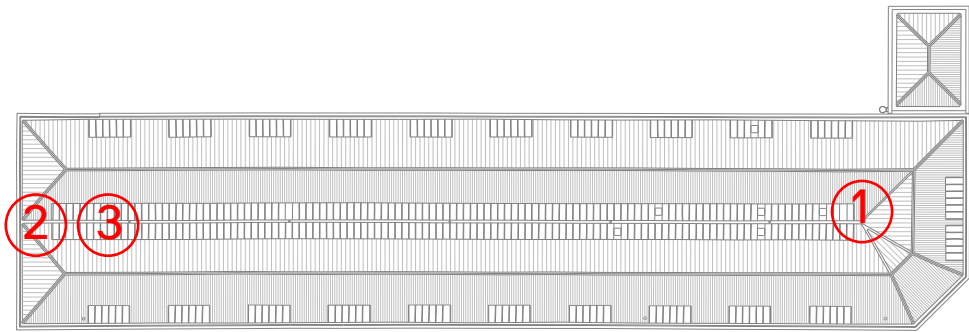


2

Lead gutter
Patch repairs with roofing felt
Lead Flashing

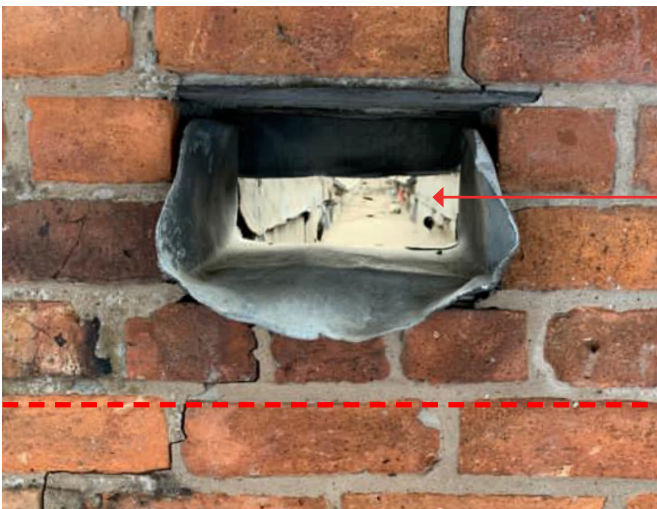
Parapet gutter

2.3 Existing Gutter Condition



1

Lead Flashing
Aluminium Gutter



Chute outlet
Positioned too
high for gutter.
Water collects
before draining.
Gutter base



2

Lead Flashing
Aluminium gutter
Roofing felt
Lead Flashing

Valley gutter



3

Tide mark from
past water levels
Aluminium
gutter
Lead Flashing

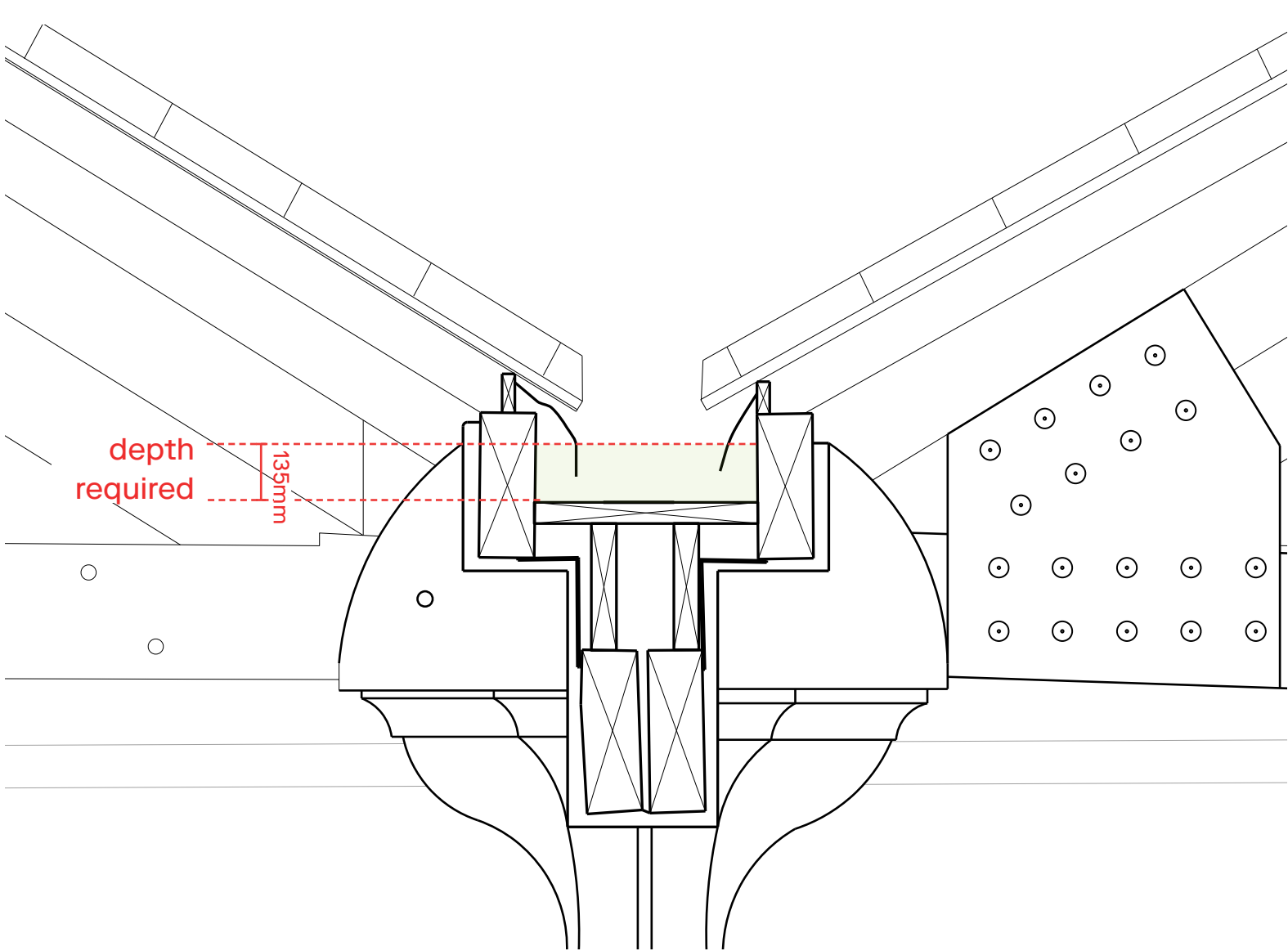
2.4 Performance Requirements

The key design requirements for the gutters are as set out in BS EN 12056-3:2000 (Gravity drainage systems inside buildings. Roof drainage, layout and calculation). This standard ensures that gutter capacity considers rainfall intensity (which takes into account the geographical location of the building and is estimated using local statistical rainfall data), the use of the building and its intended lifespan. As the Powerhall is an existing building the location and size of the existing rainwater pipes is also taken as a key parameter for the design.

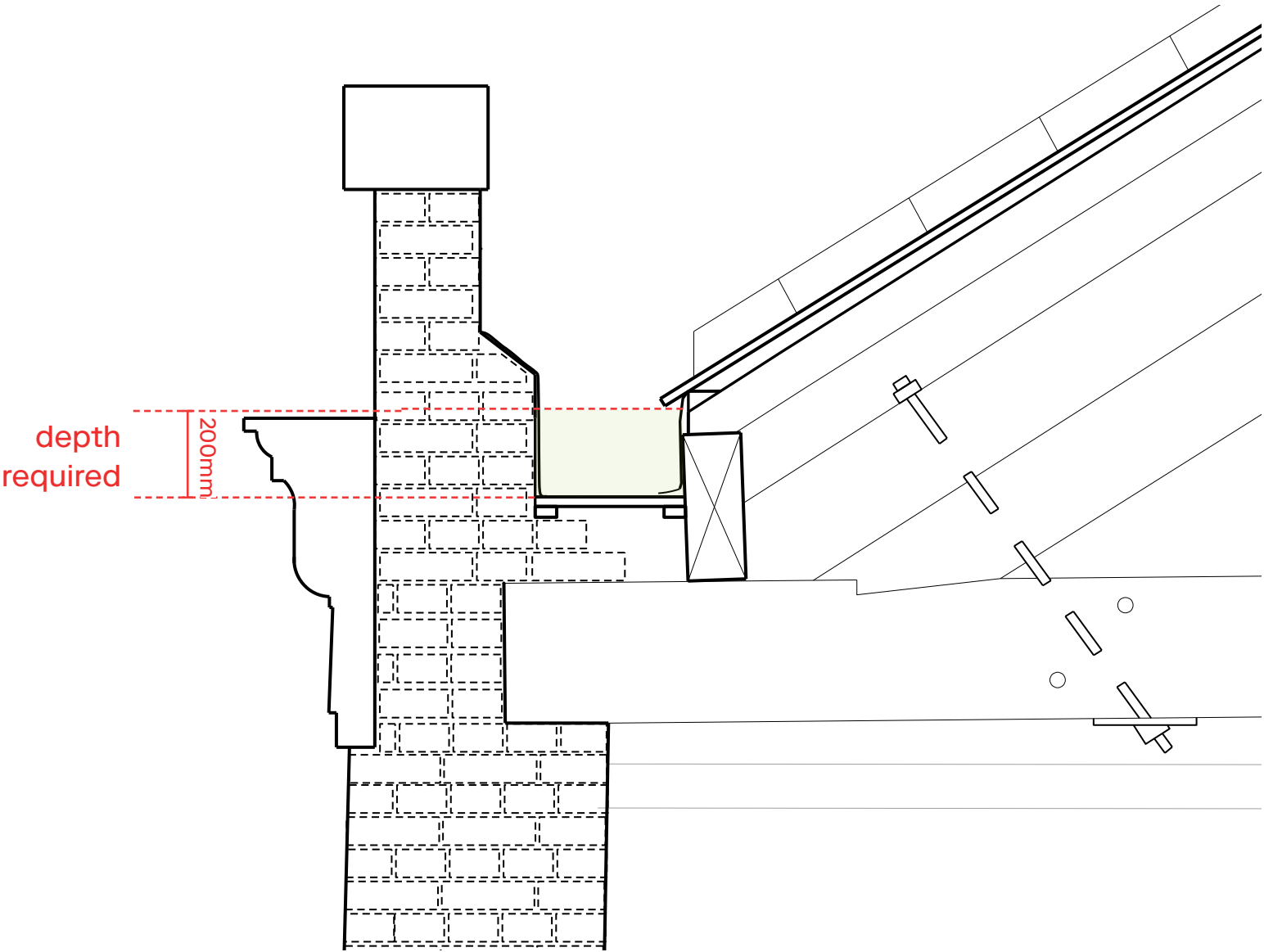
As an important listed building the design team's recommendation is to use conservative figures, based on a 500 year return period (i.e. a 500 year "storm" event) with a 20% margin applied to consider the anticipated impact of climate change throughout this period.

2.5 Existing Gutter Capacity

The sections below show the existing gutter condition at the valley and parapet, with the required capacity shown in green. The capacity requirement is achieved at the existing valley gutter but too low along the existing parapet.



Valley Gutter



Parapet Gutter

 Required gutter capacity

3 Lead vs Modern Gutters

3.1 Option 1: Lead Gutter Linings

3.1.1 Principles for lead gutters

3.1.2 Traditional Lead gutter linings

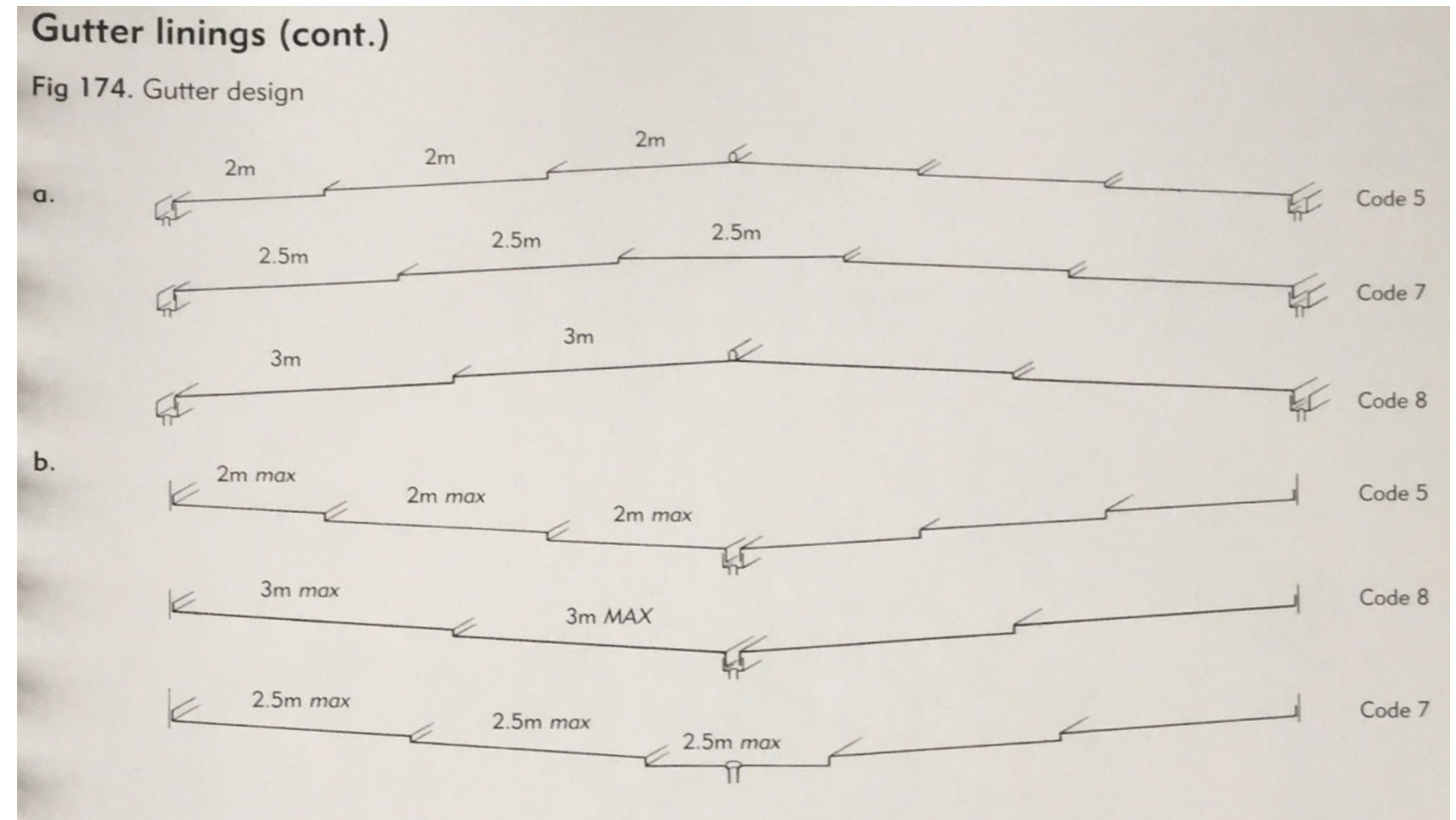
3.1.3 Valley gutter

3.1.4 Parapet gutter

3.1.5 Lead expansion joints

3.1.1 Principles for lead gutters

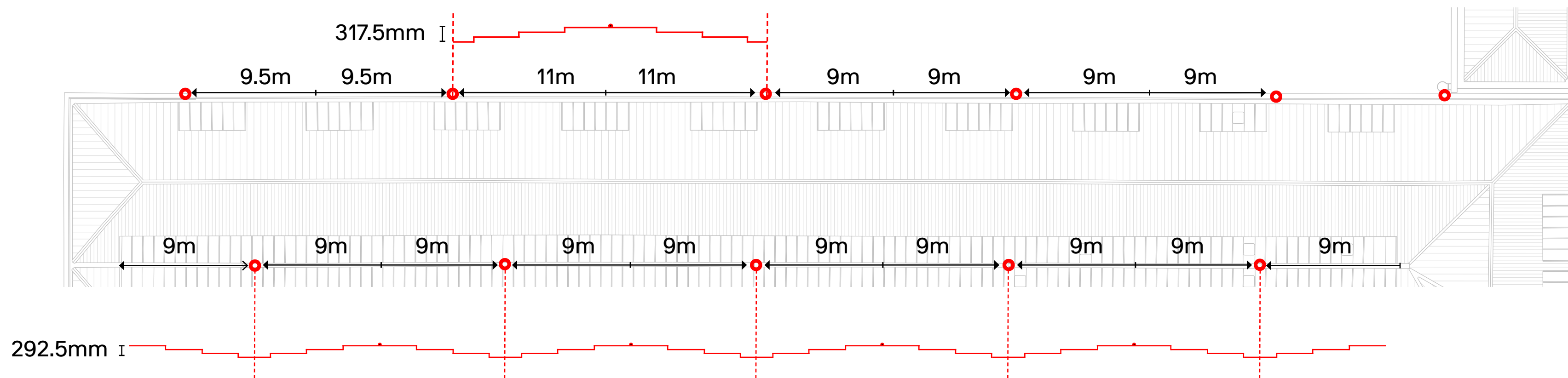
Lead gutters require a minimum 1/80 fall across their length, in addition to 60mm drips at least every 3m to make robust joint connections between pieces. (source: Rolled Lead Sheet: The Complete Manual)



Drip Design Lead Gutter Lining

3.1.2 Traditional Lead Gutter Linings

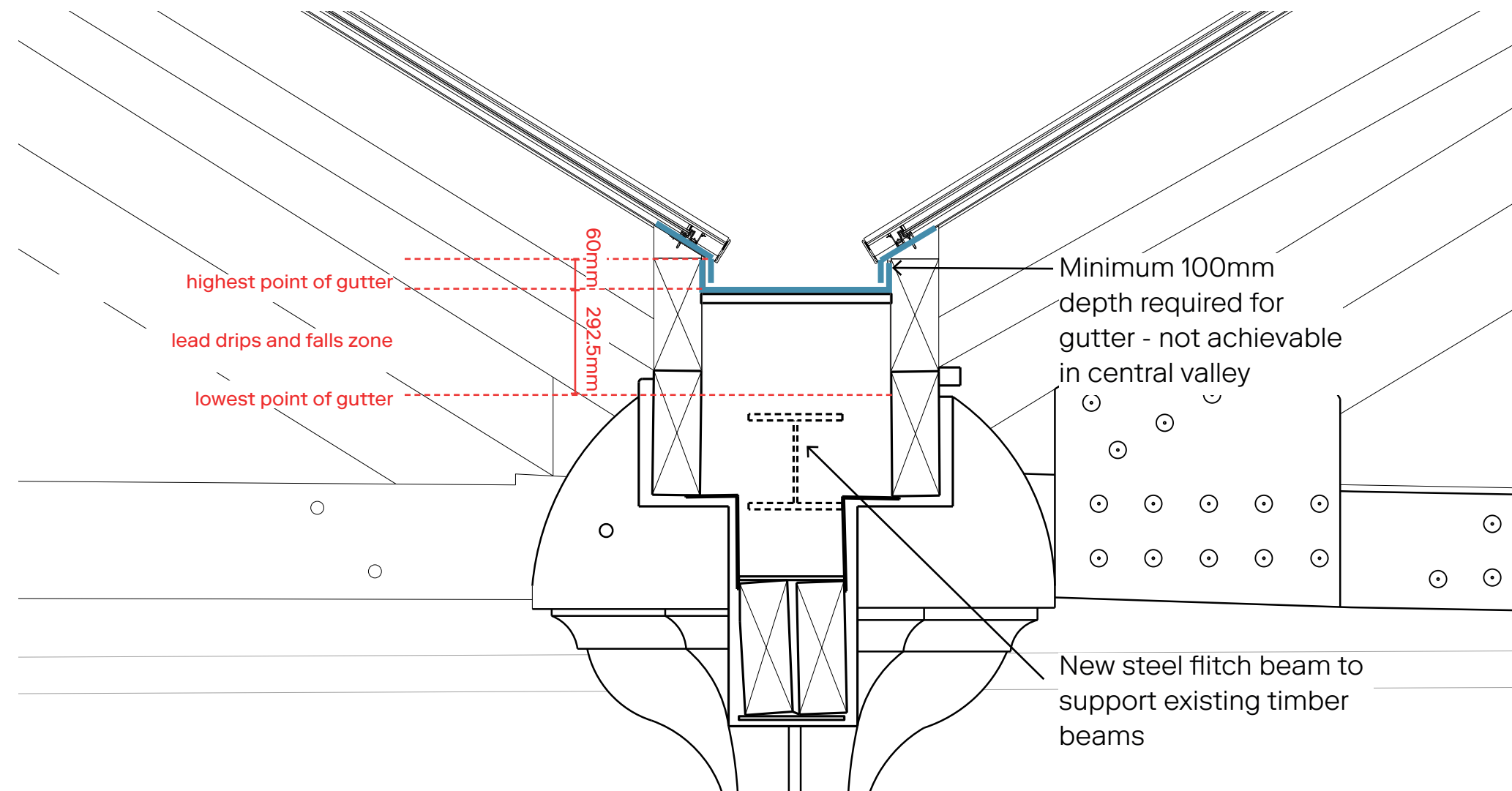
Based on the existing below ground drainage provisions and modern best practice standards for lead gutters, 292.5mm will be required for falls and steps to the valley gutter. For the parapet gutter the required falls vary with the greatest at approximately 11m, requiring 317.5mm total drop.



Whilst lead gutters were most likely employed in the construction originally, it is unlikely that the gutter capacity requirements would align with the challenges of current and anticipated rainfall events. Equally falls and steps within the gutters may not have met the best practice standards required today. The water ingress issues recently witnessed in relation to the gutters stem from the insufficient capacity and the lack of robust detailing. The existing lead lined parapet gutters are seemingly laid flat due to the inability to achieve the falls outlined above.

3.1.3 Valley Gutter

Lead gutters require a minimum 100mm depth at the highest point. (source: Rolled Lead Sheet: The Complete Manual). This minimum depth cannot be achieved in the valley gutter due to the concealed flitch beam repairs previously identified. A lead gutter could only be achieved in this location if an exposed flitch beam repair solution was adopted.



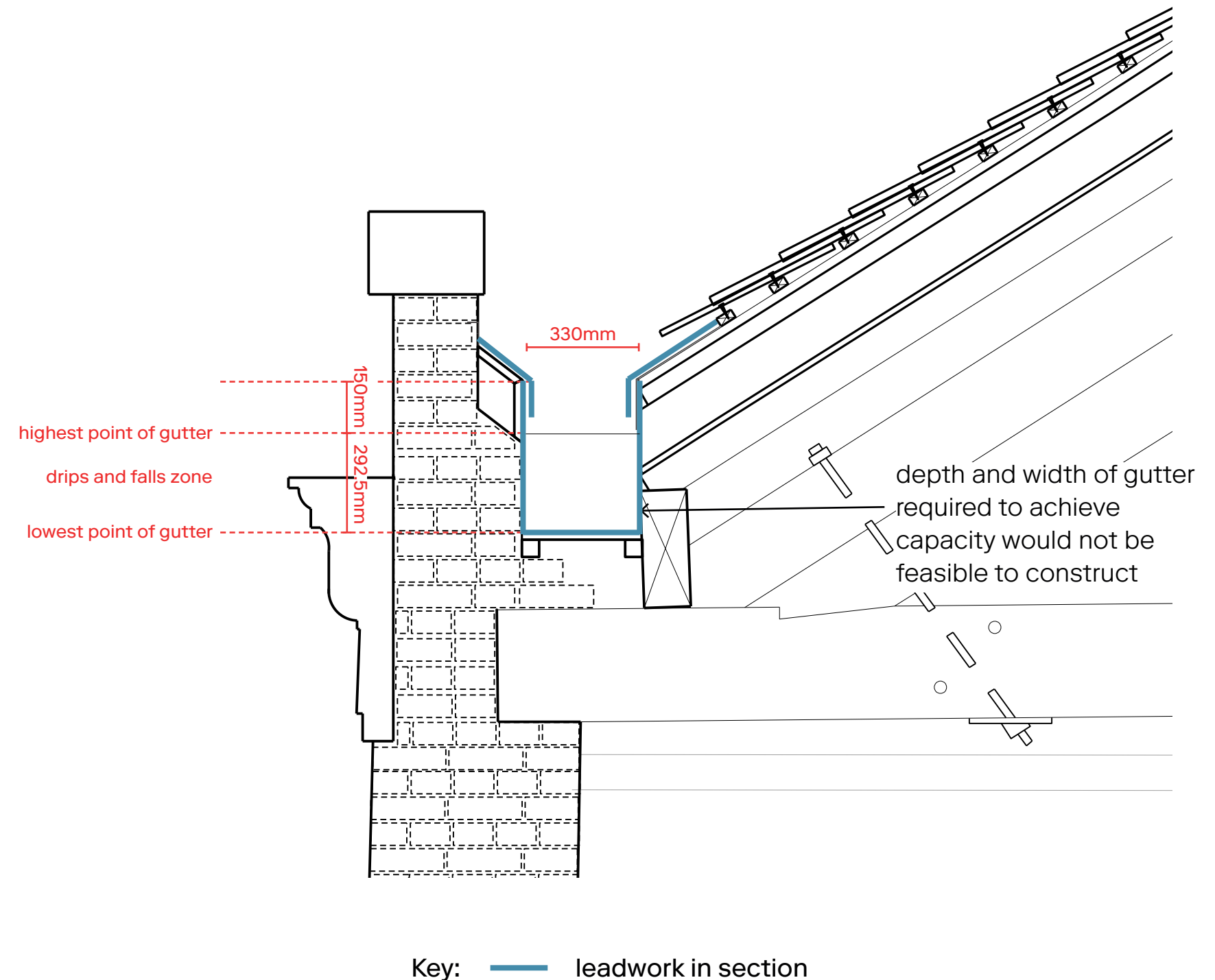
Key: — leadwork in section

Valley gutter detail - lead lining

3.1.4 Parapet Gutter

Due to the increased depth of the roof, achieved by the proposed insulation build up the required falls, drips and minimum depths for a lead lined gutter can be achieved. However, the contractor's specialist roofing subcontractor has advised that it will not be feasible to form the lead linings and details in such a deep, narrow gutter.

Along the parapet gutter 150mm minimum depth can be achieved with the increased build up of the roof, giving the capacity required for the gutter. However, it would not be feasible to construct such a narrow and deep gutter in lead due to the requirement for hand formed joints and drips.

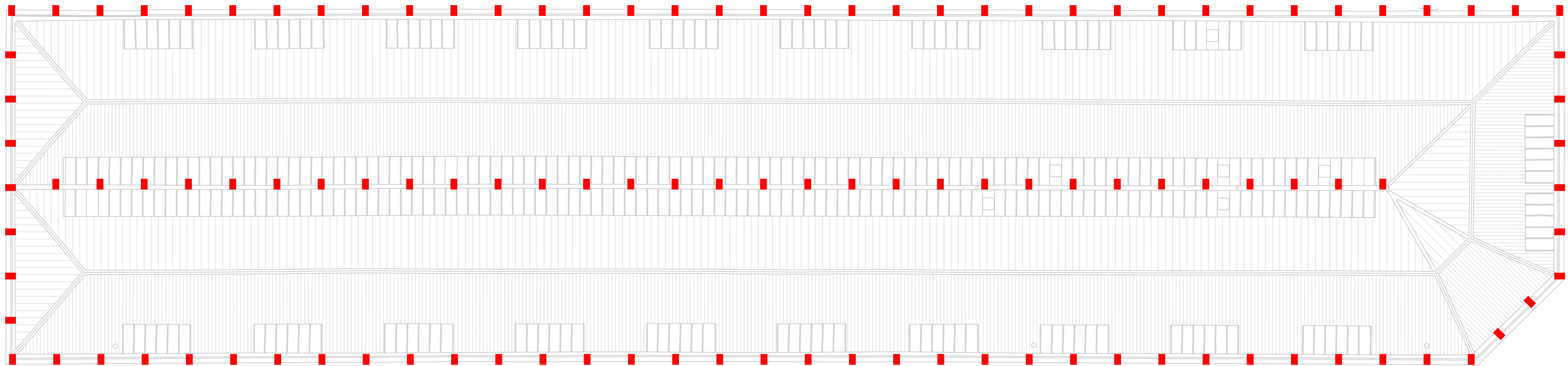


Lead Lining

3.1.5 Lead Expansion Joints (T-Pren or Similar)

A modern solution to jointing lead sheets with allowance for thermal expansion is to use neoprene expansion joints, such as the T-Pren system. The benefit of these joints is that they are flush, and replace the traditional method of using drips, significantly reducing falls distances over long gutter lengths between downpipes.

Using this system would allow lead gutters to be installed with a flat bed, without falls, which allows the required capacity to be more easily achieved. However this approach when used on the Power Hall would require approximately 190 expansion joints when used with code 5 lead, or 125 expansion joints when used with code 8 lead.



expansion joints at 3m centres required on a code 8 lead gutter

3.1.5 Lead Expansion Joints (T-Pren or Similar)

T-pren are not aware of their system being used on gutters as long as those on the Power Hall (the longest lead gutter they advised that uses T-pren joints in lead is 76m on Dunblane Cathedral).

Neoprene expansion joints do not have the robustness of traditional drips - T-Pren offer a guarantee of 10 years and suggest a service life of circa 25 years, but experience in practice suggests that the joints would need to be replaced after 15 years to mitigate the risk of failure causing water ingress. It is for this reason that both the Lead Association and RIBA recommend avoiding these joints wherever possible.

Having a significant number of these joints greatly increases the risk of failure and locating the exact failure point would be difficult given the number of joints. This option is not feasible due to the maintenance and cost liabilities and as it is not a tried and test solution on a roof of this size.

The construction method of this type, where the lead is installed in a modern way onto a flat gutter, would also not require specialist craftsmen to install and so some of the benefits of using lead would be lost.



T-Pren expansion joints

3.2 Option 2: Modern Gutter Linings

3.2.1 Modern materials

3.2.2 Parapet gutter

3.2.3 Valley gutter

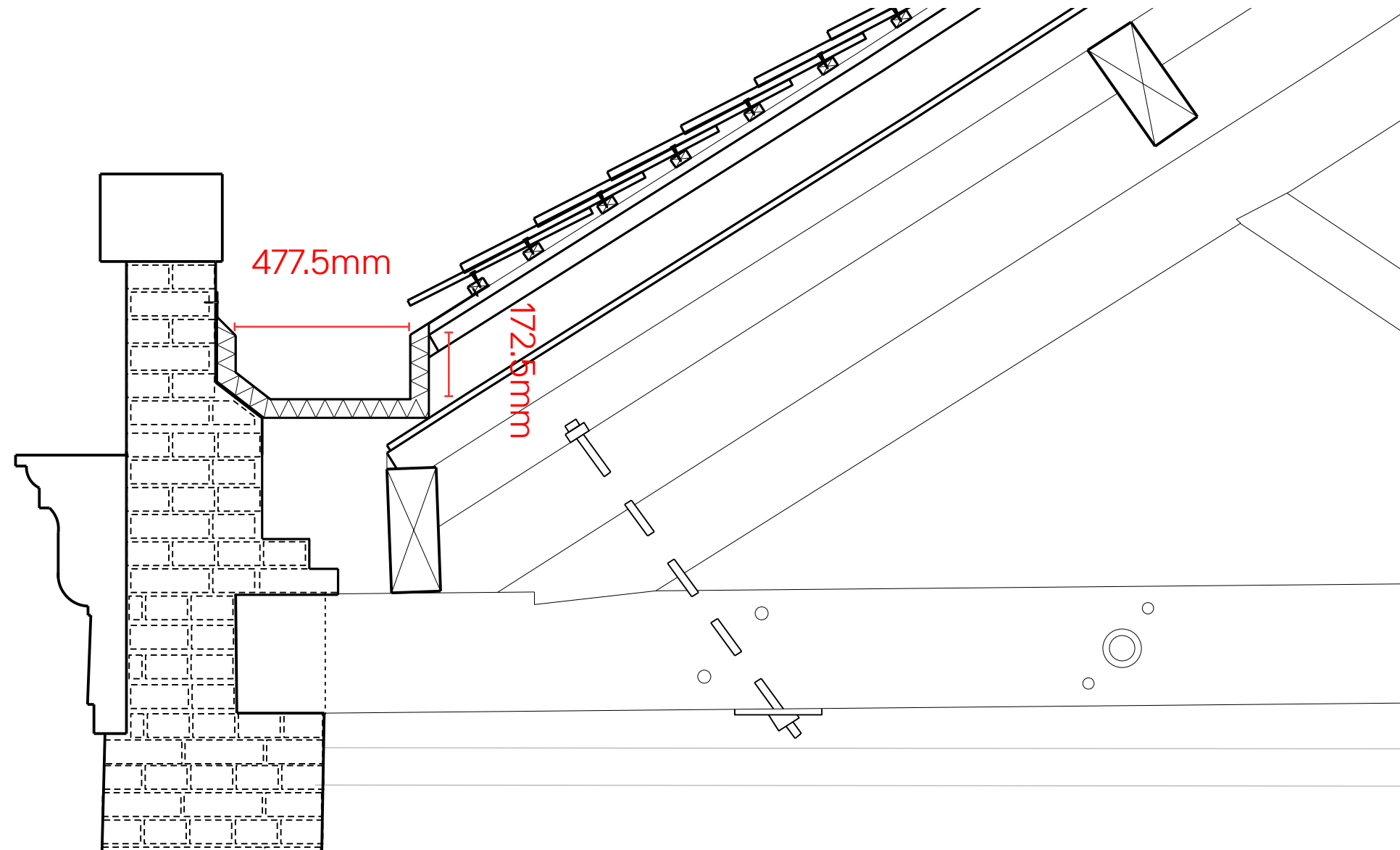
3.2.1 Modern materials:

Replacing the existing (non-historic) lead and aluminium gutters with modern materials brings the following key benefits:

- Increased capacity (following best practice guidelines with respect to local rainfall data and a consideration of climate change) to eliminate the water ingress issues
- Improved detailing to eliminate the risk of future water ingress issues
- Addition of insulation to protect the historic timber structure and deliver a more sustainable, energy efficient design in use
- Improved maintainability, which is key to ensuring future water ingress issues are avoided
- Gutters constructed from modern materials can be laid flat, which also aides their integration into existing buildings where there are constraints to achieving falls.

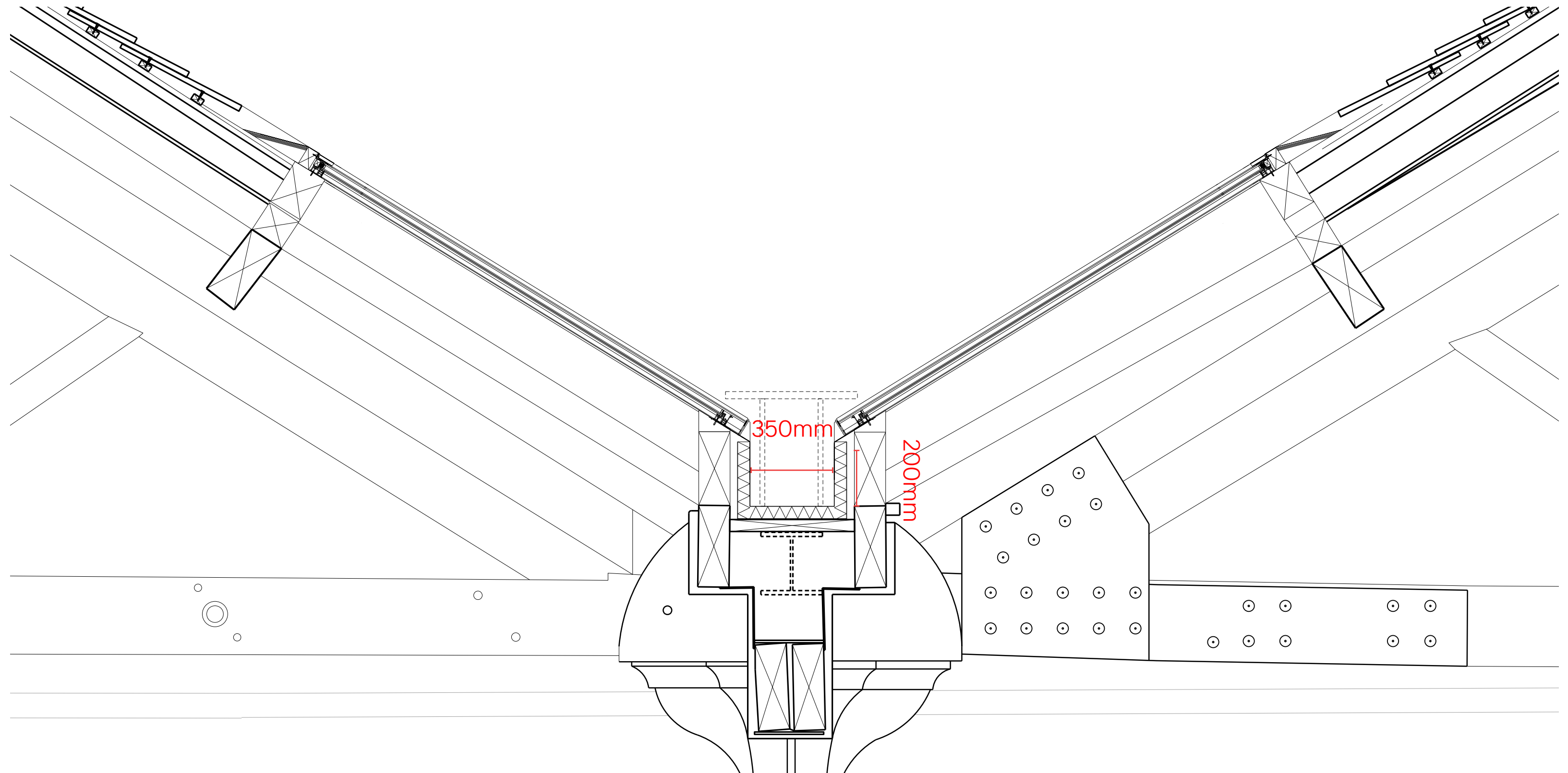
3.2.2 Parapet Gutter

Due to the proposed increase in the roof depth, stemming from the addition of insulation to the roof build up, a wider, flatter gutter profile can be achieved to allow for more robust construction. This would have the benefit of being away from the existing structure, and be easier for maintenance. The configuration would allow a membrane lined insulated metal gutter to be installed along the length of the parapet, with welded joints between sections.



Cross sectional area of 0.07m² required

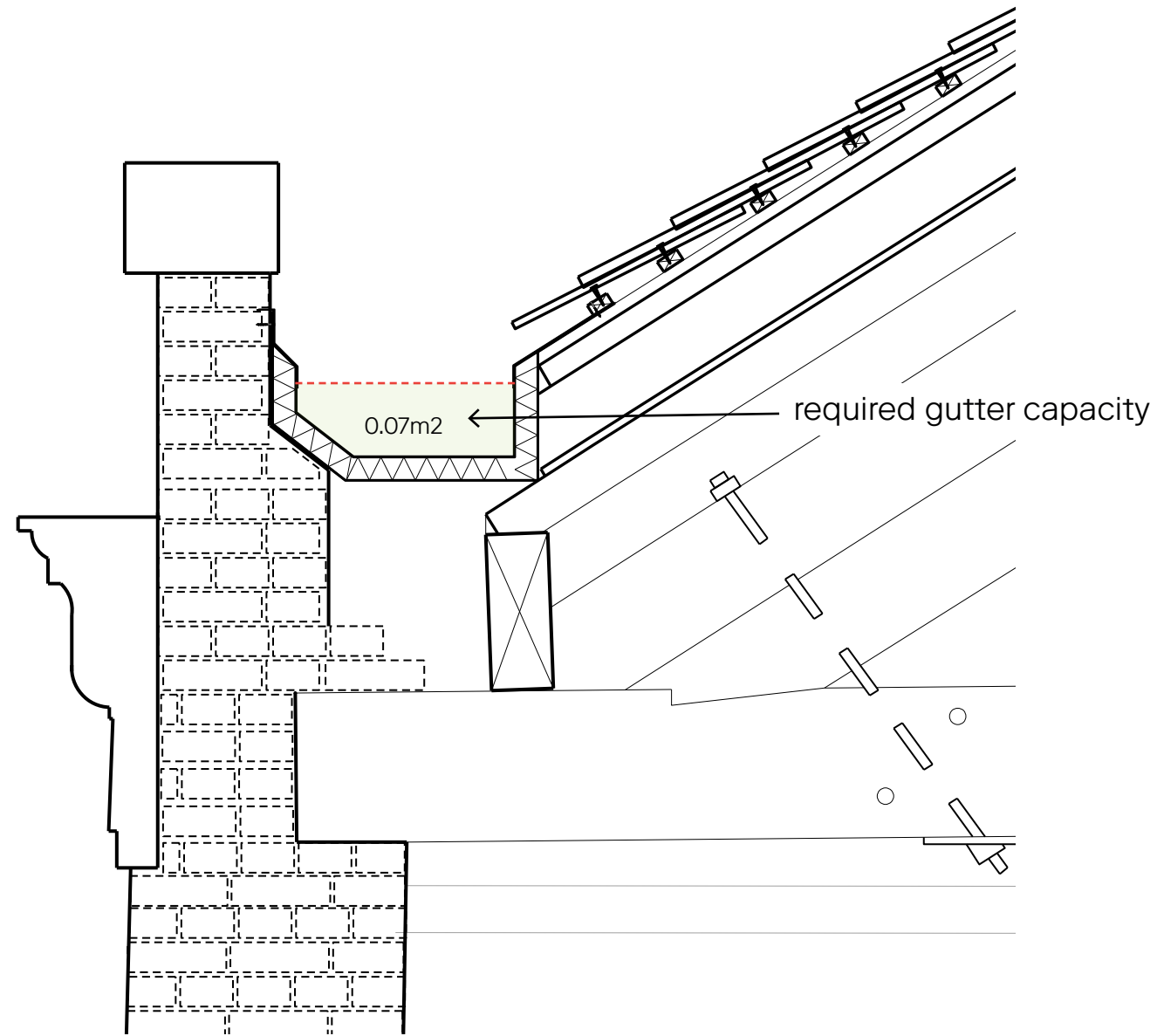
3.2.3 Valley Gutter



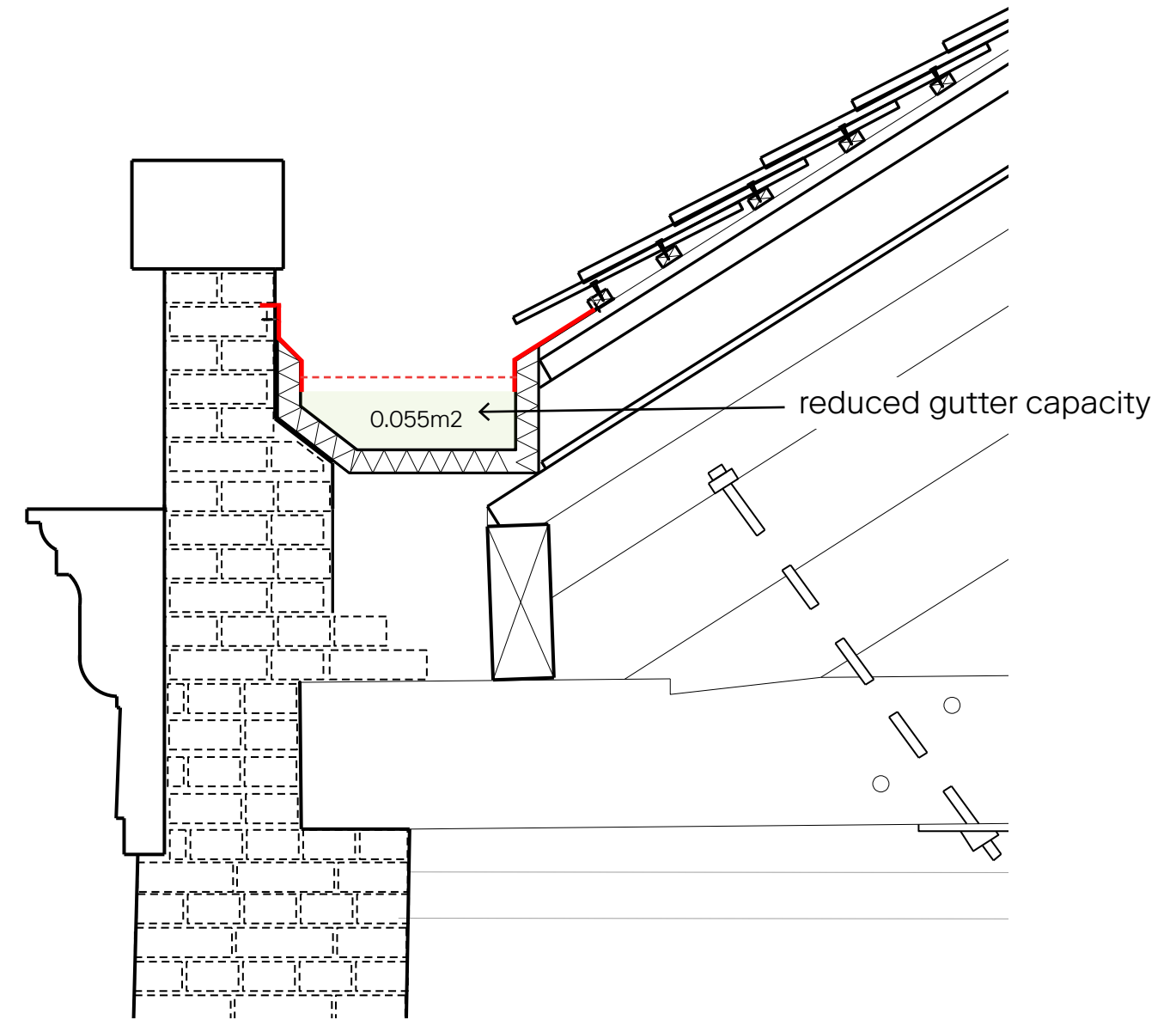
Cross sectional area of 0.07m² required

3.3 Gutter Flashing

Lead flashings have been considered in combination with membrane lined gutters however these would effectively reduce the capacity of the gutters, and are therefore not considered feasible



Insulated membrane lined gutter with integral flashings



Insulated membrane lined gutter with lead flashings

4 Summary of Options

Option	1a: Lead gutters	1b: Lead gutters with T-Pren Joints	2: Membrane lined gutters	3: Membrane lined gutter with lead flashings
Advantages	Heritage: Lead is likely the material used for the guttering when the building was originally built Longevity: Robustly detailed gutters with drips can be expected to last 60-100 years Craftsmanship: Specialist skills would be required for the installation due to the traditional construction techniques.	Heritage: Lead is likely the material used for the guttering when the building was originally built Capacity: Due to requirements for drip details and falls along the gutter length, it is not possible to achieve the required capacity in the central valley without changing the flitch beam support strategy	Capacity: Due to the engineering and flush jointing system of a membrane lined gutter, a required increased capacity can be achieved. Longevity: Membrane lined gutters have a 40+ year lifespan and come with a 25 year guarantee. Improved detailing can be achieved, compared with the existing condition, which is critical for protection of the structure in perpetuity Cost: Reduced cost allows increased budget towards elements of the project with direct public benefit.	Heritage: Lead is likely the material used for the guttering when the building was originally built Longevity: Membrane lined gutters have a 40+ year lifespan and come with a 25 year guarantee, to ensure protection to the historic structure for many years to come.
Disadvantages	Capacity: Due to requirements for drip details and falls along the gutter length, it is not possible to achieve the required capacity in the central valley without changing the flitch beam support strategy Buildability: Due to the required shape of the parapet gutter to allow for the required drips, it would be very difficult to form the leadwork at the deepest points, creating additional cost and programme risk. Cost: An increased cost will impact the budget which can be allocated to elements of the project which give direct public benefit. Hot works: Required as part of the construction of leadwork details, this adds risk to historic timber structure	Longevity: T-Pren joints have a 10 year warranty, and are therefore not recommended by Lead Authority and RIBA due to their lack of longevity. They would also be required at least every 3m, Meaning 125+ joints will be prone to leakage in the future. This could result in further damage to the heritage fabric. Cost: An increased cost will impact the budget which can be allocated to elements of the project which give direct public benefit. Hot works: Required as part of the construction of leadwork details, this adds risk to historic timber structure Craftsmanship: No specialist skills would be required for the installation due to the modern construction techniques.	Heritage: The use of modern materials does not match the original, however a similar slate grey colour can be specified, and the difference would not be visible except when on the roof.	Cost: An increased cost will impact the budget which can be allocated to elements of the project which give direct public benefit. Capacity: Using lead flashings reduces the gutter capacity compared to an integral membrane solution.
Conclusion	Lead valley gutter not feasible; insufficient depth achievable Lead parapet gutter not feasible; gutter proportions required to accommodate capacity requirements within existing building constraints are not buildable.	The number of joints are a significant risk. This option is not feasible due to the maintenance and cost liabilities and as it is not a tried and test solution on a roof of this size.	Using modern materials is the preferred approach as it provides the most robust, cost effective and buildable approach.	Lead flashings are not feasible as they reduce the effective capacity of the gutters