DESIGN
Initial principles

Design of the appropriate system for a specific project must always be preceded by a detailed audit of the proposed site to establish:

- *Existing* factors and considerations applicable to the site
- *Predicted* factors relating to the site's use following the planned development, and the parameters within which the installation is required to function
- The type of *function or application* suggested by this audit.

The required design information to be established by this audit is summarised in the **Design Information Checklist** in **Section 2.2**.

Successful design also requires an understanding of the design philosophy behind each of the Wavin Stormwater Management systems.

Once the project criteria have been established from the site audit, there are then two key parts to the design procedure:

- Hydraulic design
- Structural design.

2.1.1 Wavin systems design philosophy: AquaCell

The AquaCell unit has been designed to combine high physical strength with good three-dimensional flow performance.

Hydraulic function

Water entering a box structure made up of AquaCell units dissipates quickly. The unit design allows single point access for the three main pipework systems:

- Inflow
- Outflow
- Air release.

The primary function of the AquaCell unit is for the management of storm run-off from impermeable surfaces. This can be utilised in three ways:

- *Infiltration*: water is collected in the units during rainfall and allowed to drain away by soaking into the surrounding ground over a substantial period of time after the rain has stopped
- *Attenuation*: water is collected in the units during rainfall and released at a reduced flow rate through a flow control device into an appropriate outfall. This reduces peak flows in the watercourse and thereby minimises the risk of flooding
- *Conveyance*: units are used as an alternative to conventional pipework, providing increased online storage and slower transfer rates into watercourses and sewers. This gives the benefit of attenuation and, if so designed, infiltration.

Structural function

The AquaCell units are designed to maintain structural integrity, individually and in multi-unit assemblies, under both dead loads (e.g. covering and surrounding earth) and imposed loads (e.g. transient pedestrian and light vehicular traffic).

Independent testing

Hydraulic and structural testing of AquaCell units was supervised by the University of Salford, a well-respected independent authority in this field.

Hydraulic testing was conducted in a flume – 13m long and 1.2m wide – at a variety of water depths, flow rates and gradients, using a series of AquaCell units. This served to establish a fully validated understanding of AquaCell's hydraulic performance capabilities.

Further testing determined the structural capacity of the system. This involved direct loading and long term creep tests on single AquaCell units.

NOTE: Detailed test methodology used in these independent tests is described and explained in **Appendix 4**. Design parameters established by the tests are included in Design procedures (**2.3** and **2.4**)

2.1.2 Wavin systems design philosophy: Garastor

Hydraulic function

The Garastor domestic attenuation system was developed in collaboration with Bryant Homes. The complete system provides an innovative method of creating a substantial, temporary water storage area in the void space under the floor slab of a residential property garage (**Fig. 2.6**) or under a soft landscaped area (**Fig. 2.8**).

The key component in this system is the Garastor flow control, a plastic inspection chamber with built-in flow control device and overflow.

During high intensity rainfall, water from the roof or hard standing areas is diverted via the Garastor control unit into a void created between the walls and beneath the concrete floor of a domestic garage, or to an adjacent small reservoir created from AquaCell units. As the storm subsides the rainwater can be slowly released back into the main drainage system.

The Garastor system has undergone independent assessment by the University of Edinburgh to test flow and discharge rates.

Design considerations

2.2.1 General considerations

The following is a summary of the information which is normally required to establish the design parameters for Wavin Stormwater Management systems. This includes a thorough understanding of all the physical and environmental attributes of the site, as well as the anticipated practical requirements and criteria for its future functioning in times of heavy rainfall.

Where necessary, these are explained in more detail in following pages.

2.2.2 General considerations

Infiltration or attenuation?

The full site audit will help determine whether infiltration is required and/or possible – or whether attenuation and temporary storage is more appropriate. This may simply be dictated by the physical attributes of the site (e.g. soil type and properties). However, environmental considerations may be particularly influential (*see* **Section 2.2.3**).

Geotextile or geomembrane?

This in turn will establish whether a *permeable* geotextile or *impermeable* geomembrane wrapping should be specified for the AquaCell installation(s).

The choice of these materials is also subject to a number of physical and performance criteria (*see* **Section 2.4.2**).

Bedding, backfill and cover fill specification?

There are special considerations for the materials to be used for bedding and filling around AquaCell assemblies. These are described in detail in a later section which includes detailed design data for backfill specification (*see* **Section 2.4.3**).

2.2.3 Environmental considerations

Stormwater quality

Using the AquaCell system to infiltrate stormwater, or to temporarily store it on site, can provide other environmental benefits besides reduced flood risk to streams and rivers.

It may also reduce the impact of pollutants present in stormwater run-off if they are infiltrated and filtered in the underlying soils.

However, as with any drainage system the designer must ensure that new risks are not introduced. In each case, a site specific risk assessment of the likely effects of the use of the system on local water resources should be undertaken by the client, particularly where infiltration is being used.

Roof water run-off

The Environment Agency's Groundwater Protection Policy identifies that installation of soakaways to discharge only roof water is acceptable in most situations. However, on contaminated sites, care must be taken to ensure that the water does not mobilise the contaminants, and that the water can be discharged below the base of contamination.

Surface water run-off

Surface water run-off can wash pollutants into watercourses or the soil. The nature and amount of pollution is dependent upon the land use and human activities within a catchment. Similarly, the impact of surface water run-off is difficult to predict as it is not only dependent upon the type and volume of pollution transported, but also upon the nature and sensitivity of the receiving waters.

Hence the design and long term performance of stormwater management systems needs to take into account this potential variability of environmental conditions over the operating life.

Design information checklist

Description	Information Sources
A. Existing factors	
Topography	Site survey or inspection
Area of catchment*	Site survey
Hydrology of catchment	Site inspection and observations
Soil type*	Site investigation
Structural properties of soil – CBR, stiffness	Site investigation and laboratory testing
Infiltration potential of soil*	Site investigation
Contamination*	Site investigation and desk research
Details of receiving water/ watercourse/aquifer	Environment Agency, Scottish Environment Protection Agency or water and sewerage company
Environmental sensitivity of site	Environment Agency, Scottish Environment Protection Agency or water and sewerage company
Groundwater vulnerability and source protection status	Environment Agency, Scottish Environment Protection Agency or water and sewerage company
B. Predicted factors	
Development type and land use	Proposed development plans
Traffic loads	Proposed development plans
Rainfall data*	Meteorological Office or Wallingford Procedure
Discharge design criteria – quantity	Environment Agency, Scottish Environment Protection Agency or water and sewerage company
Discharge design criteria – quality	Environment Agency, Scottish Environment Protection Agency or water and sewerage company
Health and safety	All affected parties
C. Planned function	
Infiltration	Conclusions from **A** and **B** audit/review
Attenuation	Conclusions from **A** and **B** audit/review

*NOTE: For individual house soakaways, only the items in italics are required.

Infiltration base

Many pollutants tend to adsorb to soil particles when infiltrated to the ground. The evidence suggests that migration of heavy metals does not extend to greater than about 500mm below the base of soakaways. Typically, therefore, the base of an infiltration system should be located at least 1m above the highest recorded groundwater level below a site to minimise the risk of pollutants being transported into groundwater.

High risk areas (stormwater hotspots)

These are areas where:

- Land use or activities have the potential to generate highly contaminated run-off, or
- The groundwater is an important source for drinking water abstraction.

Before embarking on any specific project, the Client should confirm that a Stormwater Management System is suitable for installation in the location concerned.

Hotspot areas can be categorised into three types:

- *Resource based*: areas providing a valuable resource that must be protected
- *Use based*: areas with activities which are liable to generate pollutants or material hazards
- *Ground conditions based*: where pollutants are known to be already present.

Resource based hotspots

In these areas:

- Only roof drainage should be discharged via soakaway
- For highway and other drainage, fully tanked storage systems should be used, with outlet via pipes to surface water sewers or watercourses.

Hotspots defined by resource include:

- Groundwater inner source protection zones.

Further advice on the use of infiltration drainage over aquifers is provided in the Environment Agency's Groundwater Protection Policy.

Use based hotspots

In these areas:

- Infiltration drainage systems should not normally be used without a full assessment of the risks and consequences of both general day-to-day and major spillage
- The use of interceptors will normally be required and a mechanism for closing the outlet from the system provided
- Where the risk of pollution occurring is considered unacceptable, a fully tanked system should be used.

Hotspots defined by use include:

- Fuel stations
- Areas where hazardous/toxic materials are stored, loaded or unloaded
- Vehicle or equipment service, cleaning and maintenance areas.

Ground conditions based hotspots

In these areas:

- Where contaminated soils are present, soakaways should not be used unless the water can be discharged below the base of the contamination
- Where very minor ground contamination (non-mobile) exists, infiltration may be possible if a risk assessment establishes that any risks to groundwater are acceptable.

Groundwater pollution cannot be seen, and is difficult to put right once it has occurred. Therefore the precautionary principle should be adopted when assessing risks to groundwater and deciding if to use infiltration drainage.

2.2.4 Health & Safety: Construction (Design and Management) Regulations

Under the Construction (Design and Management) Regulations 1994 (CDM), every project design must include a site-specific Health and Safety assessment.

Risks to construction workers, users and maintenance workers need to be avoided or minimised wherever possible. These are typically associated with the design and construction of conventional drainage, such as working in excavations, excavation near services, etc.

AquaCell units

However, there are no specific issues relating to the installation, use and maintenance of the AquaCell units themselves.

In many instances, the AquaCell system can help reduce the risks of injury during construction. For example:

- The units are lightweight and easily manhandled

  Benefit: reduced risk of lifting injuries
- The system is also designed as a shallow attenuation or infiltration system

  Benefit: reduced need for deep sewer excavations.

Garastor

The Garastor system can use the house foundations, walls and garage floor slab to form the storage space. A CDM risk assessment will always be required for these elements.

There are no other specific health and safety issues relating to the design and installation of the Garastor system.

Design procedures: Hydraulic

2.3.1 Rainfall and run-off

Evaluating rainfall events

The most commonly used method for evaluating storm rainfall events in the UK is the Wallingford Procedure[v]. This assesses the total rainfall level of storms over defined time periods – ranging from 5 minutes up to 48 hours in duration.

The procedure comprises use of a series of maps, factors and charts to enable the level of any given storm to be predicted based on:

- Geographical location
- Storm return period
- Storm duration.

The output from the procedure is a depth of water in mm, which can then be multiplied by the catchment area to assess the size of infiltration/attenuation systems.

Storm duration - attenuation systems

In many attenuation systems the outflow is very small in comparison with the overall storage volume. In this case, a critical event of 120 minutes (2 hours) is typically used.

Storm duration - infiltration systems

If the outflow is large, as can be the case with infiltration systems in good soils, a number of shorter durations must be evaluated to find the critical period which leads to the largest storage volume.

To evaluate short duration rainfall events falling on buildings, use British Standard BS EN 12056-3:2000[vi]. This allows 2 – 10 minute events to be evaluated for a range of return periods and locations. In the UK 2 minutes is the commonly used concentration period for roof drainage rainfall.

Return period

The return period chosen for either of the above approaches can have a significant impact on the volumes generated.

For underground drainage systems and soakaways, 10 or 30 year events have commonly been used in the past. However, ongoing climatic change and the publication of Planning Policy Guidance Note 25: *Development And Flood Risk*, have dictated a new approach. Many area officers of the Environment Agency now request allowance for a 100 year event. Others are asking for this to be increased by a safety factor of 20%.

Reduction factors

Not all water runs off the surface. Accordingly, designers may reduce the overall catchment areas to reflect this fact. For example:

- On hard surfaces, a quantity will be retained in pore spaces and on the surface
- Even on metal roofs, a small amount will be retained as droplets.

To allow for this, use the following reduction factors:

- For hard surfacing: 10%
- For buildings: 5%.

2.3.2 Infiltration

Key factors checklist

When considering an infiltration drainage system there are a number of issues that must be investigated before embarking upon detailed design:

- Is the soil type suitable for water to soakaway?
- Is the natural groundwater level below the base of the infiltration tank?
- Will the water quality cause pollution of the surrounding ground or any underlying aquifer? (e.g. chemical pollution from an industrial site)
- Is there a suitable location for the tank away from buildings or other structures so that the water will not affect basements and foundations? (Minimum distance from buildings: 5 metres – *see* **Fig. 2.3**)
- What are the consequences of the tank becoming full due to rainfall rates above the design condition?

Site survey

These and other questions need to be addressed by a thorough site survey which is likely to involve:

- A geotechnical site investigation
- Construction of a trial pit.

This site test is exceptionally important since it proves the acceptability of the site.

Trial pit

The most commonly used method is set out in Building Research Establishment (BRE) Digest 365[vii]. A typical procedure is as follows:

- A pit is excavated down to the level of the proposed infiltration tank. The pit should be between 0.3 and 1m wide and 1 to 3m long
- The pit is filled with water to the invert level of the proposed inlet pipe
- The water level in the pit should be noted at regular intervals and the total time taken for it to empty recorded
- This process should be repeated at least twice more
- The time taken to fall from 75% full to 25% full is used in the calculation of a soil infiltration coefficient, which is used in the design
- If this coefficient is less than 10^{-6} m/s, the site is likely to be deemed unsuitable for infiltration
- If the area of the proposed tank is large (e.g. larger than a small single house development), further pits should be dug at 25m intervals.

As a guide a gravel will yield values in the region 0.1 to 0.001, whilst silty clay or solid rock could be as low as 10^{-10} (**Table 1**).

Table 1 *Typical infiltration rates*

Soil Type	Typical Infiltration rate
Gravel	$10^{-1} – 10^{-3}$ m/s
Sand	$10^{-2} – 10^{-5}$ m/s
Silt	$10^{-5} – 10^{-9}$ m/s
Clay	$< 10^{-9}$ m/s
Chalk*	$10^{-3} – 10^{-5}$ m/s

From Construction Industry Research and Information Association (CIRIA) Project Report 21[vii]

* Blocky fissured chalk where fissure flow is dominant
Excludes putty chalk and Chalk Marl.

DESIGN
Design procedures: Hydraulic

System design

For the design of the system there are two approaches, either of which may be adopted:

- The Construction Industry Research and Information Association (CIRIA) Report 156 "Infiltration Drainage – Manual of Good Practice"[ix]
- BRE Digest 365 "Soakaway Design".

A comparison of these design approaches can be found in **Appendix 1**.

Simplified Approximate Approach

Infiltration design to either the BRE or CIRIA methods can be complex. Each requires detailed site infiltration rate information which may not be available on very small sites (e.g. a single house development).

The design parameters in **Table 2** allow an estimate of the required tank size to be made based on the area to be drained and soil type. It assumes:

- 100% run-off
- A 1 in 100 year storm event of critical duration
- UK Location
- Both vertical sides of structure available for infiltration (trench layout).

The above method is an approximation only, and may not reflect accurately the infiltration performance of a specific site.

For a more accurate approach, one of the more complex methods (BRE or CIRIA) should be used. These are compared in **Appendix 1**.

A worked example for the simple method can be found in **Appendix 2**.

Design volumes and areas

For users of the BRE 365 or CIRIA 156 methods, two look-up tables showing volumes and areas for trench or cuboid type installations are given in this section (**Tables 3** and **4**).

Calculation principles

AquaCell units are 1m x 0.5m x 0.4m. Although the sides of an AquaCell box are not totally open, in use they are wrapped in a geotextile. This allows water to be adsorbed into contact with the whole fabric/soil interface.

Accordingly:

- The total side and base areas are used in calculations
- Storage volume is 95% of the total volume.

Linear trench configuration

Fig. 2.1 shows a typical linear trench configuration.

Table 3 shows the volume and surface area of a trench layout. These figures can be multiplied by the trench length.

Cuboid configuration

Fig. 2.2 shows a typical cuboid configuration.

Table 4 gives details for some typical 3D installations. These are site specific and the data is supplied as a guide to the expected values.

EXAMPLE

Trench 40m long and 2 units deep

- *Volume 0.38 x 40 = 15.2 m³*
- *Side areas of 1.6 x 40 = 64 m²*

Soakaways: minimum distances

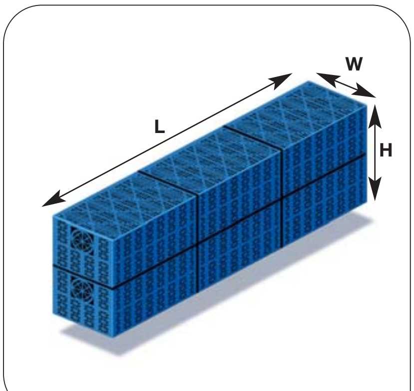

Fig. 2.1: *Typical linear trench configuration*

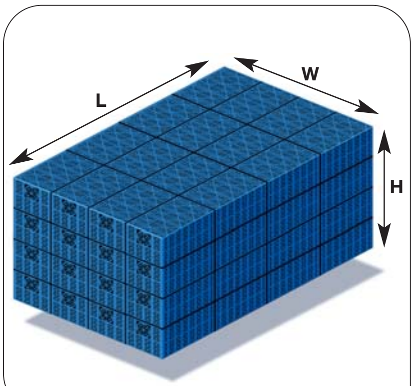

Fig. 2.2: *Typical cuboid configuration*

Table 2 *Design parameters for single house roof soakaway*

Soil Type	Maximum Impermeable Catchment Area per AquaCell unit (m²)	No. of AquaCell units per 100m² catchment area
Gravel	95.0	2
Sand	14.4	7
Chalk*	7.9	13
Silt	0.475	211
Clay	Consult Wavin for project specific information	

* Blocky, fissured chalk, where fissure flow is dominant. EXCLUDES putty chalk and Chalk Marl.

Table 3 *Volumetric data per linear m for a 1 unit (0.5m) wide trench configuration*

Number of units high	Volume m³	Side area m²	Base area m²
1	0.19	0.8	0.5
2	0.38	1.6	0.5
3	0.57	2.4	0.5

Table 4 *Volumetric data for 3D usage, 2 units high*

Units long	2 wide (0.5m side)			4 wide (0.5m side)			8 wide (0.5m side)		
(1m side)	Vol m³	Side m²	Base m²	Vol m³	Side m²	Base m²	Vol m³	Side m²	Base m²
1	0.76	3.2	1.0	1.52	4.8	2.0	3.04	8.0	4.0
2	1.52	4.8	2.0	3.04	6.4	4.0	6.08	9.6	8.0
4	3.04	8.0	4.0	6.08	9.6	8.0	12.16	12.8	16.0
8	6.08	14.4	8.0	12.16	16.0	16.0	24.32	19.2	32.0
10	7.60	17.6	10.0	15.20	19.2	20.0	30.40	22.4	40.0
100	76.00	161.6	100.0	152.00	163.2	200.0	304.00	166.4	400.0

Design procedures: Hydraulic

Soakaways or reservoir tanks must be a MINIMUM of 5 metres from the nearest building or other structures (**Fig. 2.3**).

Fig. 2.3 shows two alternative soakaway configurations: one designed using the CIRIA 156 method; the other using the BRE method. The BRE method leads to a trench type layout, which can cause installation problems on smaller constricted sites, but reduces the number of units required.

Soakaway layouts

The modular nature of the AquaCell system makes various trench layouts possible. **Fig. 2.4** shows some suggested layout types (BRE-style) to allow trenches to be installed with greatest efficiency.

2.3.3 Attenuation

Key factors checklist

For an attenuation system, the key factors to be determined are:

- What is the anticipated run-off volume from the site?
- What is the allowable discharge rate to the appropriate outfall?
- By how much does run-off volume exceed this limit?
- What storage volume is required to hold the excess?
- How many AquaCell units are required to provide this storage volume?

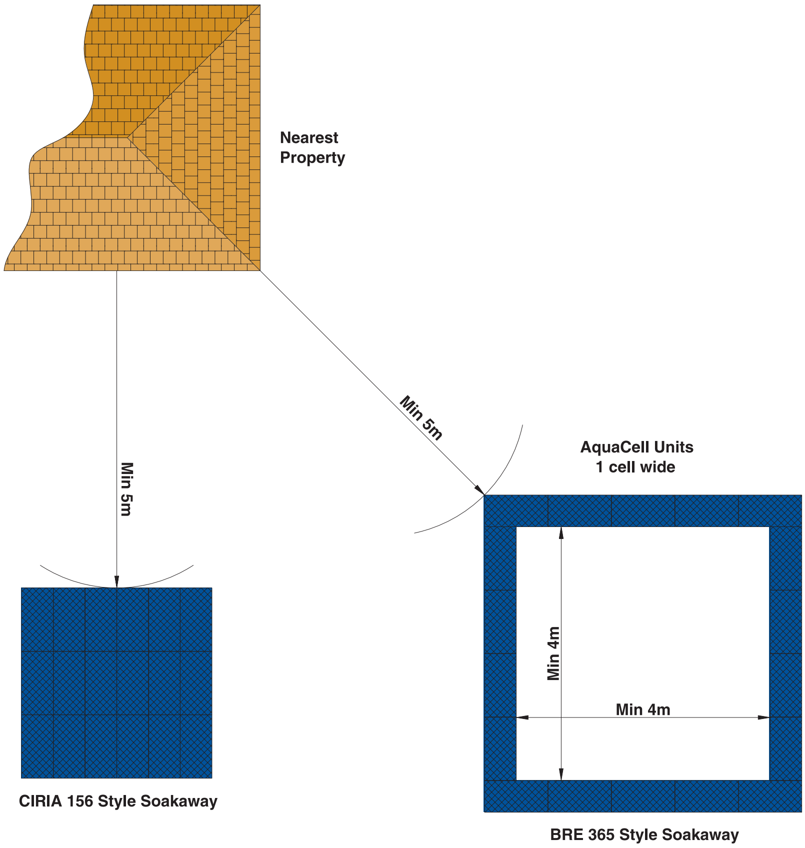

Fig. 2.3 *Minimum distances for soakaways*

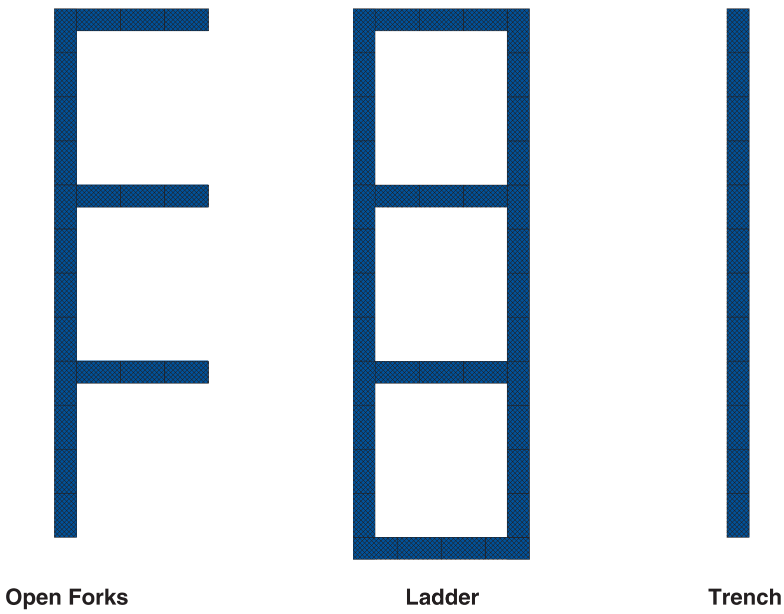

Fig. 2.4 *Typical BRE-style soakaway trench layouts*

Design procedures: Hydraulic

Calculation principles

Firstly, calculate the anticipated run-off volume [**A**] from the site. This is normally based upon a 2 hour storm of a return period appropriate for the catchment (*see rainfall and run-off* **Section 2.3.1**).

Establish the allowable discharge rate from the site to an appropriate outfall. This will normally be set by the Environment Agency or Planning Authorities.

Calculate the outflow volume [**B**] that can be discharged at this rate over the two hour period (**Table 5**).

Subtract this allowable discharge (outflow) volume from the run-off volume [**A–B**]. This defines the excess volume [**C**] which needs to be stored in AquaCell units constructed as an underground tank.

Calculate the number of AquaCell units needed to contain this excess [**C**]. **Table 6** provides a quick-reference calculator for this purpose. The storage volume is actually equal to 95% of the external dimensions of the tank to be created.

Outflow volume

Table 5 shows the outflow volume (in cubic metres) for different discharge rates (litres per second) over a 2 hour storm. The volumes are cumulative, so volume lost from higher discharge rates can be easily calculated (*see* EXAMPLES *on the right*). The required storage volume is obtained by subtracting this figure from the calculated run-off total.

2.3.3.1 AquaCell system

Storage volumes

Table 6 gives storage volumes for a tank consisting of a single layer of up to 180 AquaCell units.

Volume is cumulative for each successive layer. Accordingly, if the tank is two units high, its capacity is simply double the single layer volume for the configuration used.

Table 5 *Run-off volumes for a 2 hour storm*

Discharge (l/s)	Volume lost in 120 mins (m^3)
0	0.0
1	7.2
2	14.4
3	21.6
4	28.8
5	36.0
6	43.2
7	50.4
8	57.6
9	64.8

EXAMPLE

- *7 l/s outflow = 50.4 m^3 volume over 2 hours*
- *14 l/s outflow = 7 l/s x 2 = 100.8 m^3 volume over 2 hours*
- *11 l/s outflow = 9 l/s + 2 l/s = 79.2 m^3 volume over 2 hours*

Table 6 *Volume (m^3) of tank created from the given number of single layer AquaCell units*

Number of units long \ Number of units wide	1	2	3	4	5	6	7	8	9
1	0.19	0.38	0.57	0.76	0.95	1.14	1.33	1.52	1.71
2	0.38	0.76	1.14	1.52	1.90	2.28	2.66	3.04	3.42
3	0.57	1.14	1.71	2.28	2.85	3.42	3.99	4.56	5.13
4	0.76	1.52	2.28	3.04	3.80	4.56	5.32	6.08	6.84
5	0.95	1.90	2.85	3.80	4.75	5.70	6.65	7.60	8.55
6	1.14	2.28	3.42	4.56	5.70	6.84	7.98	9.12	10.26
7	1.33	2.66	3.99	5.32	6.65	7.98	9.31	10.64	11.97
8	1.52	3.04	4.56	6.08	7.60	9.12	10.64	12.16	13.68
9	1.71	3.42	5.13	6.84	8.55	10.26	11.97	13.68	15.39
10	1.90	3.80	5.70	7.60	9.50	11.40	13.30	15.20	17.10
11	2.09	4.18	6.27	8.36	10.45	12.54	14.63	16.72	18.81
12	2.28	4.56	6.84	9.12	11.40	13.68	15.96	18.24	20.52
13	2.47	4.94	7.41	9.88	12.35	14.82	17.29	19.76	22.23
14	2.66	5.32	7.98	10.64	13.30	15.96	18.62	21.28	23.94
15	2.85	5.70	8.55	11.40	14.25	17.10	19.95	22.80	25.65
16	3.04	6.08	9.12	12.16	15.20	18.24	21.28	24.32	27.36
17	3.23	6.46	9.69	12.92	16.15	19.38	22.61	25.84	29.07
18	3.42	6.84	10.26	13.68	17.10	20.52	23.94	27.36	30.78
19	3.61	7.22	10.83	14.44	18.05	21.66	25.27	28.88	32.49
20	3.80	7.60	11.40	15.20	19.00	22.80	26.60	30.40	34.20

Volume in m^3

EXAMPLE

- *Tank which is 4 AquaCell units wide, 6 units long, and 1 unit high (i.e. single layer) creates tank with 4.56 m^3 volume*
- *Tank which is 4 AquaCell units wide, 6 units long, and 3 units high (i.e. triple layer) creates tank with 3 x 4.56 m^3 volume = 13.68 m^3*

The single layer volumes have been calculated from the equation:
Volume = 0.19 x number of boxes wide x number of boxes long
A worked example for the simple method can be found in **Appendix 2**.

DESIGN

Design procedures: Hydraulic

Design software

Software for the design of the required number of AquaCell units is available from Wavin. This enables the user to input:

- *Allowable discharge from the development*
- *Storm duration (defaults to 2 hours).*

Unit configurations are then changed until the required total storm flow is achieved.

Flow control

In the attenuation application, the AquaCell units are wrapped with an impermeable geomembrane. Water enters the tank through one or more inlet pipes and normally exits through a single pipe to the outfall.

However, the outflow from the tank of AquaCell units must be controlled to comply with the discharge rate consent that has been set for the site.

Outflow positioning and head calculations

The invert level of the outflow pipe should be flush with the bottom of the lowest unit to allow the tank to drain.

As the tank fills, a depth of water develops on the upstream side of the outflow control. For a tank which consists of 2 layers of AquaCell units, this water depth would rise to 0.8m when the units were full, creating a driving head to push the flow through the control device. For design purposes, the head used in calculations is taken as that at the centre line of the outflow device.

Flow control methods

There are four main methods to achieve this outflow control:

1. *Orifice plate*. A thin plate, with a small sharp-edged hole in it, which is installed at the upstream end of a larger pipe. It is normally positioned flush with the invert of the pipe. The hole is often circular but this is not a requirement of the concept.

   The required diameter [**D**] of the orifice (in millimetres) may be calculated using the following equation, in which **Q** = flow rate (m³/s) and **H** = head of water (m):

$$D = \sqrt{\frac{463.627Q}{\sqrt{H}}}$$

   NOTE: This equation is valid only for small orifices with sharp edges. *For the general equation from which this is derived, see* **Appendix 3**.

   The flow rate will vary with the head in the tank, and so it is prudent to take only 50% of the peak flow rate when calculating the volumes discharged.

2. *Garastor control chamber.* A single size orifice and overflow system built into a plastic inspection chamber. This can be used with AquaCell units where very low discharge rates are required. *See* **Figs. 2.7** *and* **2.9** for Garastor design charts.

3. *Vortex controls*. Devices which perform the function of orifices, but which are geometrically designed to spin the flow through the hole leaving an air core.

   The actual hole is much larger than the equivalent orifice, but achieves the same degree of throttle. This means that the hole is less prone to blockage. These devices are designed to order by the manufacturers.

4. *Small pipe*. For this option, the pipeline to the outfall is designed with a hydraulic gradient defined by the difference in level between the top water level in the tank and the soffit of the pipe at its discharge point to the outfall (or into the first manhole, if this exists).
   The required pipe size is identified by using hydraulic pipe flow tables.

   This option is normally only used for larger flow rates because, for low flows and short pipe runs, the pipe size can become small and hence prone to blockage by leaves and other debris that may enter the system.

   Pipe friction will change over time, and the flow rate will reduce, as a consequence of the growth of a film of biological material on the pipe lining.

See **Table 7** *for comparative features and benefits of these flow control options.*

Maintenance access

For all flow control designs, it is sensible to incorporate access (via a manhole or similar) to the location of the pipe entry, orifice or vortex control. This will enable easy removal of any blockage. The orifice itself may be protected by a debris screen (**Fig. 2.5**).

Table 7 *Features and benefits of various flow control devices*

	Orifice Plate	Garastor	Vortex-control	Small Pipe
Cost	low	low	high	no extra cost
Usage	any flow	single low flow	any flow	large flow rates
Design method	simple calculations	design graph	by manufacturer	simple calculations
Risk of blockage	medium	medium	low	high
Adjustable	fit new plate – low cost	No	Purchase of new device – high cost	No

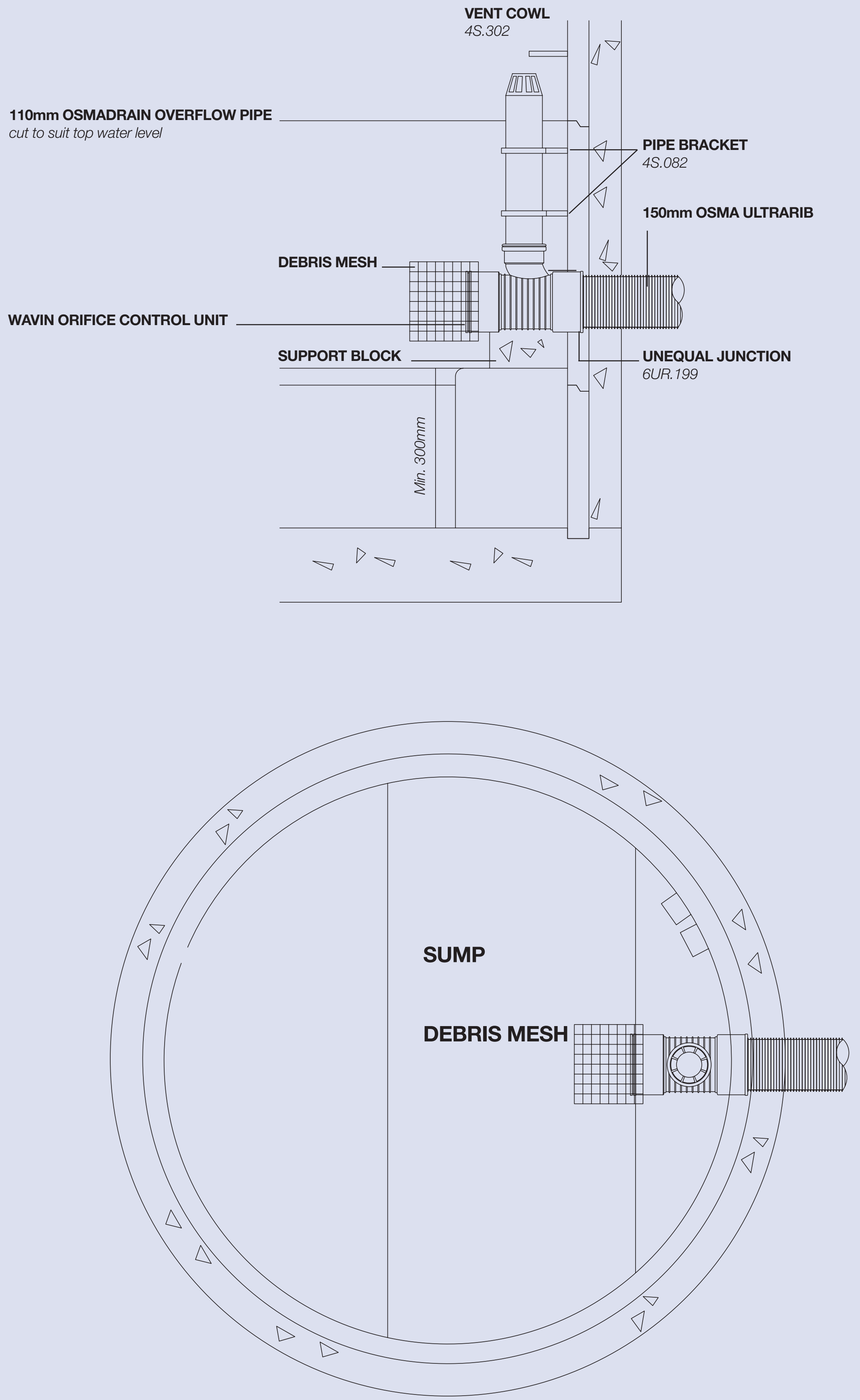

Fig. 2.5 *A Protected Orifice Plate*

Design procedures: Hydraulic

Garage void application

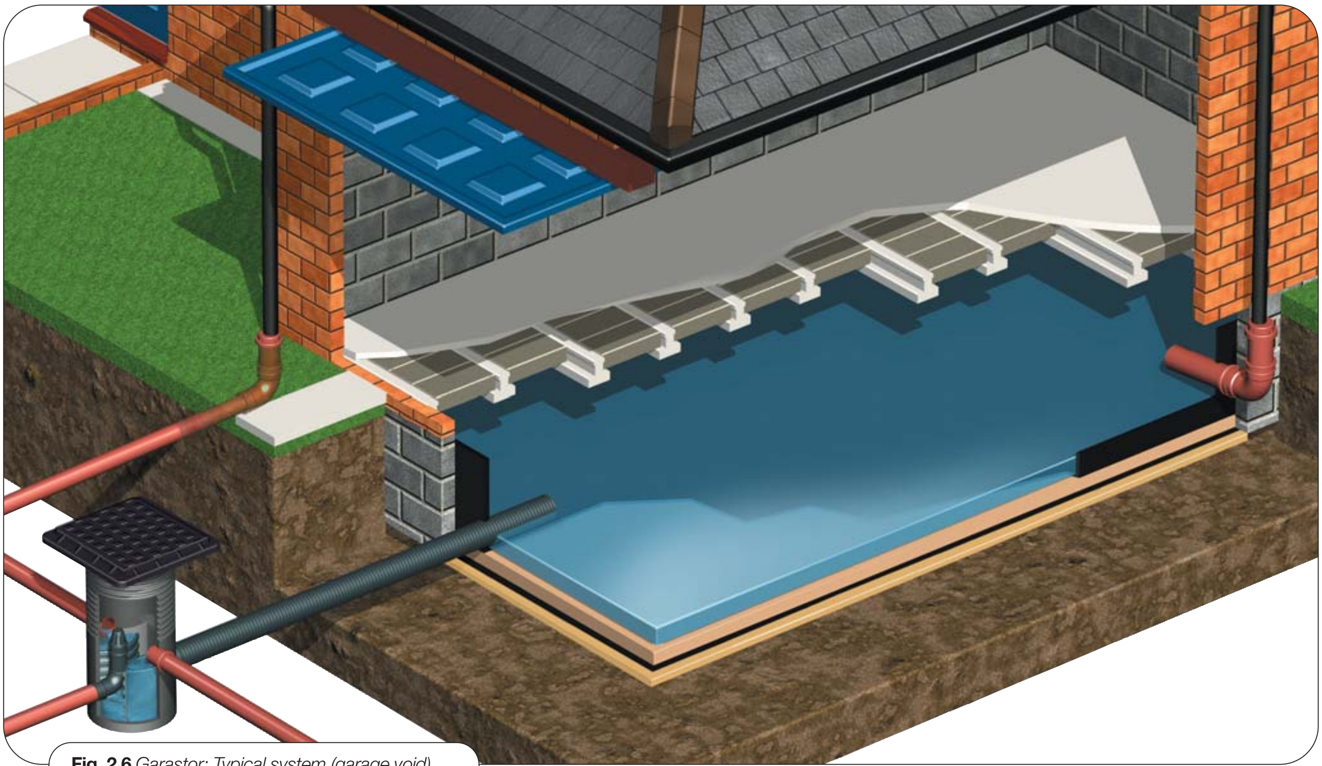

Fig. 2.6 *Garastor: Typical system (garage void)*

2.3.3.2 Garastor system

Application options

The Garastor control chamber application may be designed to control attenuation in conjunction with:

- A storage void created beneath the floor of a garage (**Fig. 2.6**)
- A storage void (made up of AquaCell units) under garden and driveway areas (**Fig. 2.8**).

Required storage volumes

The volume of the required storage facility may be influenced by consideration of:

- Area contributing to run-off
- Design basis in terms of length of storm return.

For each of the applications, an indicative chart is provided as a guide to required volumes, correlating these factors at a number of design levels (**Figs. 2.7** *and* **2.9**).

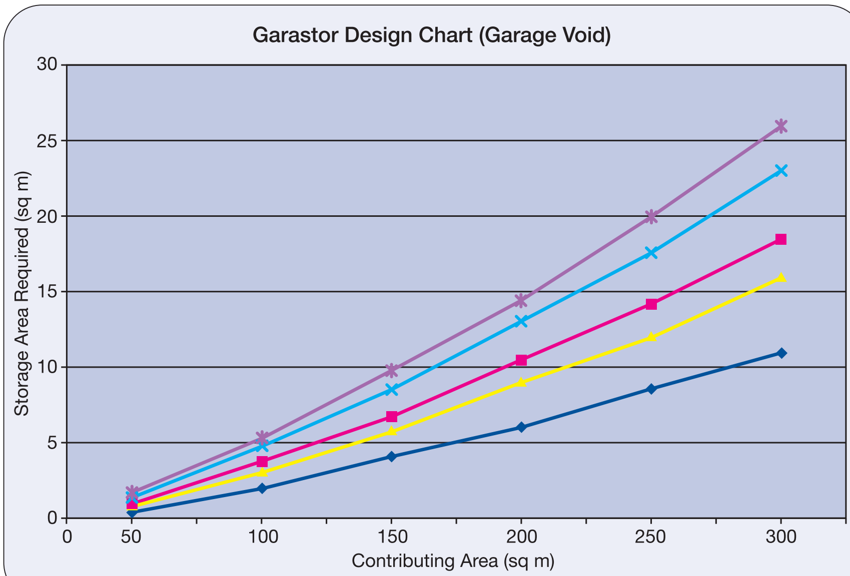

Fig. 2.7 *Garastor: Design chart (garage void)*

This chart is for indicative purposes only and is not for use in detailed design. Templates and data files, for use in detailed design of Garastor applications, are available from Wavin Plastics Limited. Curves created by WinDes drainage software (©Micro Drainage 2001).

- Storage Area Req. 10 year ret
- Storage Area Req. 30 year ret
- Storage Area Req. 50 year ret
- Storage Area Req. 100 year ret
- Storage Area Req. 150 year ret

Garden void application

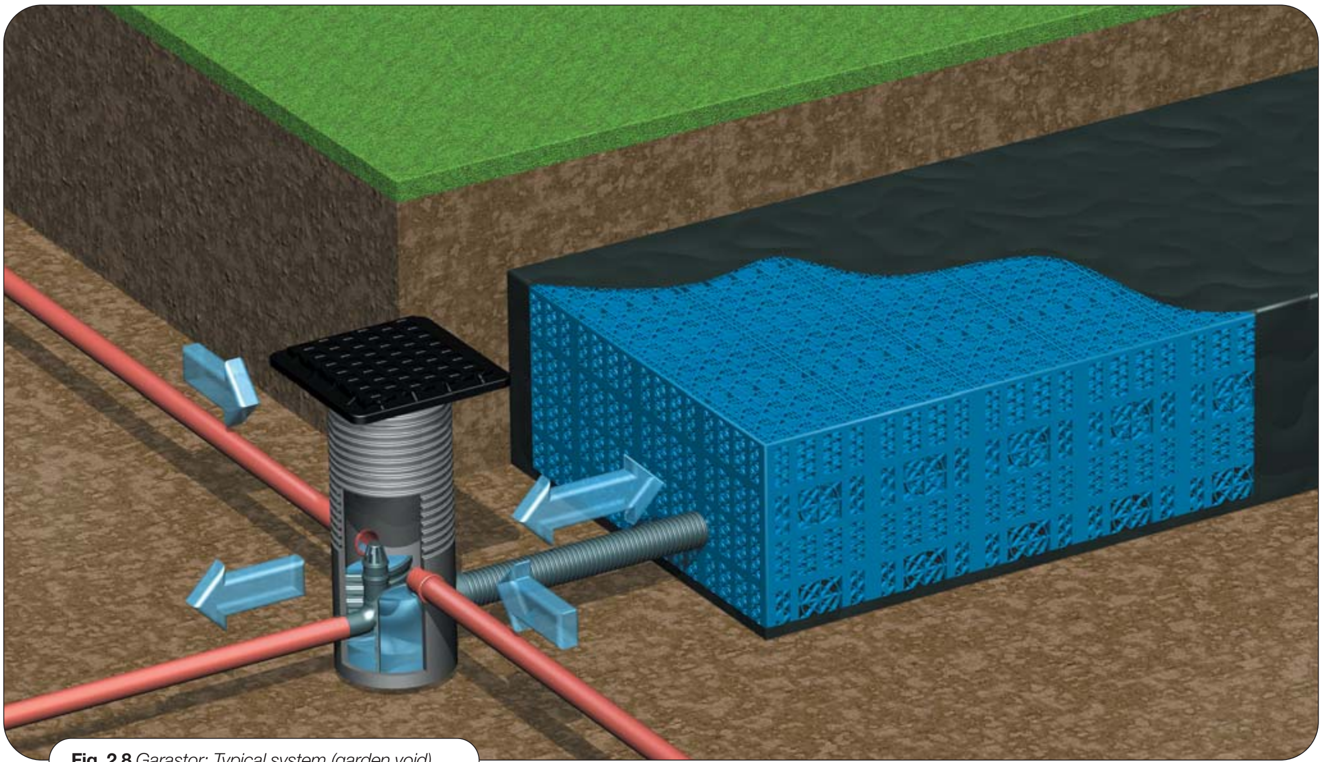

Fig. 2.8 *Garastor: Typical system (garden void)*

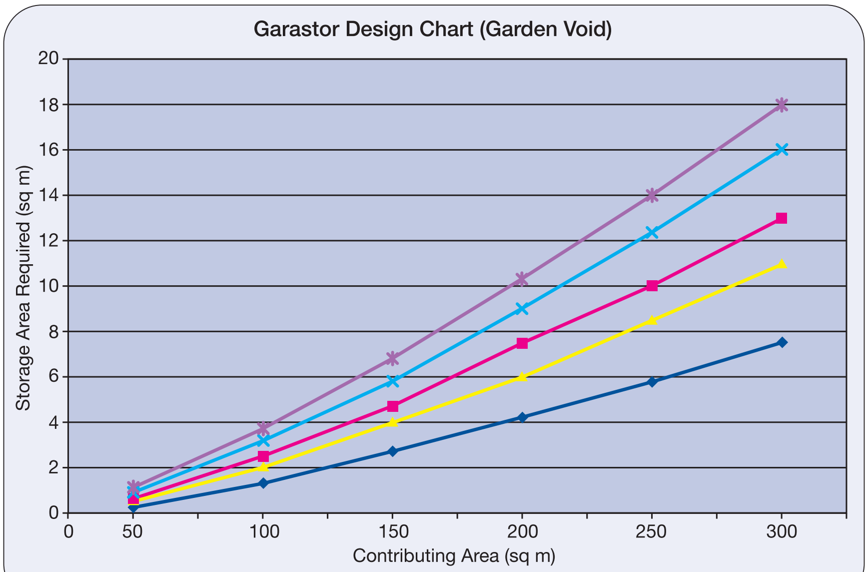

Fig. 2.9 *Garastor: Design chart (garden void)*

This chart is for indicative purposes only and is not for use in detailed design. Templates and data files, for use in detailed design of Garastor applications, are available from Wavin Plastics Limited. Curves created by WinDes drainage software (©Micro Drainage 2001).

2.3.4 Siltation management

Transportation of silt and debris

When stormwater passes over paved or natural surfaces, it will pick up particles of sand, silt and grit. These particles are transported by the shear forces generated by the velocity of the moving water. They may be carried in suspension, or moved by rolling and saltation along the surface over which the water is flowing.

The water will also move other debris. This may include leaves or rubbish which can be transported by floating. The washing of debris from a surface normally happens at the start of a storm and is often known as 'the first flush'.

DESIGN
Design procedures: Hydraulic

Build-up

If debris enters the AquaCell units (whether in attenuation or infiltration applications), the still water within the unit will have insufficient velocity to keep the particles moving. This can lead to any of the following undesirable consequences:

- Debris will be deposited in the AquaCell units around the pipe entry
- Some of the void intended for water storage will begin to fill up
- Organic matter may start to decay
- Noxious gases may build up.

Prevention

To prevent this, it is recommended that a silt trap is planned for incorporation into the pipework at the inlet to the tank (**Fig. 2.10**).

To be effective, there must be a maintenance plan that ensures regular cleaning of the silt trap. Otherwise, if the trap is full, any additional debris will simply pass into the tank.

Off-line construction

To reduce the risk of siltation further, AquaCell tanks may be constructed off-line.

In this case, the throttle arrangement for the allowable discharge is located in a manhole chamber on the main surface water run-off pipe. This means that low flows pass straight through the throttle and never enter the tank. Much of 'the first flush' debris is transported direct to the outfall in this way.

When the flow exceeds the capacity of the throttle, depths build up in the manhole and water backs up into the tank. Heavy debris travelling along the invert of the main pipe will not be carried into the tank. In special circumstances scum boards can be used to prevent the transfer of floating material.

2.3.5 Manifold design

Connection into an AquaCell unit is made by removing a 150mm diameter break-out section, allowing free discharge into the cell.

The capacity of this input pipe is limited and may be insufficient for the anticipated flow load. The flow load may therefore be split between a number of 150mm inflow pipes from the adjacent manhole (**Fig. 2.11**).

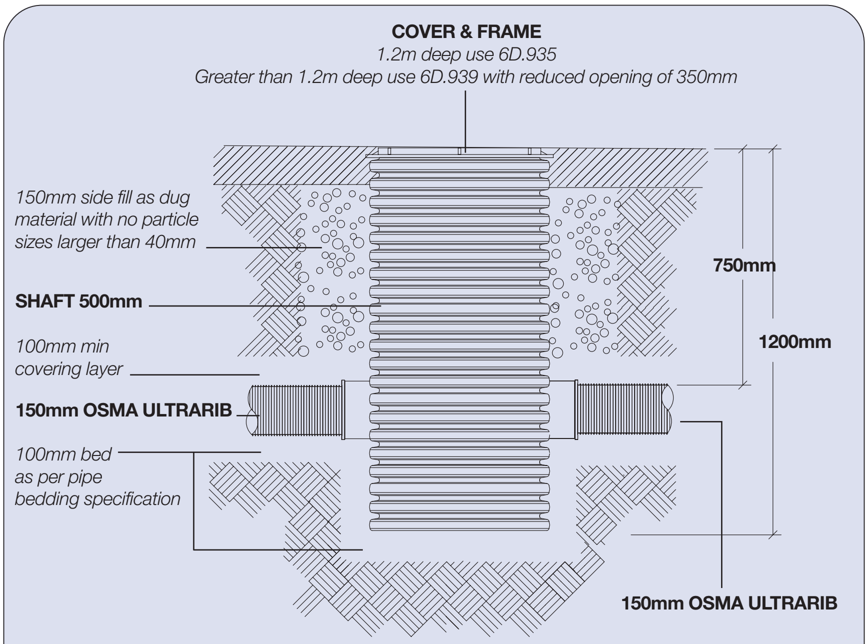

Fig. 2.10 *Typical silt trap design*

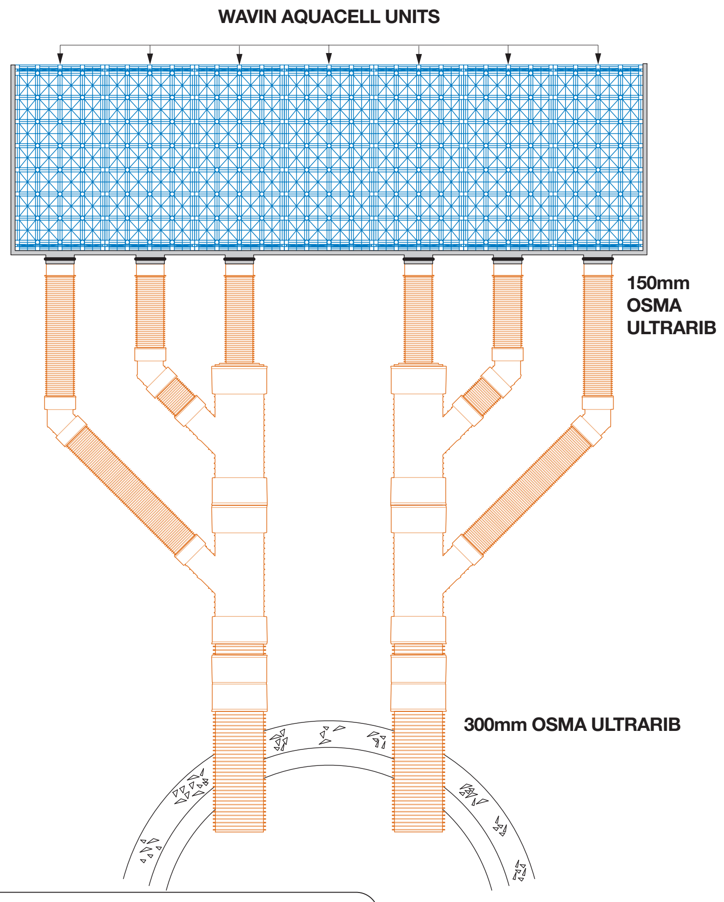

Fig. 2.11 *Typical manifold design*

DESIGN
Design procedures: Hydraulic

Table 8 shows the maximum areas which can be drained according to the number of inflow pipes provided. This has been calculated to the following assumptions:

- Paved surfaces: 2 year, 3-5 minute event
- Eaves drained roofs: 1 year, 2 minute event
- Internal gutters: 500 year, 2 minute event.

Table 8 *Multi-pipe Manifolds*

Surface type	Number of Inlet Pipes 1	2	3	4	5	6
Paved Area	1110	2220	3330	4440	5550	6660
Roof Area*	841	1682	2523	3364	4205	5046
Roof Area**	210	420	630	840	1050	1260
	Drainable area in m²					

* Roofs drained by eaves gutters, close (within 25m) to the attenuation site

** Roofs drained by internal gutters, close (within 25m) to the attenuation site (especially siphonic roof drainage)

2.3.6 Venting

The venting of air from box storage systems is an important mechanism.

However, the diameter of these outlet pipes does not need to match that of the inlet pipes because:

- The rapid inflow from a peak storm event into the storage void will be of short duration and will fill only a small proportion of the volume required for a longer event
- Air is much more compressible than water, so only part of the inflow volume needs to be vented during the storm event
- A longer-term event which could fill the storage void will flow in much more slowly, and will not require large venting solutions
- Air can flow in pipes with less resistance than water, and so a similar size pipe will convey more air than it would water.

Accordingly, It is therefore recommended that one vent pipe, 110mm in diameter, is provided per 7,500 square metres of impermeable catchment area on a site.

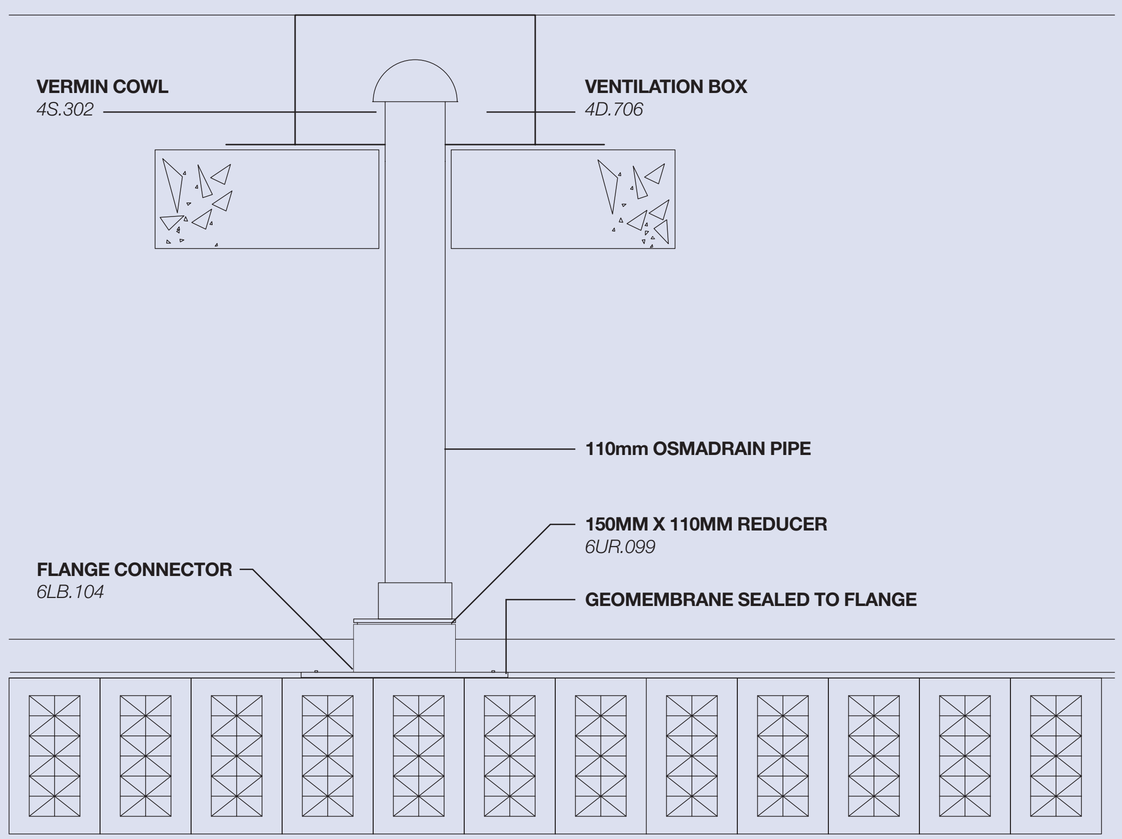

Fig. 2.12 *Typical air vent design*

Design procedures: Structural

2.4.1 Structural testing

The independent testing of AquaCell units at Salford University included the determination of their structural capacity. Direct loading and long term creep tests were carried out on single units.

The results from these tests have been used to generate the following structural design parameters:

- Direct loading
- Deformation.

NOTE: Detailed test methodology used in these independent tests is described and explained in **Appendix 4**.

Direct loading

Typical results are shown in **Fig. 2.13**.

Design parameters for the AquaCell units, as determined from the test results, are given in **Table 9**.

Deformation

Typical results are shown in **Fig. 2.14**. From these, a long-term rate of deflection can be determined and long-term deformations for periods up to 20 years estimated[x].

2.4.1.1 AquaCell: domestic soakaways

For small scale applications as soakaways for individual house roof drainage, the AquaCell system is typically located below a garden (5m minimum from the building). In this situation there are no traffic loads.

Use **Table 10** to determine design depths.

2.4.1.2 AquaCell: large scale storage or infiltration

AquaCell units used for large scale storage or infiltration must be designed to carry all the loads that will be applied. These loads will include:

- Dead loads
- Imposed loads.

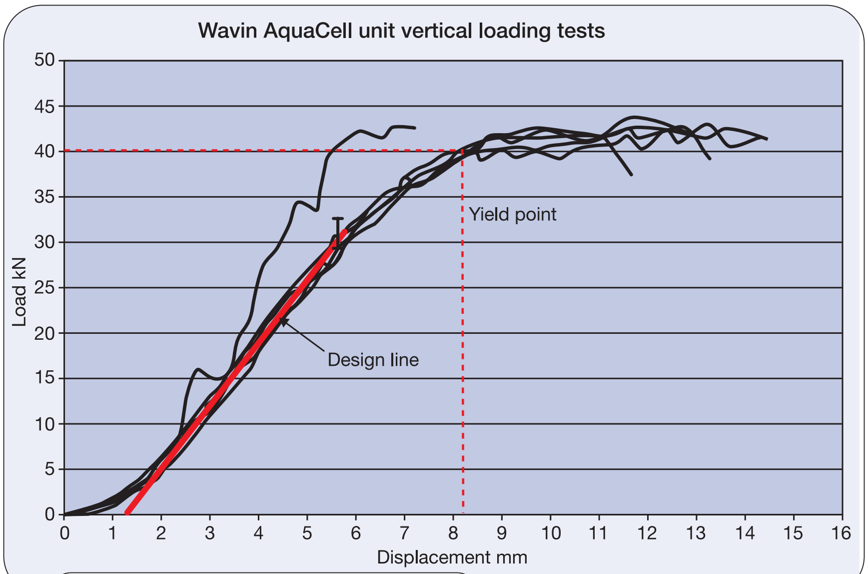

Fig. 2.13 *Typical loading test results: vertical*

Table 9 *Loading design parameters for AquaCell units*

	Vertical loading on top face	Lateral loading on side face
Ultimate compressive strength at yield	560kN/m²	77.5kN/m²
Short term deflection	1mm per 97.0kN/m² applied load	1mm per 7.0kN/m² applied load
Long term deflection at up to 10 years, 20°C 10kN load	Deflection (mm) = 0.4705Ln (time in hours)	

NOTE: Partial factors of safety as appropriate should be applied to these values for design (*see* **Appendix 4**, Section 3)

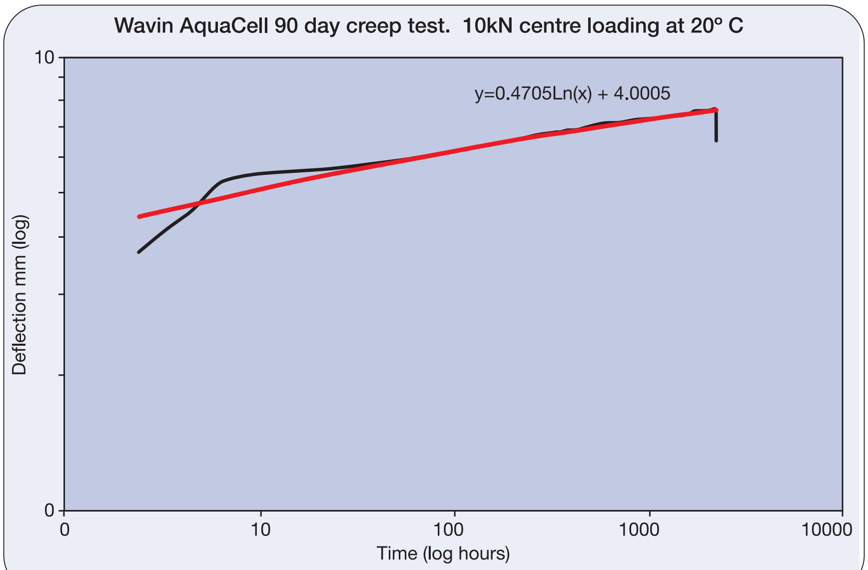

Fig. 2.14 *Typical creep test results*

Table 10 *Design criteria for use of AquaCell system as soakaway for individual house*

Maximum depth to base of units*	2.95m
Minimum cover depth cover units (to prevent accidental damage)	0.5m

*Assumes a minimum value for the angle of shearing resistance of the surrounding soil of 29º. This should be confirmed from the results of the site investigation. Groundwater must be at least 1m below base of units. No traffic loads.

Design procedures: Structural

Dead loads

Dead loads are permanent loads applied to the units. They include:

- The weight of fill placed over the top
- Lateral earth pressure loads acting on the side of the system.

These factors determine the maximum depth of installation and maximum cover depth.

Imposed loads

Imposed loads are transient loads due to vehicle or pedestrian traffic and construction traffic.

There must be sufficient cover fill to allow distribution of point loads from wheels and thus prevent localised crushing of the units. The spread of load depends on the type of materials overlying the units.

For *well compacted* type 1 sub-base, a load spread of 45° may be appropriate.

However, for *poorly compacted* selected as dug fill, a distribution of 27° is more typical.

Design limits

Use the design parameters and estimated loads to determine:

- The maximum depth of installation
- Maximum and minimum cover depths

for AquaCell units.

The criteria provided in **Tables 11** and **12** can be used to design the AquaCell units for installation below lightly trafficked and non-trafficked areas. These design tables are only applicable in temperate climate conditions such as the UK.

Full scale field trials of the AquaCell system have been undertaken in the United Kingdom which have confirmed the design approach adopted and the performance of the AquaCell units.

Heavier loads

The AquaCell system can be used where greater loads are anticipated. These may be areas trafficked by commercial and heavy goods vehicles, and includes all vehicles in excess of 2500kg gross weight. However, specific design advice should be sought from Wavin for these situations.

Design information, required to carry out a comprehensive design for these circumstances, will include:

- Type of vehicle
- Maximum anticipated vehicle weight.

Table 11 *Maximum installation depths (to base of units)*

Typical soil type	Maximum depth of installation (to base of units)				
	Typical angle of shearing resistance, ϕ	With groundwater at 1m below ground level and units wrapped in geomembrane		Without groundwater (below base of units) – normal case	
		Trafficked area (cars only)	Non-trafficked	Trafficked area (cars only)	Non-trafficked
Stiff over consolidated clay, eg London Clay	24°	1.65m	1.75m	2.35m	2.50m
Normally consolidated silty sandy clay, eg Alluvium, Made Ground	26°	1.70m	1.80m	2.50m	2.65m
Loose sand and gravel	29°	1.80m	1.90m	2.85m	2.95m
Medium dense sand and gravel	33°	1.90m	2.00m	3.30m	3.45m
Dense sand and gravel	38°	2.05m	2.15m	4.10m	4.25m

NOTES
1. Horizontal ground surface is assumed
2. Loosening of dense sand or softening of clay by water can occur during installation. The designer should allow for any such likely effects when choosing an appropriate value of ϕ.
3. It is assumed that no shear planes or other weaknesses within the structure of the soil are present.
4. The design is very sensitive to small changes in the assumed value of ϕ. The ϕ value assumed should therefore be confirmed by a chartered geotechnical engineer. In clay soils it may be possible to utilise cohesion in some cases.
5. Design table is only applicable for car parks or other areas trafficked only by cars or occasional refuse collection trucks or similar vehicles (typically one per week).

Table 12 *Minimum cover depths over top of AquaCell units*

Location	Minimum cover depth
Non-trafficked areas, eg landscaping	0.50m
Car parks, vehicle up to 2500kg gross mass, AquaCell system up to three units wide in trench	0.60m
Car parks, vehicle up to 2500kg gross mass, AquaCell system greater than three units wide	0.75m

Assumes 27° load distribution through fill material and overlying surface of asphalt or block paving, and trafficking by occasional refuse collection trucks or similar vehicles (typically one per week) is acceptable.

DESIGN
Design procedures: Structural

- Type of road or use (e.g. residential road, lorry park, industrial unit)
- Anticipated number of vehicle movements
- Type of surfacing (e.g. block paving, asphalt or concrete)
- Soil conditions.

Flotation

When the units are wrapped in geomembrane and placed below the groundwater table, flotation may occur.

To prevent this, the weight of the soil over the top of the units must be greater than the uplift force caused by the units' buoyancy in the water. This can be achieved with most fill types if the depth of cover fill is equal to, or greater than, the depth of penetration of the units below the groundwater level.

Construction loads

Construction plant such as excavators can impose significant loads on the AquaCell system. The following guidelines should be observed:

- Tracked excavators (not exceeding 21 tonnes weight) should be used to place fill over the AquaCell units when the geotextile or geomembrane wrapping has been completed (*see* **Section 2.4.2**)
- At least 300mm of fill should be placed before the excavators or trucks delivering the backfill are allowed to traffic over the installed units
- Compaction plant used over the AquaCell units should not exceed 2300kg/metre width. This will allow the compaction of Type 1 sub-base in 150mm layers over the units in accordance with the Specification for Highway Works[xi]
- All other construction plant should be prevented from trafficking over the system once it is installed and surfacing completed, unless a site specific assessment demonstrates that it is acceptable
- In particular cranes should not be used over, or place their outriggers over, the system.

Bearing capacity load and settlement

For lightly loaded applications (as detailed in this Manual) the bearing capacity of the underlying soils should not typically be exceeded by the AquaCell System. Settlement of the underlying soils should therefore be negligible.

However, on weak or compressible soils, such as very soft clay and silt or peat, the bearing capacity and settlement characteristics should be confirmed by a geotechnical engineer.

Infiltration below trafficked areas

Care should be taken when the AquaCell system is used for infiltration below trafficked areas and close to structures. It is important to ensure that the infiltrating water will not soften the soils or cause loss of fines – and therefore cause settlement.

2.4.1.3 Garastor system: garage void

Structural design

When the Garastor system utilises a suspended floor slab to form a void below garages to store stormwater, the suspended slab and associated walls and foundations will require structural design.

This should be in accordance with the relevant design codes and current prevailing Building Regulations.

Lining of void

To prevent softening of the soils below the foundations or loss of fines leading to settlement, the void beneath the garage should be lined as follows:

1. Underneath the concrete base of the void area there should be a 1200g polythene damp proof membrane.
2. Bitumastic paint should be applied to the walls of the void area and to the underside of the reinforced garage floor beams.

2.4.1.4 Garastor system: garden void

This application involves the Garastor Control Chamber connected to AquaCell units. Accordingly, structural design should follow guidance given for AquaCell (*see* **Section 2.4.1.1** *and* **Section 2.4.1.2**) as relevant to the proposed location, anticipated loading and required capacity of the storage void.

2.4.2 Geotextiles and geomembranes

Geotextiles: function

A geotextile is wrapped around the AquaCell system in infiltration applications. This filtration layer has the following functions:

- Preventing clogging of the soil which surrounds the units with silt that is present in run-off
- Preventing soil entering the units
- Protection around geomembrane in storage applications.

Geotextiles: properties and performance

The physical properties and performance of available geotextiles vary widely. There can also be marked differences in such attributes as UV resistance, durability and robustness during installation.

Accordingly, the selection of an appropriate geotextile for a specific AquaCell infiltration installation deserves very careful consideration. This should be done with particular reference to the surrounding soil properties and required performance.

Important aspects to consider are:

- *Pore size*: should be designed and specified to assist infiltration and prevent migration of fine soil particles
- *Permeability and breakthrough head*: the geotextile should not limit flow of water in the system, and should have a similar or greater permeability than the surrounding materials
- *Puncture resistance*: the geotextile must be able to resist the punching stresses caused by loading on sharp points of contact
- *Tensile strength*: the geotextile should have sufficient strength to resist the imposed forces from traffic or other loading.

Geotextile should be selected according to specific site conditions. However, typically a 300g non-woven material will be suitable for most situations. Unless either the surrounding soil characteristics exhibit a high degree of fines /low infiltration capacity and/or there is risk of damage from in-ground contaminants, when specialist advice should be sought.

Design procedures: Structural

Geomembranes: function

A geomembrane is wrapped around the AquaCell system in attenuation/storage applications where infiltration is not possible or permitted. This impermeable layer can have the following functions:

- Preventing release of attenuated/stored water to surrounding ground
- Preventing inflow of pollutants from contam- inated subsoil into the storage reservoir
- Lining of Garastor system storage void beneath a garage.

Geomembranes: properties and performance

The importance of specification and selection of the right impermeable geomembrane for AquaCell installations cannot be understated. Its integrity and suitability are key to successful performance as required.

It is crucial that the specified material will:

- Withstand the rigours of installation
- Resist puncture
- Resist multi-axial elongation stress and strains associated with settlement
- Resist environmental stress cracking
- Resist damage from in-ground contaminants
- Remain intact for the full design life of the AquaCell installation.

Geomembranes less than 1mm in thickness are unlikely to meet these criteria, and are not recommended for use with the AquaCell system.

Geomembranes: sealing

The long term integrity of the joints is equally as critical as the selection of the geomembrane. To ensure total impermeability:

- Joints between adjacent sheets of impermeable geomembranes should be sealed correctly using proprietary welding techniques

IMPORTANT NOTE: Jointing with tape is not recommended as this places reliance on the mechanical properties of the tape to maintain the integrity of the system.

- The integrity of joints should be demonstrated by non-destructive testing.

Advice on seam testing is given in CIRIA Report 124[xii].

2.4.3 Backfill and bedding specification and placement

Non-trafficked areas

In areas where the AquaCell system is not subject to traffic loads, such as below pedestrian areas, gardens or landscaping, the system can be backfilled with selected as dug material.

This material should NOT contain:

- Pieces of rock or gravel above 75mm in diameter
- Any other sharp materials (e.g. metal) which could pierce the units, or cause uneven loading and cause them to fail.

Selected fill material should be compacted to 90% maximum dry density. A minimum of 300mm working space will be required around the units to allow compaction.

Trafficked areas

When the AquaCell system is installed below car parks and other trafficked areas, the use of well compacted backfill and cover fill is particularly important.

In these areas, a well compacted granular material should be used:

- Recommendation: Type 1 or Type 2 sub-base as defined in the *Specification for Highway Works* (*see* **Table 14**)

For backfill to the sides of the AquaCell system:

- Recommendation: Type 1 or Type 2 sub-base, or Type 6P (side fill only) selected granular material.

The material should be compacted in accordance with *Table 6/1* or *8/1* of the *Specification for Highway Works* and taking into account the recommended maximum roller weight (*see Construction loads* **2.4.1.2**).

The precise material used will depend on the overlying pavement design and, if appropriate, the requirements of the adopting authority.

Table 14 *Backfill specification for use under trafficked areas*

Grading Sieve size	Percentages passing by mass		
	Sub base Type 1	Sub base Type 2	Type 6P selected granular fill
75mm	100	100	100
37.5mm	85–100	85–100	–
20mm	60–100	60–100	–
10mm	40–70	40–100	–
5mm	25–45	25–85	–
600 micron	8–22	8–45	–
75 micron	0–10	0–10	–
63 micron	–	–	<15
Other requirements			
Ten percent fines value (BS 812: Part 111)	50kN	50kN	30kN
Soundness value (BS 812: Part 121)	>65	>65	n/a
Material passing 425 micron sieve	Non-plastic	Plasticity index <6	n/a
Uniformity coefficient	n/a	n/a	>5

2.4

DESIGN
Design procedures: Structural

Preventing uneven loads

For placement between the AquaCell units and the backfill:

- Recommendation: 100mm of coarse sand or a geotextile protective fleece.

  NOTE: this is NOT the same type as that required for infiltration in AquaCell soakaway applications, as described in **2.4.1.1**

This is designed to prevent angular materials imposing uneven loads that could cause failure of the units.

Typical backfill details are shown in **Fig. 2.15**.

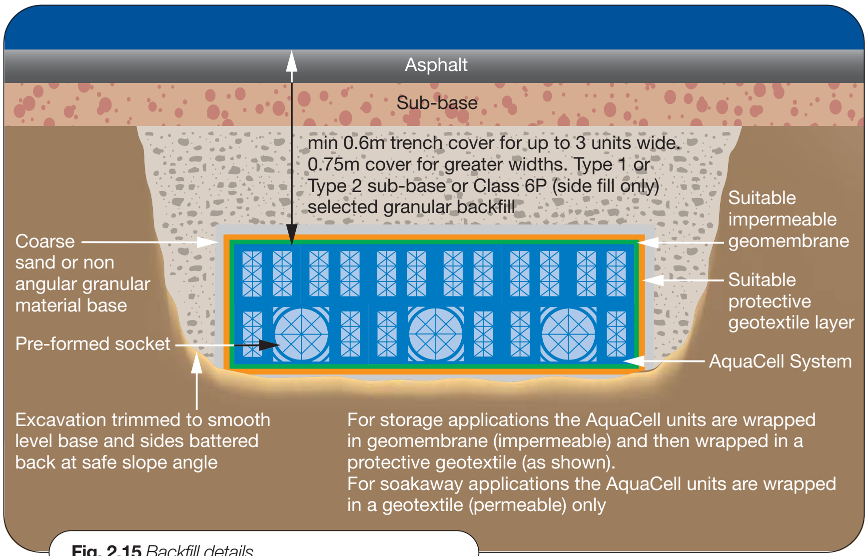

Fig. 2.15 *Backfill details*

2.5

DESIGN
Specification

Specification sheets for the Wavin Stormwater Management Systems are provided in **Appendix 5**.