COMPARISON OF ORIFICE OUTFLOW AND WATER DEPTH RESULT BETWEEN STORMSYNC AND MSMA

Drain · https://mes100.com/docs/comparison-of-orifice-outflow-and-water-depth-result-between-stormsync-and-msma/

Motivation

With the StormSync module in MiTS 3, engineers are now able to incorporate a storage system (detention pond) with drainage system and perform flow routing analysis to observe the inflow, outflow, and water depth of the detention pond. However, how can we determine whether the pond routing results generated by StormSync are in agreement with the results obtained based on MSMA methodology?

In this post, we will do a comparison on the inflow, outflow and water depth result between Dynamic Routing in StormSync and Modified Puls Method (Level-Pool Routing) in MSMA using rectangular and circular outlets of different sizes.

Rectangular opening (mm):

1. 800 x 800
2. 1200 x 1200
3. 1800 x 1800

Circular opening (mm):

1. ∅800
2. ∅1200
3. ∅1800

Information

- Catchment: 20 ha
- Design Storm ARI : 5 years
- Pond top area: 9000m2
- Pond bottom area: 7000m2
- Pond depth: 3.00m

Result summary (Max Flow and Max Water Level)

Rectangular Orifice 800 x 800

Critical Storm Duration: 60 mins

Module	StormSync	MSMA	% Difference
Peak Inflow (m3/s)	3.881	3.881	0.00
Peak Outflow (m3/s)	1.700	1.700	0.00
Max Pond Water Level (m)	1.400	1.399	0.07

Rectangular Orifice 1200 x 1200

Critical Storm Duration: 45 mins

Module	StormSync	MSMA	% Difference
Peak Inflow (m3/s)	4.741	4.741	0.00
Peak Outflow (m3/s)	2.720	2.805	3.13
Max Pond Water Level (m)	1.135	1.138	0.26

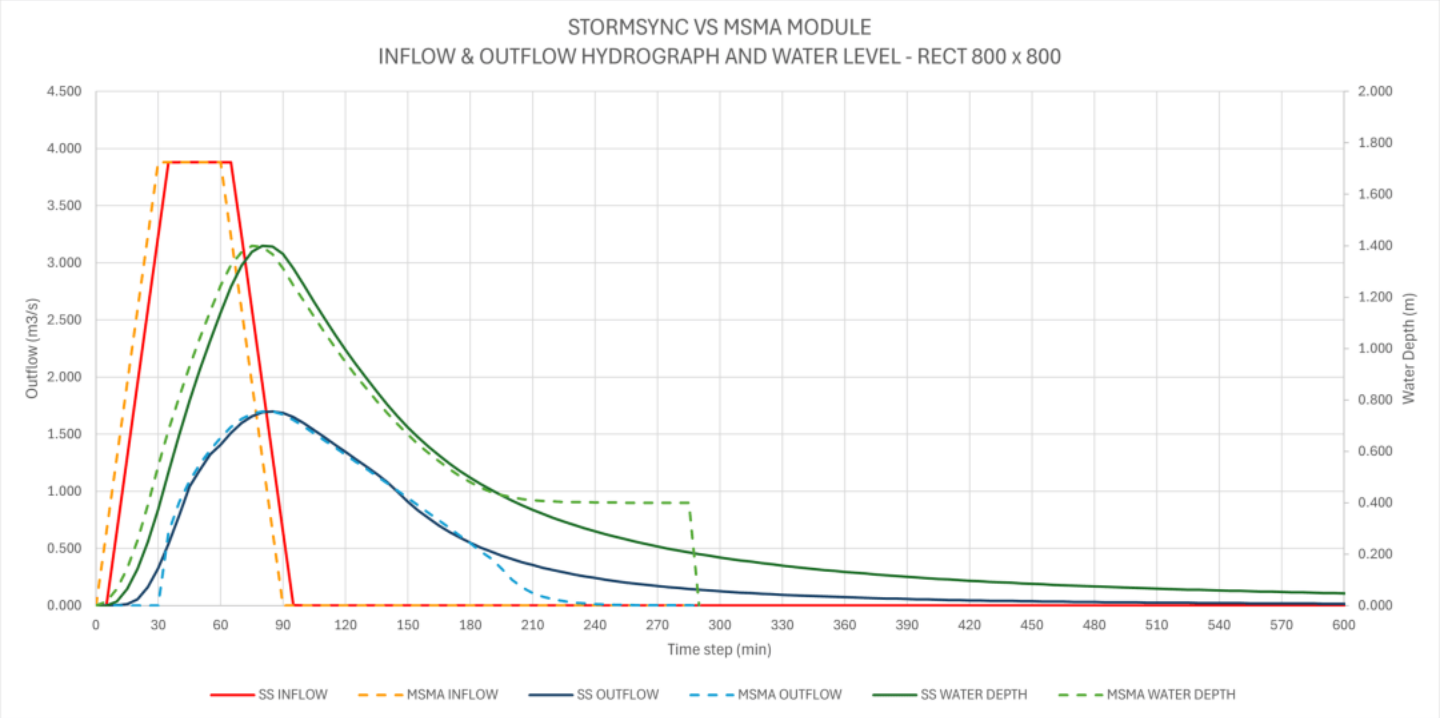
Rectangular Orifice 1800 x 1800

Critical Storm Duration: 45 mins

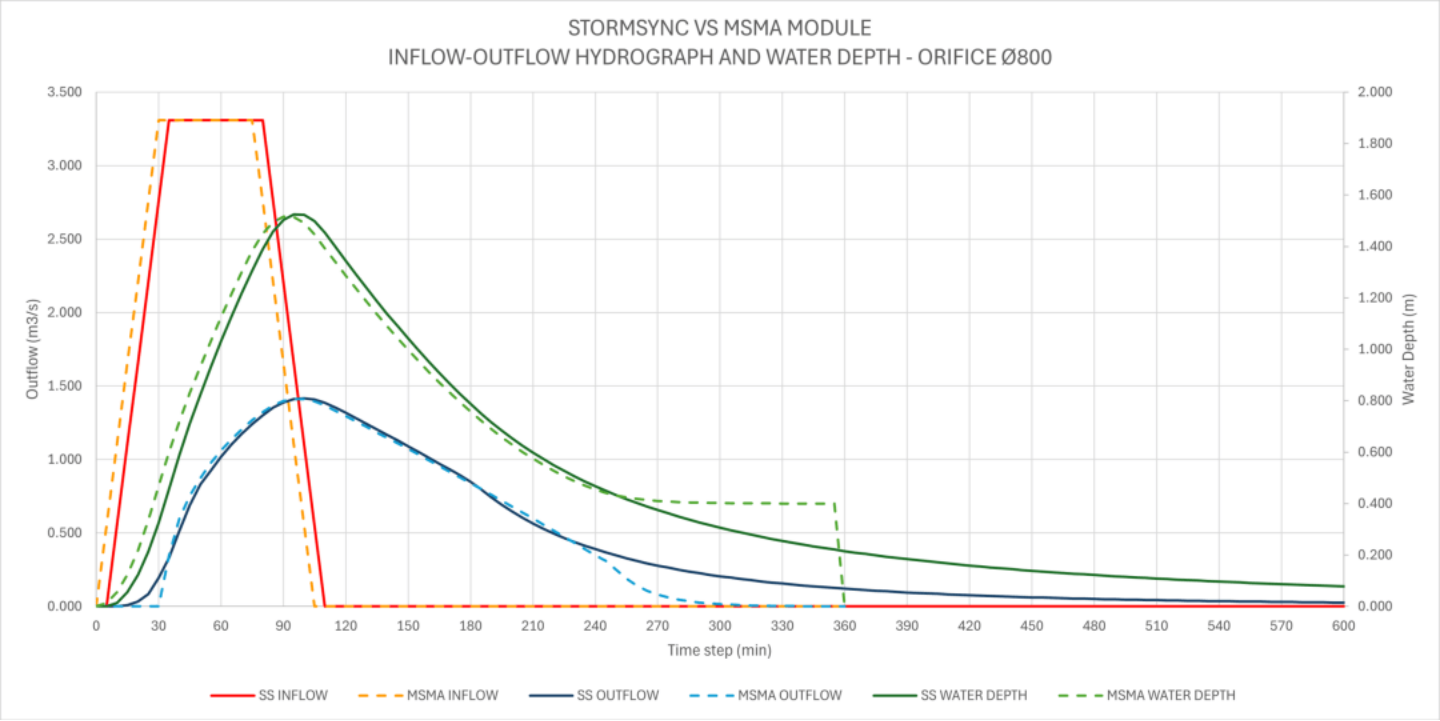
Module	StormSync	MSMA	% Difference
Peak Inflow (m3/s)	4.741	4.741	0.00

Peak Outflow (m3/s)	3.235	3.907	20.77
Max Pond Water Level (m)	0.978	1.106	13.09

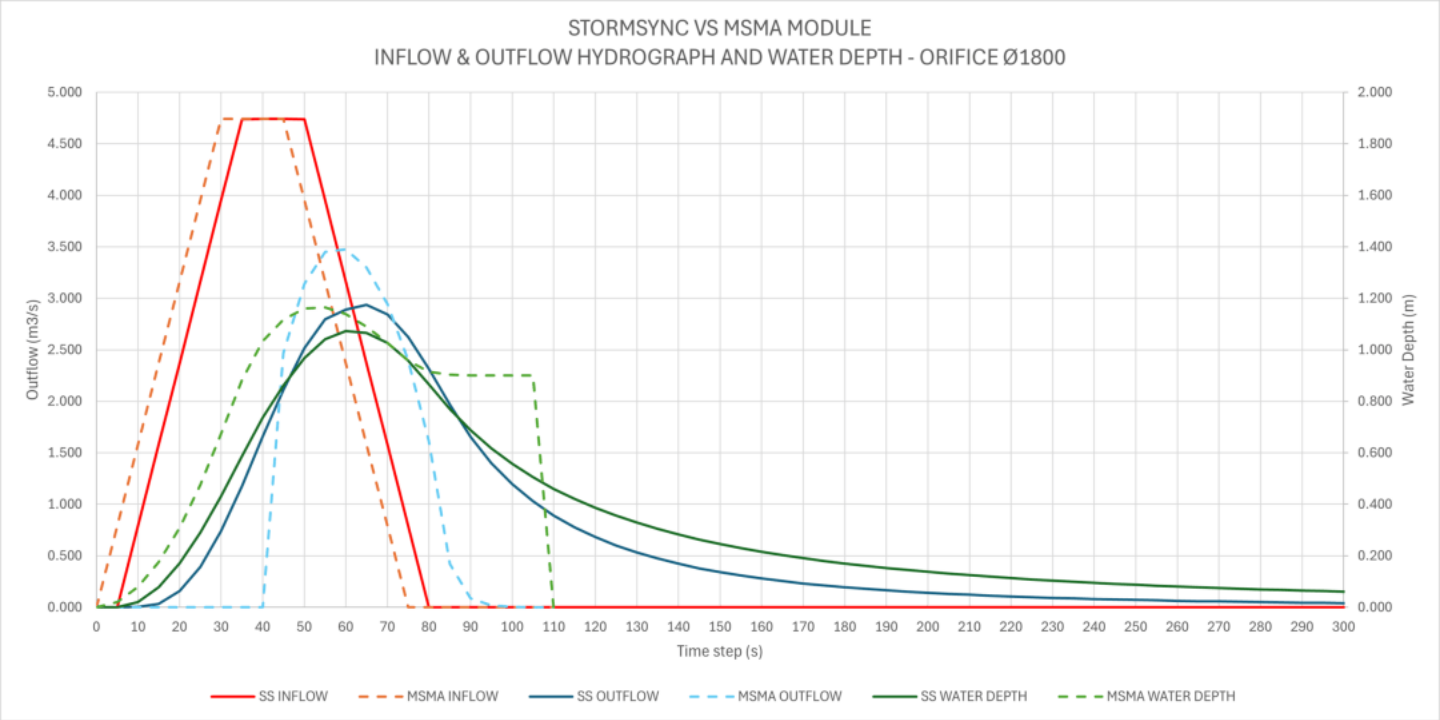
Inflow-Outflow Hydrograph and Water Level in StormSync (SS) and MSMA Module



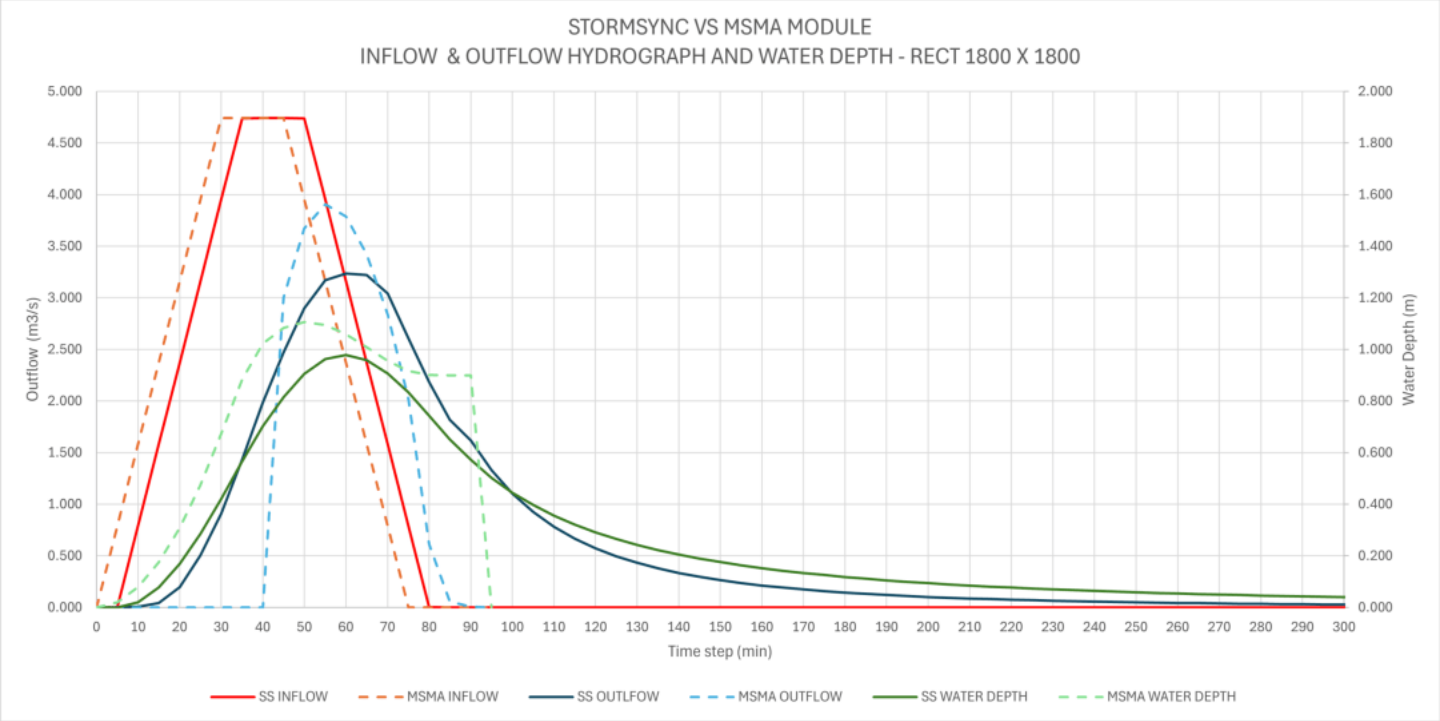
*Inflow-Outflow Hydrograph and Water Level for **Rectangular Orifice 800 x 800** in StormSync (SS) and MSMA Module*



*Inflow & Outflow Hydrograph and Water Level for **Circular Orifice Ø800** in StormSync (SS) and MSMA Module*



*Inflow & Outflow Hydrograph and Water Level for **Circular Orifice Ø1800** in StormSync (SS) and MSMA Module*



*Inflow & Outflow Hydrograph and Water Level for **Rectangular Orifice 1800 x 1800** in StormSync (SS) and MSMA Module*

The table depicts that the percentage difference in maximum pond outflow and maximum pond water level increases significantly between the two modules as the outlet size increases.

From the table and hydrographs above, both modules produce the same peak inflow for all outlet sizes, which confirms that the same modelling configuration and input parameters were consistently applied in both modules. The hydrograph shows that the StormSync and MSMA modules produce comparable results for smaller outlet sizes. However, as larger outlet size is used, noticeable differences are observed in the hydrograph shape, peak outflow, and pond water depth response.

We will fact check the outflow calculation obtained in StormSync with orifice formula to verify whether StormSync applies the orifice equation correctly.

Standard orifice formula (for both Rectangular and Circular Orifice Type):

$$Q = C_d \times A_o \times (2gH)^{0.5}$$

Where:

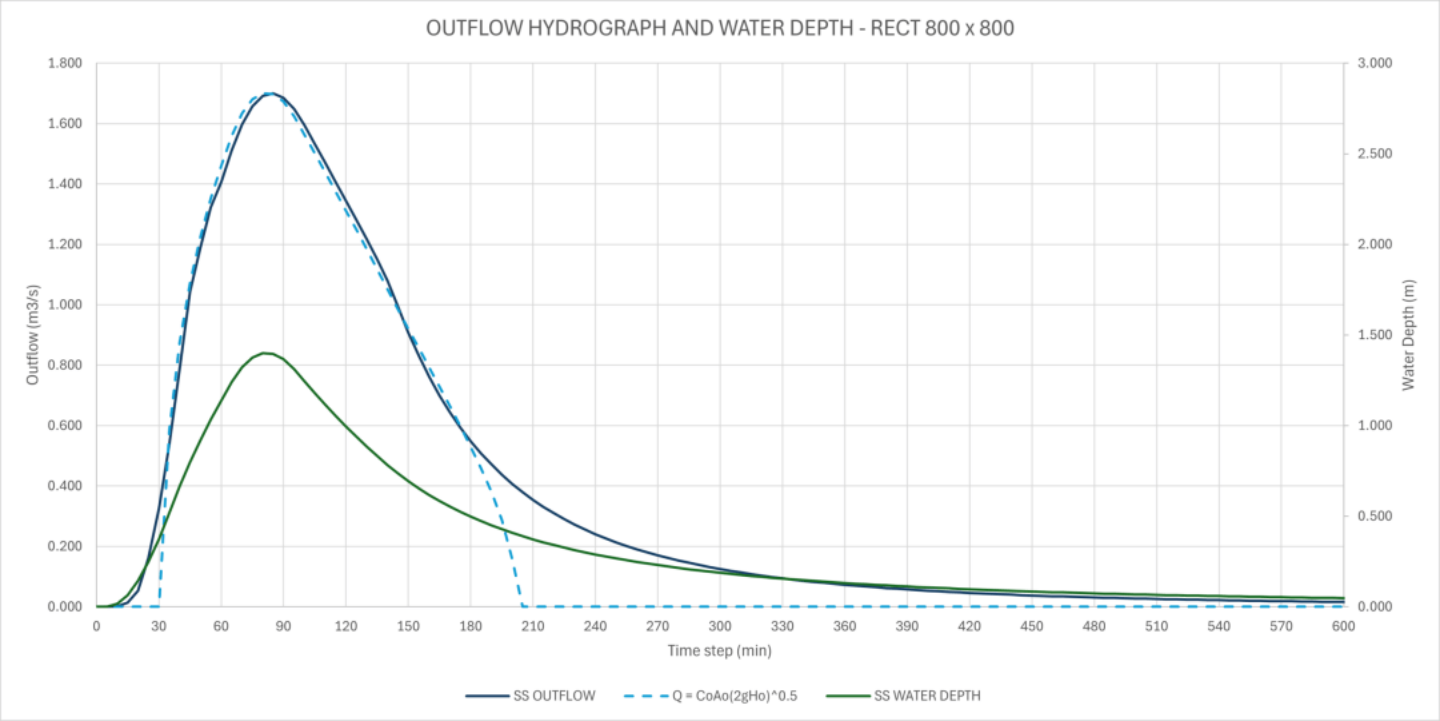
C_d : 0.60

A_o : Cross-sectional area of orifice

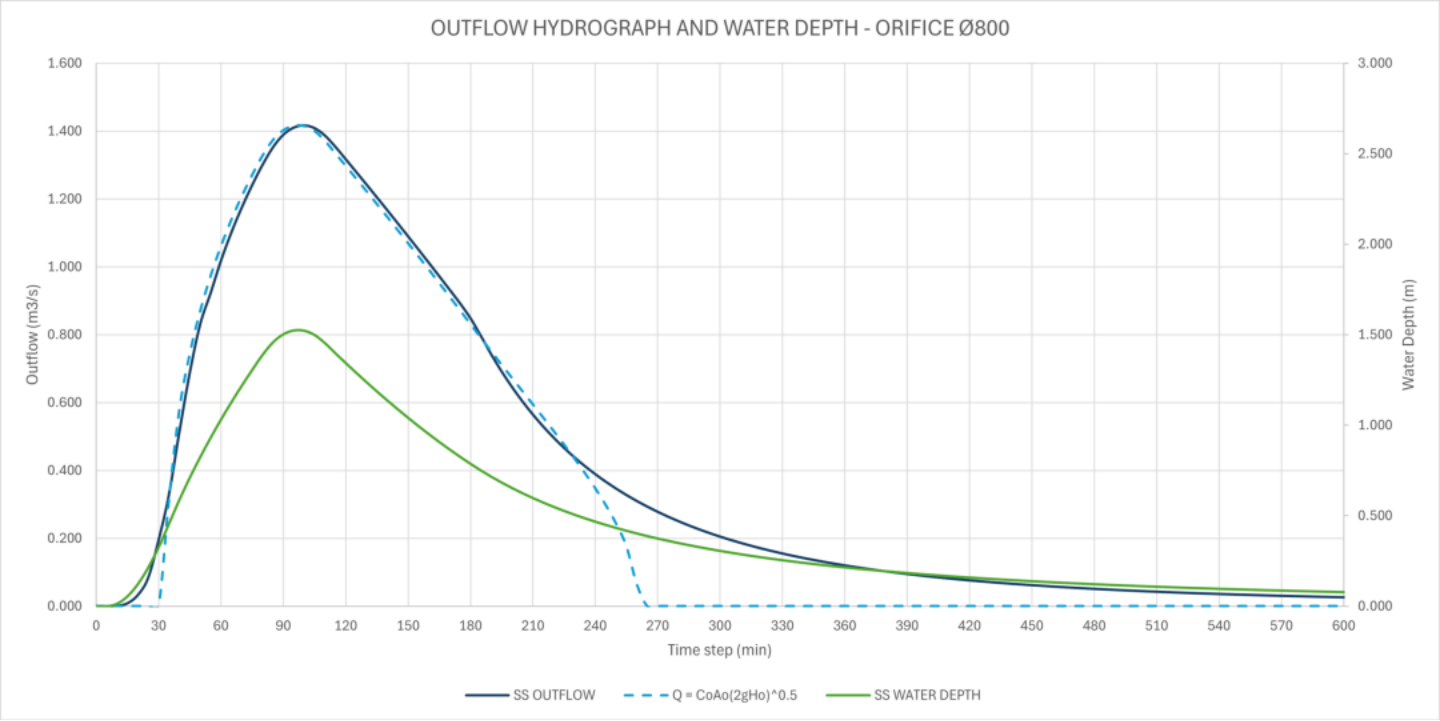
g : 9.81 m/s2

H : Effective head of the orifice, measured from water level until centroid of the opening

Outflow Comparison between StormSync (SS) and Orifice Equation.



*StormSync Module: Outflow and Water Depth result for **rect opening 800mm x 800mm***



*StormSync Module: Outflow and Water Depth result for **circular opening Ø800***

Discussion

Orifice formula will be the governing equation when water depth is higher than orifice centroid (partially/ fully submerged condition)

From the two graphs above, here is the observation that can be drawn:

- **Phase 1:** From 00:00 until 00:35 (rect & circular openings)
- **Phase 2:** From 00:35 until 03:00 (rect opening) // 00:35 until 03:50 (circular opening)
- **Phase 3:** From 03:00 until 10:00 (rect opening) // 03:50 until 10:00 (circular opening)

The StormSync orifice discharge and the calculated orifice discharge are not in agreement during the first 35 minutes of storm duration **(Phase 1)**. At this stage, the pond water depth is approximately below 0.4m which is below the centroid of the circular opening.

As the water level increases from minute 00:35 until 03:00 **(Phase 2)**, the StormSync outflow and orifice discharge calculated using orifice formula greatly converges and in good agreement. During this period, it can be seen that the water depth is higher than the orifice centerline (>0.4m), indicating the orifice is partially submerged to fully submerged conditions.

The water level begins to recede mainly at 03:00 until 10:00 **(Phase 3)**, and the outflow results between StormSync and the calculated orifice discharge start to diverge significantly.

The observed divergence between the StormSync outflow and the calculated orifice discharge in Phase 1 and Phase 3 suggests that the hydraulic behaviour changes once the water level drops below the orifice centerline. Under this condition, the flow transitions from submerged orifice flow to free-flow behaviour.

Weir formula will be the governing equation when water depth is lower than orifice centroid (free-flow condition)

In phase 1 and 3, since the pond water depth is below the centroid of the opening, hydraulic behaviour will transition towards free-flow conditions, causing the StormSync outflow and the calculated orifice discharge to show greater discrepancies. Hence, the weir equation will be the governing formula specifically in low water depth. To further verify this hypothesis, a comparison was carried out between StormSync outflow and orifice discharge (using the weir equation entirely across all water depth).

Rectangular Sharp-Crested Weir formula:

$$Q = C_w \times L \times H^{3/2}$$

Where:

C_w : 1.7

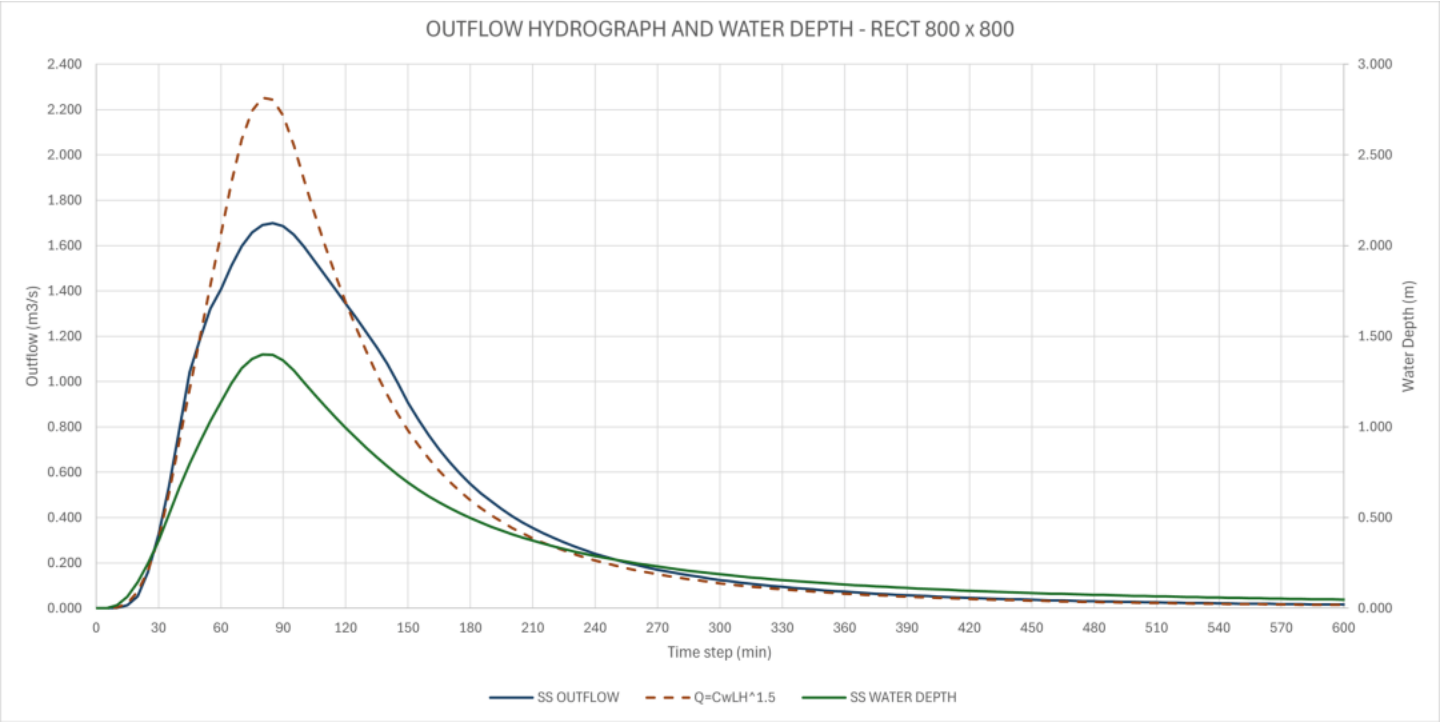
L : Width of the weir crest

H : Head of water above crest

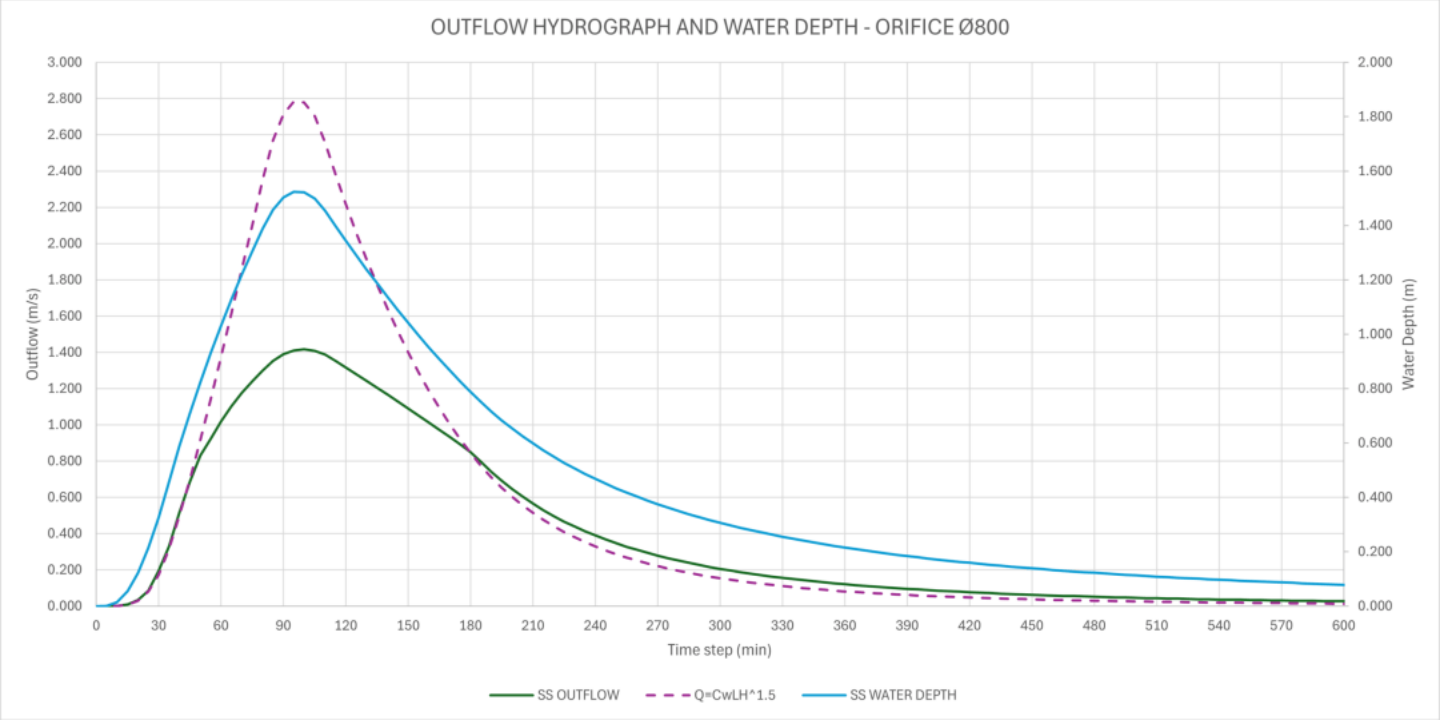
Side note:

The standard weir equation above is fundamentally developed for fixed-geometry weirs (e.g.: rectangular sharp-crested weir). In the case of circular or round weir geometries, the hydraulic behaviour cannot be represented exactly using the standard equation, as the effective crest length (L) changes with water depth due to the varying wetted perimeter of the circular opening. However, for practical comparison purposes, the standard weir equation is adopted herein as an approximation for the circular weir geometry.

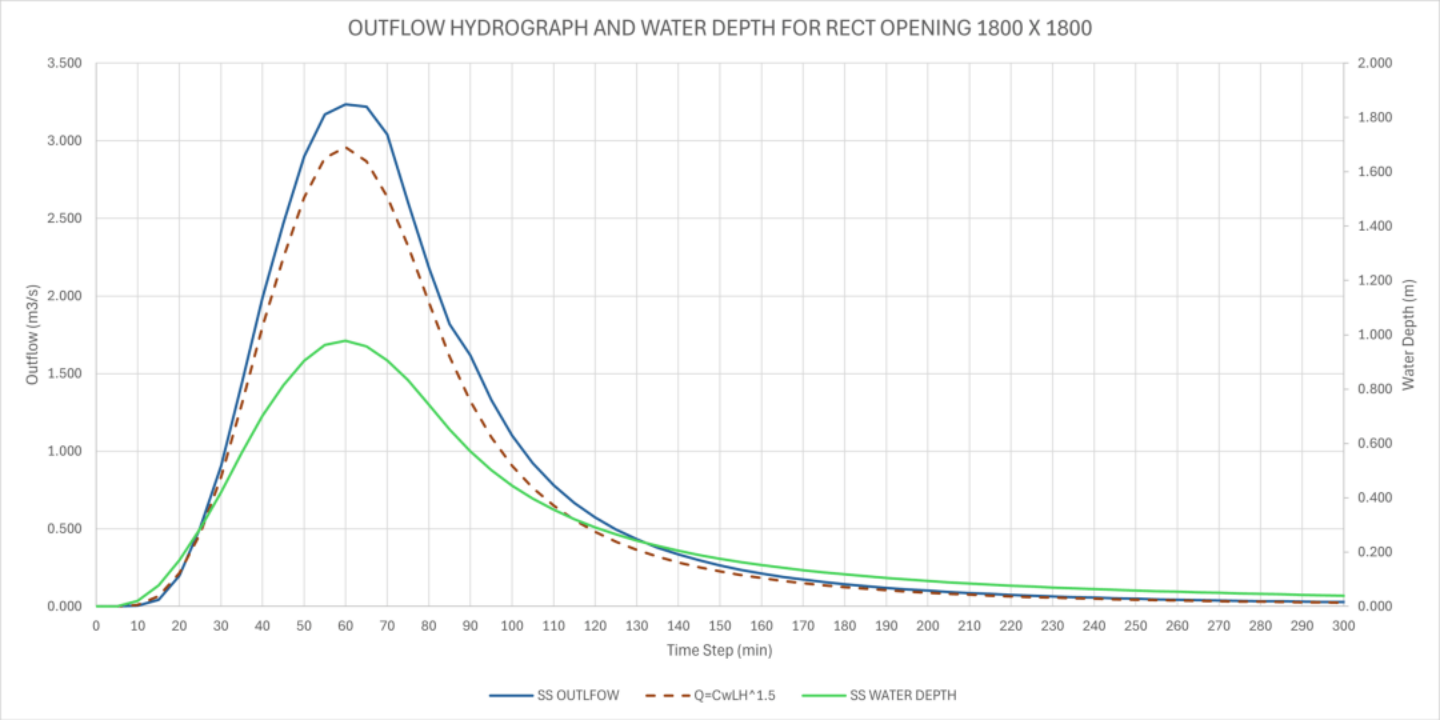
Outflow Comparison between StormSync (SS) and Weir Equation



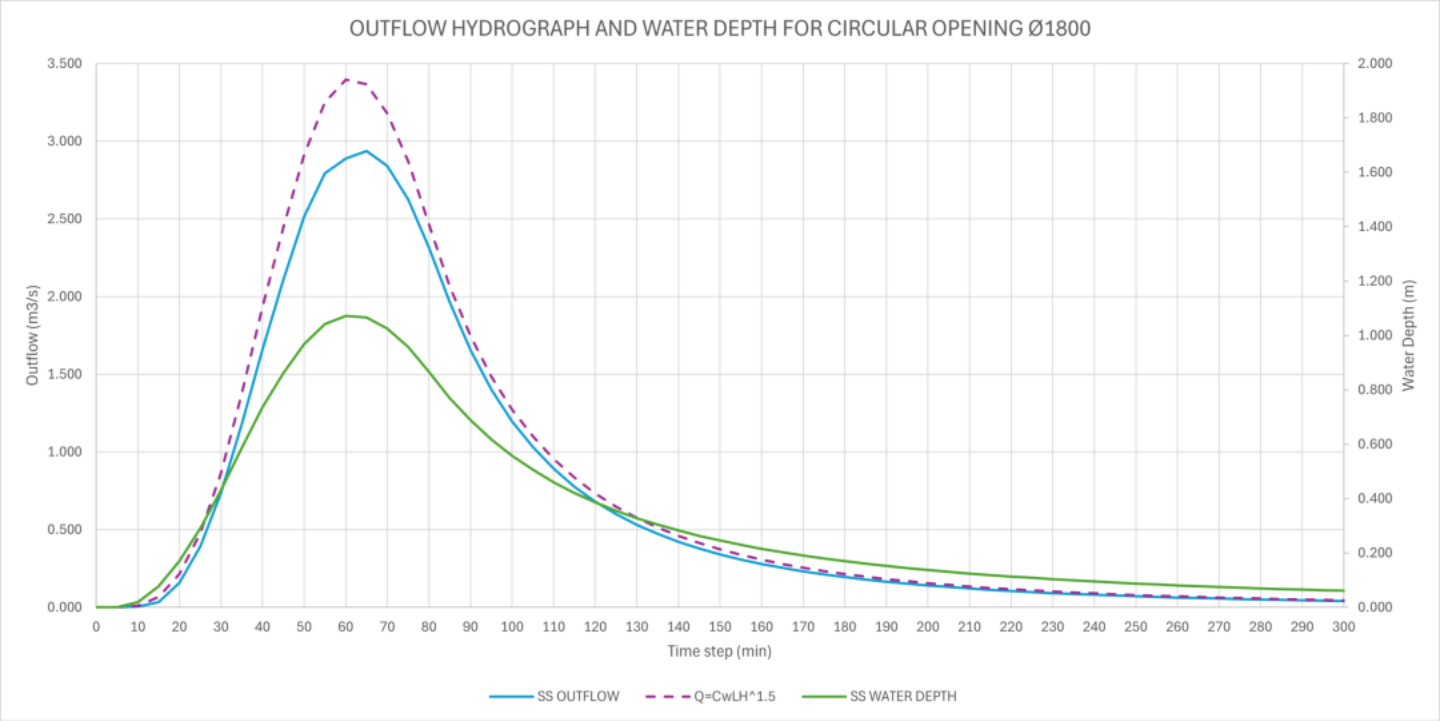
*StormSync Module: Outflow and Water Depth result for **rectangular opening 800mm x 800mm** - Weir Equation*



*StormSync Module: Outflow and Water Depth result for **circular opening Ø800** - Weir Equation*



StormSync Module: Outflow and Water Depth result for rectangular opening 1800mm x 1800mm - Weir Equation



*StormSync Module: Outflow and Water Depth result for **circular opening Ø1800** - Weir Equation*

Discussion

From the hydrographs above, the hydraulic response shows an opposite trend compared to the previous hydrographs when orifice equation is applied. When the weir formula is applied, the outflow

between StormSync and the calculated weir discharge shows **good agreement when the water depth is below the orifice centroid level** (at **Phase 1** and **Phase 3**). The weir discharge starts to diverge with the StormSync result, once the **water level is higher than the orifice centerline** (at **Phase 2**).

This indicates that the hydraulic behaviour under shallow water conditions is better represented by weir flow characteristics rather than submerged orifice flow behaviour. In addition, as larger orifice sizes are used, the centroid elevation becomes higher, causing the orifice structure under unsubmerged conditions, thus making the weir equation more dominant at low water depths.

Conclusion: Hydraulic Response of Orifice Flow is influenced by the Water Depth

From the above comparison, we can agree that the StormSync outflow result is indeed in agreement with orifice and weir formula, depending on the water level. A not well-known fact on outflow response in an orifice is that it behaves like a weir when the water level is low enough to flow through only part of the opening (unsubmerged). In this case, the standard orifice equation is no longer the governing equation, as the flow behaves more like free-flow over a “weir” (though the structure is physically orifice). So weir equation will be used instead. But once the water level rises above the top of the opening, the structure begins to behave as an orifice, where the flow passes through a submerged or partially submerged opening.

Comparing StormSync Outflow with MSMA Outflow when weir equation is used in low water depth

In the MSMA module, the **weir equation is adopted under the partial-flow condition** (water depth < centroid of opening), and orifice equation is adopted in partially/ fully submerged condition. The maximum discharge calculated in MSMA is compared against the outflow produced by StormSync.

Result summary

Rectangular Orifice 800 x 800

Critical Storm Duration: 75 mins

Module	StormSync	MSMA	% Difference
Peak Inflow (m3/s)	3.308	3.308	0.00
Peak Outflow (m3/s)	1.703	1.696	0.41
Max Pond Water Level (m)	1.406	1.394	0.85

Rectangular Orifice 1200 x 1200

Critical Storm Duration: 60 mins

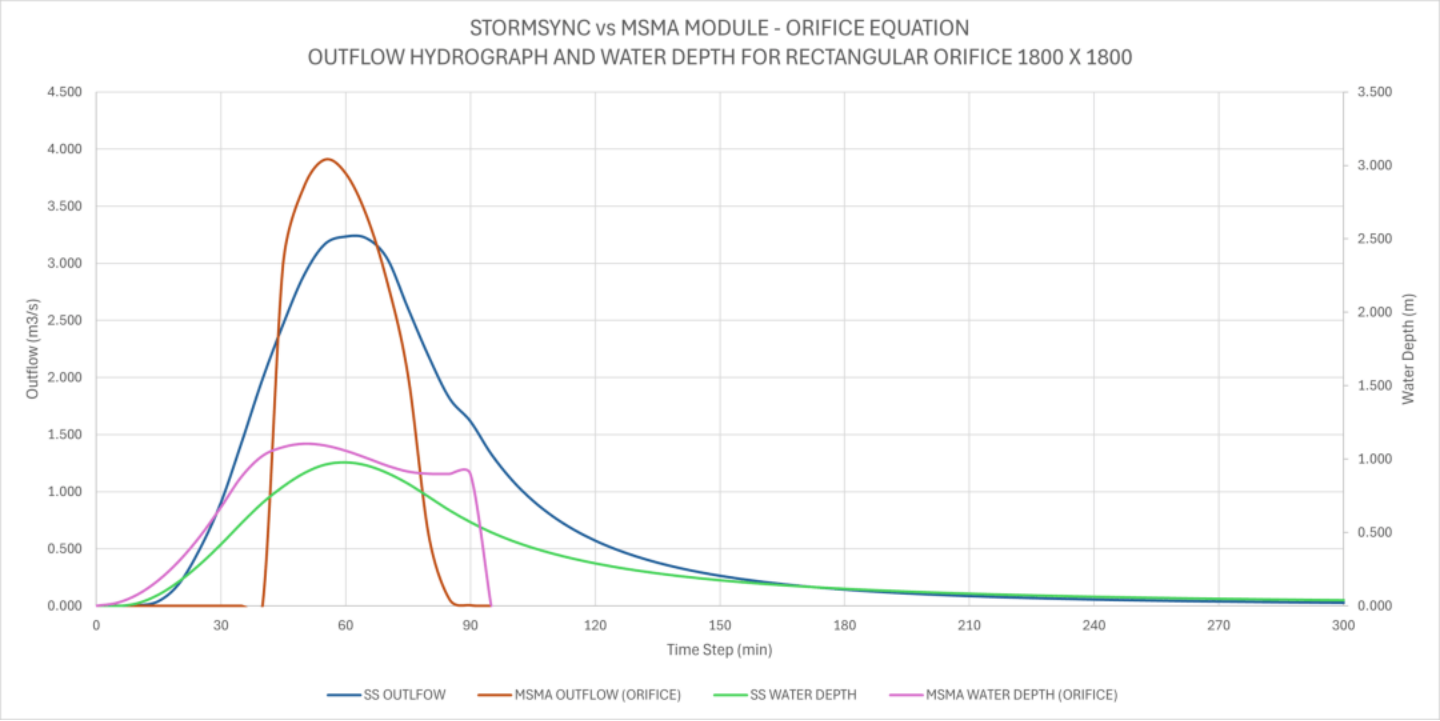
Module	StormSync	MSMA	% Difference
Peak Inflow (m3/s)	3.881	3.881	0.00
Peak Outflow (m3/s)	2.708	2.645	2.33
Max Pond Water Level (m)	1.134	1.164	2.65

Rectangular Orifice 1800 x 1800

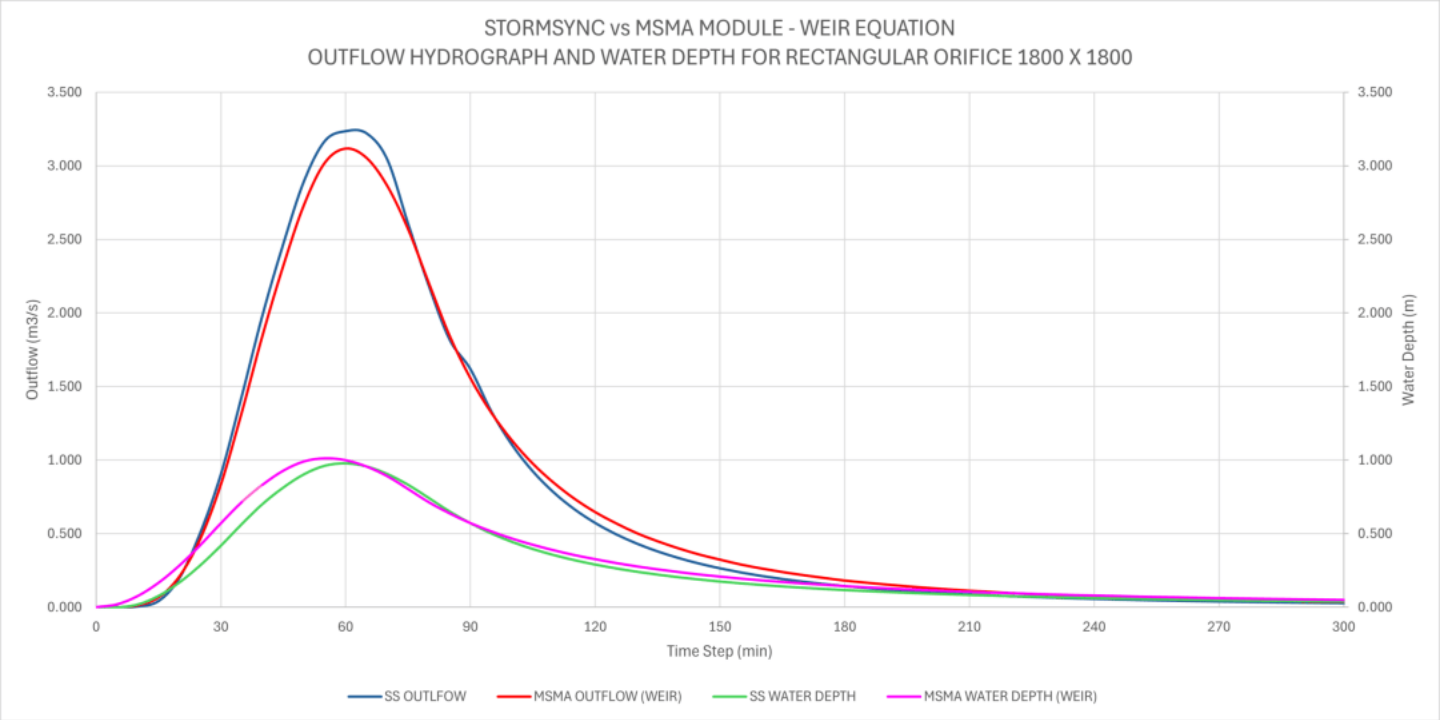
Critical Storm Duration: 45 mins

Module	StormSync	MSMA	% Difference
Peak Inflow (m3/s)	4.741	4.741	0.00
Peak Outflow (m3/s)	3.235	3.116	3.68
Max Pond Water Level (m)	0.978	1.012	3.48

Now, as the weir equation is used, the percentage difference on the peak outflow and maximum water level between StormSync and MSMA Module becomes much lower (<10% difference).



StormSync Outflow vs MSMA Outflow Equation: ***Partial Flow Method - Orifice***



StormSync Outflow vs MSMA Outflow Equation: ***Partial Flow Method - Weir***

Discussion

The MSMA Orifice result does not fully agree with the StormSync result. But when weir equation is applied in low water depth, the outflow and water depth greatly align with the StormSync result. Hence, this proves the orifice outflow behaviour will transition to orifice or weir depending on the water depth. If the water depth is lower than the opening centerline, weir equation will govern the outflow. Once the opening becomes submerged or partially submerged (high water depth), the orifice equation becomes the governing equation.

Conclusion

1. When the orifice is not submerged, it will be governed by weir equation, which SS module does, and in MSMA module, it can be done by setting the option to weir option. This will get good matching between MSMA and SS module when the water level is low.
2. When the orifice is submerged, it will be governed by an orifice equation, which SS module does, and in MSMA module, it can be done by setting the option to orifice option. . This will get good matching between MSMA and SS module when the water level is high.

It is reasonable to conclude that the flow routing approach in StormSync provides a more realistic representation of outlet behaviour compared to the MSMA calculation. This is because StormSync dynamically accounts for the transition between weir flow and orifice flow, depending on the water depth and outlet submergence condition. In contrast, the MSMA approach applies a fixed governing equation, which may not fully capture the actual hydraulic behaviour for irregular shape (i.e.: circular weir) throughout the entire routing process, particularly at low water depths.

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Ngu Soon Hui

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