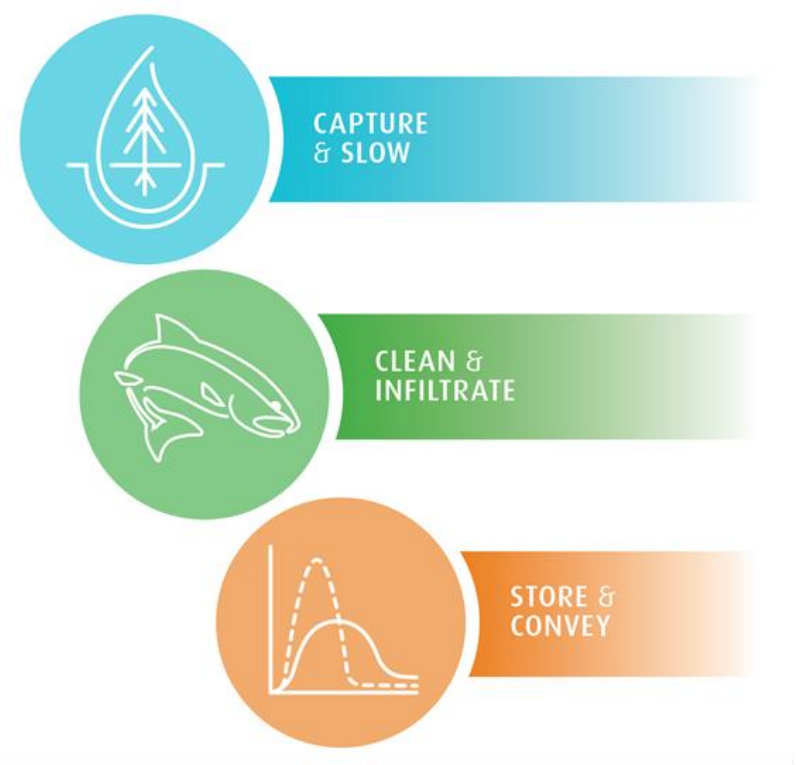

APPENDIX J – CISTERNS & DETENTION TANKS

Green Stormwater Infrastructure Design Guidelines for the Capital Region

SPRING 2019

Cisterns & Detention Tanks[1]

Description

While other GSI facilities use bioretention and infiltration systems to reduce runoff volume, cisterns and detention tanks collect and store stormwater runoff during a storm event, then repurpose it or release it at controlled rates reducing peak discharge. With such systems in place, a drainage system can accommodate higher intensity rainfall events.

Detention tanks may be located above or below ground, but typically are underground concrete vaults or corrugated pipe tanks. Detention systems should be designed to reduce peak flows to pre-developed conditions to address a number of stormwater related issues including flooding, erosion and aquatic habitat protection. Detention requirements can be estimated by various methods including the SCS (U.S. Soil Conservation Service) Unit Hydrograph and Level Pool Routing and should be performed or reviewed by a professional engineer.

Figure 1 Cisterns capturing roof water for residential indoor and outdoor non-potable water use. Photo credit: Kim Stephens, Bowen Island, BC.

Cisterns use roof and hard surfaces runoff collection systems to store water in aboveground or underground storage tanks. With minimal pre-treatment, the captured rainwater can be used for outdoor non-potable water uses such as irrigation and pressure washing, or inside the building to flush toilets or urinals. These design guidelines are only for the harvesting and storage. These guidleines do not provide design standards for systems such as indoor non-potable use.

[1] **Adapted with permission from Metro Vancouver.**
Original document: Metro Vancouver's Stormwater Source Control Design Guidelines 2012, primary author Kerr Wood Leidal Associates Ltd. with Lanarc Consultants Ltd and Goya Ngan, http://www.metrovancouver.org/services/liquid-waste/LiquidWastePublications/StormwaterSourceControlDesignGuidelines2012StormwaterSourceControlDesignGuidelines2012.pdf
Adaptations authored by: Opus International Consultants (Canada) Limited
Design guidelines drawings by: Kerr Wood Leidal Associates Ltd

Selection and Application

Figure 2 Planter watered by roof water captured in underground detention tank, Salt Spring Island Library

- Cistern systems can be used to collect rainwater from most residential, commercial, industrial or institutional roofs.
- Detention tanks and cisterns are useful on infill and re-development sites that have little room for other GSI.
- Rainwater harvesting systems can be installed underground, indoors, on the ground next to a building or on the roof (for roof collection only).
- Rainwater that is captured and stored can be used to meet both outdoor and indoor non-potable water uses.
- Some indoor non-potable uses may be restricted and separate plumbing with purple pipes may be required.
- Outdoors, harvested rainwater can be used for residential lawn and garden watering, commercial and institutional landscaping irrigation, decorative fountains, or other non-potable uses such as vehicle washing, building washing and firefighting.
- Typically, indoor uses of harvested rainwater are for non-potable purposes only. Toilet flushing is the most common large-scale indoor use of harvested rainwater. Separate plumbing, pumps, pressure tanks, and backflow preventers are necessary for indoor use of harvested water. Back-up water supply system arrangements, which can be drawn upon when the cistern runs dry, are also necessary for indoor uses.
- Cisterns must be located where roof water can be directed to the tank. Only collect roof water for reuse. Do not reuse water from parking or pedestrian areas, surface water runoff, or bodies of standing water.
- Flat, stable surfaces must be provided to support the tank and designed for the weight of the tank when full of water. Underground tanks require flat, stable subgrade, but no constructed base other than crushed rock.
- A cistern is possible in areas where infiltration methods may not be feasible such as steep or hazardous slopes, bedrock, high water table, or contaminated soils.
- An elevated cistern requires design by a qualified professional.
- Cisterns must be connected to the municipal stormwater system for overflow or to a properly designed rainwater management method with an overflow connection to the stormwater system.
- A cistern should only be used where there is a use for the water, enabling the tank to be emptied. This may include irrigation of landscaping or re-use for toilet flushing where there is a consistent demand through the wet season of the year.
- If using the rainwater within a building, a professional is required to design and install the required "purple pipe" system.
- Cisterns and detention tanks must meet the setback requirements that apply to the main building within that particular zone.
- Collectively, the total surface area of the buildings, cistern or detention tank and other structures on a property must not exceed the maximum site coverage permitted in the zone.

- Cisterns/rain barrels (less than 1,200 litres) do not have setback requirements or site coverage limits.
- Roof material can impact the end use of the water collected in the rain barrel or cistern. Currently, no water quality standards for roofing types exist, and few roofing products carry water quality test information. Individual roof products vary. It is important to be mindful that any chemical treatment of a roof, such as moss inhibitors, could be harmful to plants.

Figure 3 Cistern collecting roof water with pump (covered to the left) pumping collected roof water to the garden. Photo Credit: Victoria Compost Education Centre

Design Guidelines

1. Detailed design requirements should be evaluated for each individual application based on site-specific constraints and objectives.
2. Follow all applicable federal, provincial and municipal regulations.
3. The size of the storage tank will depend on the catchment area, seasonal rainfall pattern, demand pattern, retention time and cost.
4. To provide storage to attenuate peak discharges, the design storm will need to be considered as well.
5. A pre-treatment sump may be required to remove sediment in the runoff.
6. Provide an overflow to allow larger storms to overflow the tank.
7. Tank should be designed to allow for access for maintenance or cleaning.
8. All underground tanks should have an air space equal to 20% of the maximum depth, connected to the atmosphere by a vent.
9. The maximum depth is a function of safety and convenience of users. A depth of over 2 m is not recommended.
10. Underground tanks must have a minimum of 0.5 m of cover and must be capable of handing the loads from the surface above.
11. Discharge either by gravity or through pumping, to ensure that detention volume is available for the next storm event.

Sizing Cisterns and Detention Tanks

Cisterns

1. Determine the available pervious area that will be used for irrigation (watered area).
2. Determine the impervious area that will be directed to the cistern.
3. Ratio of watered area to impervious area should not be smaller than 2:1.
4. Cisterns are typically designed to capture the runoff from the roof. Provide 0.025 m^3 of storage per 1 m^2 of impervious area being directed to the cistern.
5. The selection of the method of analysis depends on the size of the development and the intended application of the results.
6. Analysis should be done or reviewed by a professional engineer.
7. The potential amount of rainwater that can be collected in a cistern from a rooftop catchment can be estimated with the formula:

   Annual collectable rainfall (I) = Average annual rainfall (mm) x total catchment area (m^2) x filter efficiency

   Where:

   Average annual rainfall =

   Local meteorological data supplied by local Environmental Agency or Meteorological Office.

   Filter efficiency =

   The proportion of the collected water that is available for use, following filtering. Most manufacturers recommend that a factor of 0.9 be used.

   Drainage Coefficient =

   The proportion of the rainfall that runs off the catchment and reaches the collection tank. Light rainfall will only wet the roof then evaporate; heavy rainfall can overflow from the gutter and, therefore, be lost. The following figures are appropriate for different roof types:

Roof Type	Drainage Coefficient
Pitched roof, slate tiles	0.8
Flat roof	0.5
Flat roof, gravel	0.4
Extensive green roof*	0.3
Intensive green roof*	0.2

*Note: *The use of green roofs and rainwater harvesting together can be challenging. This is applies to both the hydraulic disadvantages as well as water quality issues of colour, sediment and bacteria.*

8. The volume estimated from the above formula can be compared with the demand to establish a potential for savings.
9. A common rule of thumb for household water use is to size the tank at 5% of the available rainwater supply, or the annual demand, using the lower of the two.

Detention Tanks

1. Detention requirements for stormwater management can be estimated by various methods including: the Rational Method, SCS (U.S. Soil Conservation Service) Unit Hydrograph and Level Pool routing as examples. Use of hydraulic model is recommended to estimate the detention storage requirement.
2. The selection of the method of analysis depends on the size of the development and the intended application of the results.
3. Analysis should be performed or reviewed by a professional engineer.
4. Stormwater detention tank systems can be configured as online or offline systems.
5. Stormwater in the detention tank may be discharged either by gravity or through pumping. In order to ensure that detention volume is available for the next storm event, it is recommended that discharge systems be designed to empty the tank within 4 hours after a storm event.
6. The maximum allowable peak discharge shall be computed at the downstream end of the internal drainage system of the development prior to its connection to the public drain.
7. Maximum allowable peak discharge for the proposed development should be calculated using the Rational Formula.

   Qr = 1/360 {CiA}
   Where
   Qr = Peak runoff at the point of design [m^3/s]
   C = Runoff coefficient
   i = Average rainfall intensity [mm/hr]
   A = Catchment area [ha]
8. The runoff coefficient (C) of a site depends on its land uses or surface characteristics. Pervious areas that allow water to infiltrate into the ground, such as grass or landscaped areas located on true ground, may assume a C value of 0.45 while impervious areas like roads, buildings and pavement may assume a C value of 1.
9. For a storm of return period of T years, the rainfall intensity (i) is the average rate of rainfall from a storm having a duration equal to the time of concentration (tc) of the catchment.
10. The average rainfall intensity (i) can be obtained from the Intensity Duration Frequency curves.
11. According to the Rational Method, the peak runoff (Qr) occurs when all parts of the catchment receiving a steady, uniform rainfall intensity are contributing to the outflow. This condition is met when the duration of rainfall equals the time of concentration (tc).

12. Based on the Rational Formula, the post-development peak runoff from a development site with no runoff controls should be calculated.
13. Hydrologic and hydraulic modelling method should be used for sizing online or offline detention systems, including detention systems for larger developments (greater than 10ha) or developments with more complex drainage systems. Developers may choose appropriate hydrological and hydraulic models such as U.S. EPA SWMM, or any other similar software to size or verify the adequacy of the proposed detention system.

Guideline Specifications

Materials and Construction Practices shall meet Master Municipal Construction Document (MMCD) 2009 requirements.

Recommended Resources

Regional Manuals:

- ✓ Rainwater Harvesting Best Practices Guidebook Developed For Homeowners of the Regional District of Nanaimo (British Columbia, Canada) Regional District of Nanaimo
  http://www.rdn.bc.ca/cms/wpattachments/wpID2430atID5059.pdf

- ✓ Rainwater Harvesting on the Gulf Islands – Guide for Regulating the Installation of Rainwater Harvesting Systems – Potable and Non-potable Uses (2006), Island Trust
  http://www.islandstrustfund.bc.ca/media/39066/guide_for_regulating_rainwater_harvesting_systems.pdf

- ✓ Rainwater Harvesting on the Gulf Islands - Frequently Asked Questions
  http://www.islandstrustfund.bc.ca/media/39063/rainwater_harvesting_faq.pdf

- ✓ Owner's Manual Rainwater Harvesting and Water Supply System (2006), Island Trust
  http://www.islandstrustfund.bc.ca/media/39069/ranr_harvesting_system_manual.pdf

Websites:

- ✓ Canadian Association for Rainwater Management
  http://www.canarm.org/

- ✓ Rainwater Harvesting, Canadian Mortgage and Housing Corporation
  https://www.cmhc-schl.gc.ca/en/inpr/su/waho/waho_002.cfm

Cisterns and Detention Tanks Design Example for R mm/24-hour Criteria

Scenario Description – Commercial/Industrial Detention Tank

A detention tank is proposed to capture a portion of the runoff from a building roof (see illustration below).

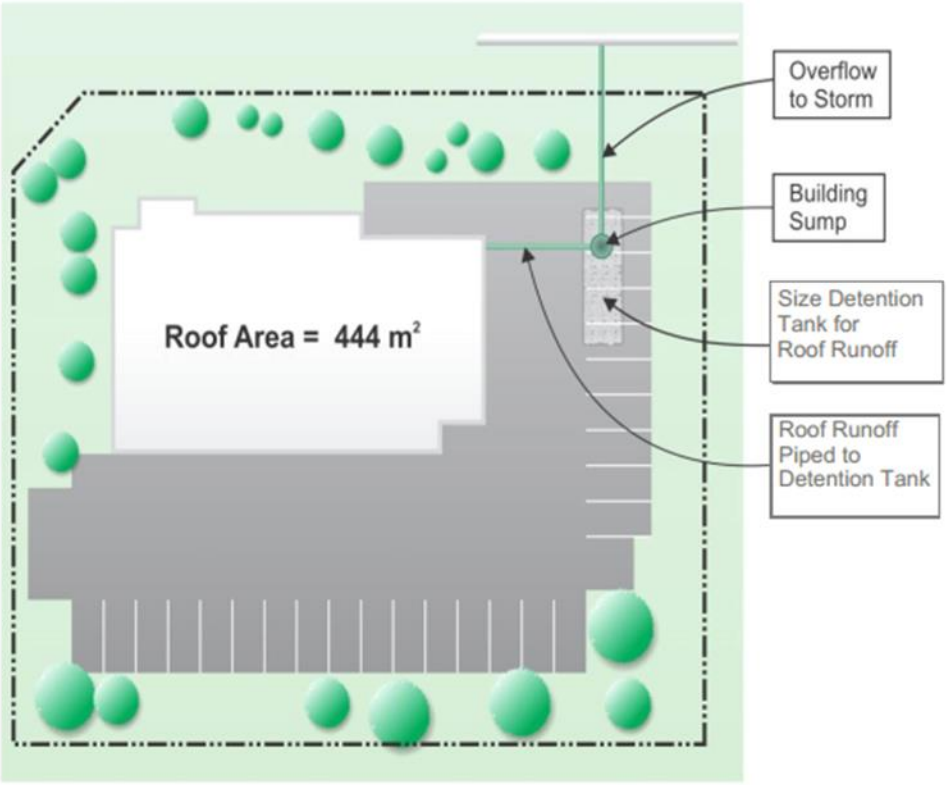

Figure 4 Example - Roof area draining to detention tank

The following parameters are known:

- Roof area = 444 m²
- Annual rainfall = 1,300 mm
- 2-year 24-hour rain depth = 53 mm
- Capture target is 72% of 2-year 24-hour rain amount = 38 mm

Determine the cistern volume.

Scenario Description – Commercial, Industrial Detention Tank

The potential annual amount of rainwater that can be collected in a cistern or detention tank from a rooftop catchment can be estimated with the formula:

Annual collectable rainfall (I) = Average annual rainfall (mm) x total catchment area (m2) x filter efficiency

Where:

Average annual rainfall = local meteorological data supplied by local Environmental Agency or Meteorological Office.

Filter efficiency = The proportion of the collected water that is available for use, following filtering. Most manufactures recommend that a factor of 0.9 be used.

Drainage Coefficient = The proportion of the rainfall that runs off the catchment and reaches the collection tank. Light rainfall will only wet the roof then evaporate; heavy rainfall can overflow from cutter and therefore be lost. The following figures are appropriate for different roof types.

Roof Type	Drainage Coefficient
Pitched roof, slate tiles	0.8
Flat roof	0.5
Flat roof, gravel	0.4
Extensive green roof*	0.3
Intensive green roof*	0.2

*Note: *The use of green roofs and rainwater harvesting together can be challenging. This is dies to both the hydraulic disadvantages as well as water quality issues of colour, sediment and bacteria.*

Assuming a flat roof and filter efficiency of 0.9, Annual collectable rainfall = 1,300 mm x 444 m^2 x 0.5 x 0.9 = 260,000 L.

Scenario Description – Residential Cistern

An aboveground cistern is proposed to capture runoff from the roof of a single-family home for irrigation use.

- Roof area = 180 m^2
  Ratio of watered area to impervious area should not be smaller than 2:1 for irrigation use:
  watered area = 180 x 2 = 360 m^2
  Provide 0.025 m^3 of storage per 1 m^2 of impervious area being directed to the cistern:
  180 m^2 x 0.025 m^3/1 m^2 = 4.5 m^3

GSI Driver Effectiveness – Runoff Reduction and Contaminant Removal

International Stormwater BMP Database http://www.bmpdatabase.org/ is a recommended resource for performance summaries of GSI facilities and latest research.

Cisterns and detention tanks do not reduce runoff volumes, unless stored and used for irrigation, outdoor washing or indoor non-potable uses such as toilet flushing. These systems do not provide treatment of stormwater runoff, unless designed for sediment removal through settling. If the water is not re-purposed the water may be released into storm drain system during dry days, to reduce peak flows. The following table shows the effectiveness of cisterns and detention tanks facilities for GSI drivers, including pollutant removal and stormwater runoff reduction.

Table 1 Runoff Reduction and Pollution Removal Summary Table

Cisterns and Detention Tanks GSI Facilities	
GSI Driver	***Estimated Effectiveness or typical % Removal**
Capture & Slow – Volume Runoff Reduction	% re-purposed
Store & Convey – Rate Control Delay Peak	If sufficient storage is provided
Clean & Infiltrate – Water Quality Treatment	
Total Suspended Solids (TSS)	If filtered

Note: * Performance of individual GSI facilities will vary depending on site-specific contexts and facility design.

Maintenance

- Inspect tank annually and clean, as required.
- Sediment should be removed from the tank bottom and floatables removed from the water surface.
- Maintain any sumps or upstream pre-treatment regularly to ensure proper operation.

INSPECTION ACTIVITIES	SCHEDULE
Inspect for proper functioning	After every major storm for the first few months to confirm design drain times
Inspect for pollutant contamination, standing water, trash and debris, sediment accumulation	Semi-annual and after extreme events
Inspect pre-treatment devices and diversion structures for damage and sediment accumulation	Semi-annual and after extreme events
MAINTENANCE ACTIVITY	**SCHEDULE**
Cleaned plugged air vents	As needed
Remove sediment, debris, and oil/grease from pre-treatment devices when sediment depth exceeds 15% diameter of storage area	As needed
Repair joint between tank and inlet/outlet pipes	As needed
Repair/replace tank and pipes if tank/pipe is bent out of shape by more than 10% if its design shape	As needed

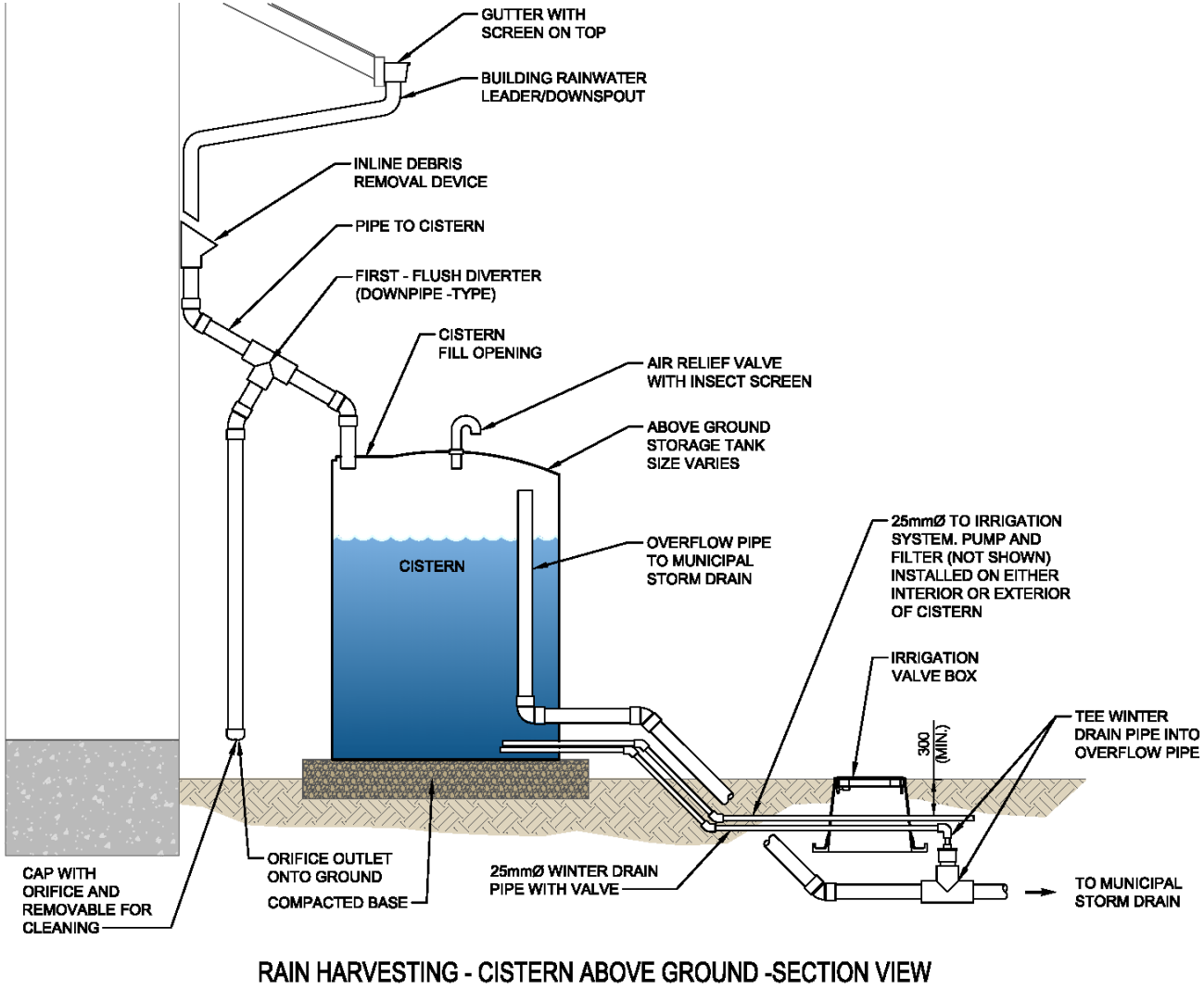

Figure 5 Rain Harvesting – Cistern Above Ground – Section View

Above depicts re-purpose of harvested roof water for irrigation purposes. This can be placed with a simple hose bib or a plumber may design a non-potable indoor (purple pipe) system requiring the BC Plumbing Code.

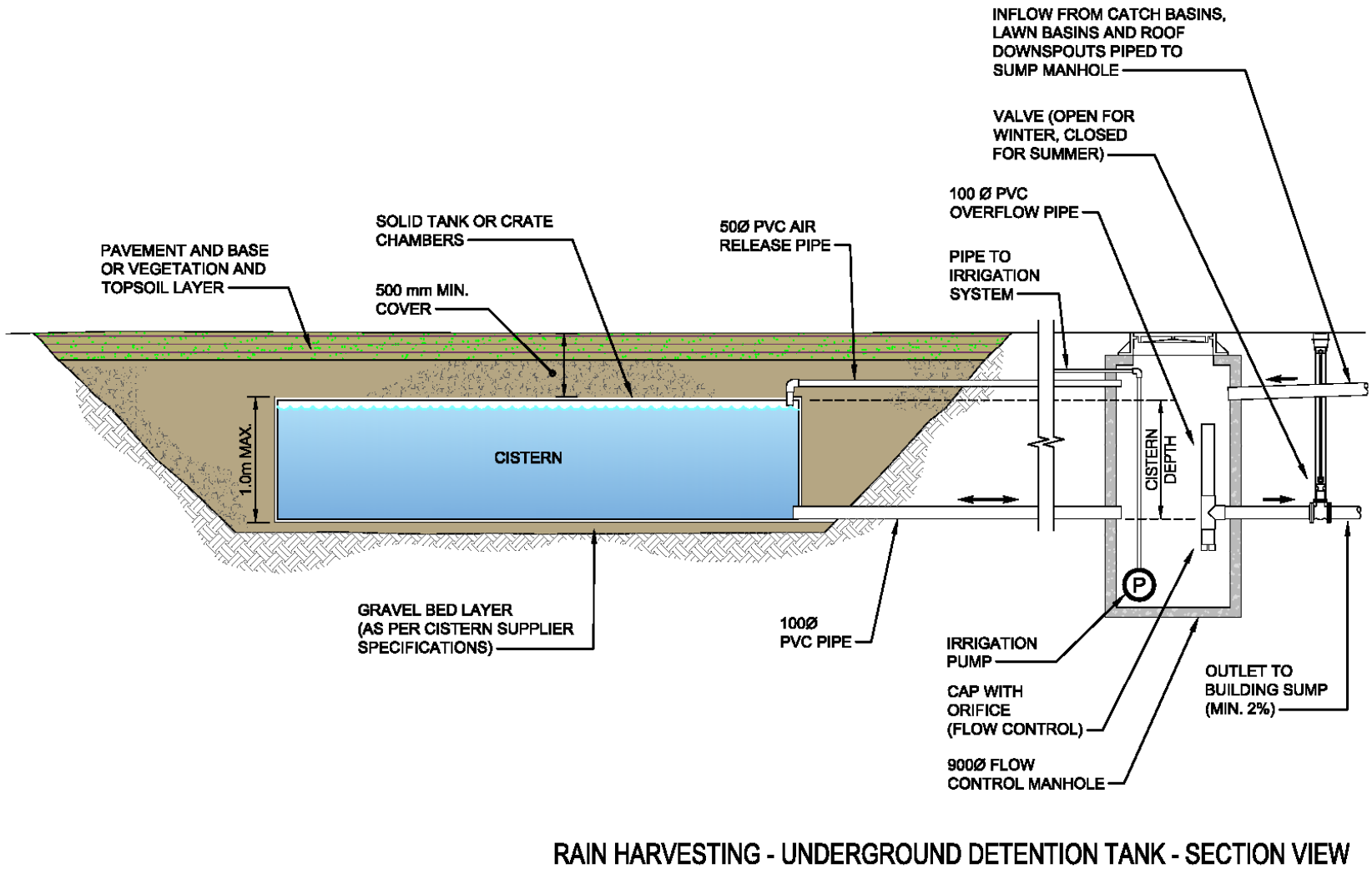

Figure 6 Rain Harvesting – Underground Detention Tank – Section View