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TUNNELWELL® STORMWATER INFILTRATION DEVICE TESTING BY GROUNDWATER MODELLING

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ABSTRACT:

3D FEFLOW groundwater modelling is used to compare the infiltration performance of a bank of Tunnelwell® units, as perhaps used across the front of a typical new housing lot, compared with alternative infiltration devices like soakwells which traditionally do not occupy the entire frontage.

The results show that the larger plan area of Tunnelwell® compared with equivalent storage soakwells, provides for more rapid stormwater infiltration and consequently a lower groundwater recharge mound between parallel subsoil drains.

Separate analysis of optimum spacings for Tunnelwell®, based on equations for optimising groundwater abstraction bore spacings to reduce interference effects, shows typically 5 m spacing is appropriate. Closer spacing does not enhance infiltration ability.

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1 INTRODUCTION

Infiltration of stormwater has traditionally relied on open basins either fenced or in parks, or buried infiltration devices on private lots. The latter typically comprise vertical cylindrical storage with slotted sides and open base, referred to in WA as soakwells.

A recently developed alternative infiltration device, Tunnelw ell®, requires no geotextile wrapping or blue metal surround, but is simply backfilled with compacted sand.

Tunnelwell® possesses greater plan area than the equivalent storage soakwell.

To research the advantage of this greater plan area in terms of infiltration rate a modelling study was conducted.

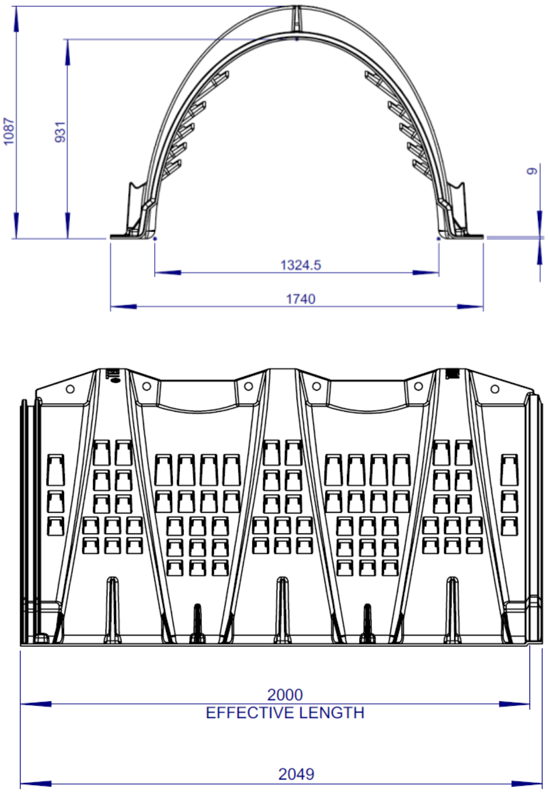
JDA was appointed by Sentry Holding Pty Ltd to apply the 3D groundwater model FEFLOW to analyse and compare the impact of Linear Tunnelwell® and circular soakwells for stormwater infiltration on groundwater mounding height between parallel subsoil drains. A separate analysis is presented for suitable spacing of Tunnelwell®.

2 MODELLING PARAMETERS

It is assumed that each housing lot is 300m^2 (30m length by10m width), and that each lot will need to provide storage for the first 15mm rainfall using an infiltration device (ID). Based on this, the total required ID storage is 3.8 m^3 using an impervious area percentage of 85%. In order to provide 3.8 m^3 ID storage on each lot, two 1.5 m diameter soakwells (1.2 m depth) or two 1.0 m^3/m Arch Tunnelwells® (each 2.0m long storing 2.0m^3) are required, see Table 1 below. Note that the plan infiltration area of the Tunnelwell configuration is 1.9 times that of the equivalent soakwells (6.80 divided by 3.54 = 1.9). A drawing of the Tunnellwell® unit is included in Figures 1a and 1b.

***Table 1:** Soakage Device Parameters*

Soakage Device	Dimensions	Base Area (m^2)	Storage Volume (m^3)	Required Quantity	Total Base Area (m^2)	Total Base Area/Soakwell Base Area
Soakwell	1.5m Diameter, 1.2m Depth	1.77	2.1	2 (4.2m^3)	3.54	1.0
Tunnelwell	1.7m Width, 2.0m Length, 1.1m Depth	3.40	2.0	2 (4.0m^3)	6.80	1.9



***Figures 1a (Top) and 1b (Bottom):** Left View and Front View of 1.0m^3/m Arch Tunnelwell®*

Figures 2 and 3 show the model extent with 2 rows of 5 residential lots located either side of a north-south oriented road. The road reserve is 14 m wide with 8 m sealed and 3 m verge on both sides. The subsoil drain (in black) is installed on the western side of road verge.

For the garden areas at the front and rear (green) and the road verges, a 70% rainfall recharge rate has been applied, with infiltration at source. The lot roof and paved areas (orange) also are assumed to have 70% rainfall recharge rates, concentrated to the soakage devices (blue) at front of lots. Under the lot roof area, a zero recharge has been applied. Road area (grey) is assumed to be drained through a piped system (out of the model), not to soakage devices.

The model uses the Future Climate Projections for Western Australia [1], consistent with the IPWEA (2016) guideline on Specification Separation Distances for Groundwater Urban Development.

Figure 2: *Soakwell (SW) 2×1.5m Diameter 1.2m Deep at the front of the Lots*

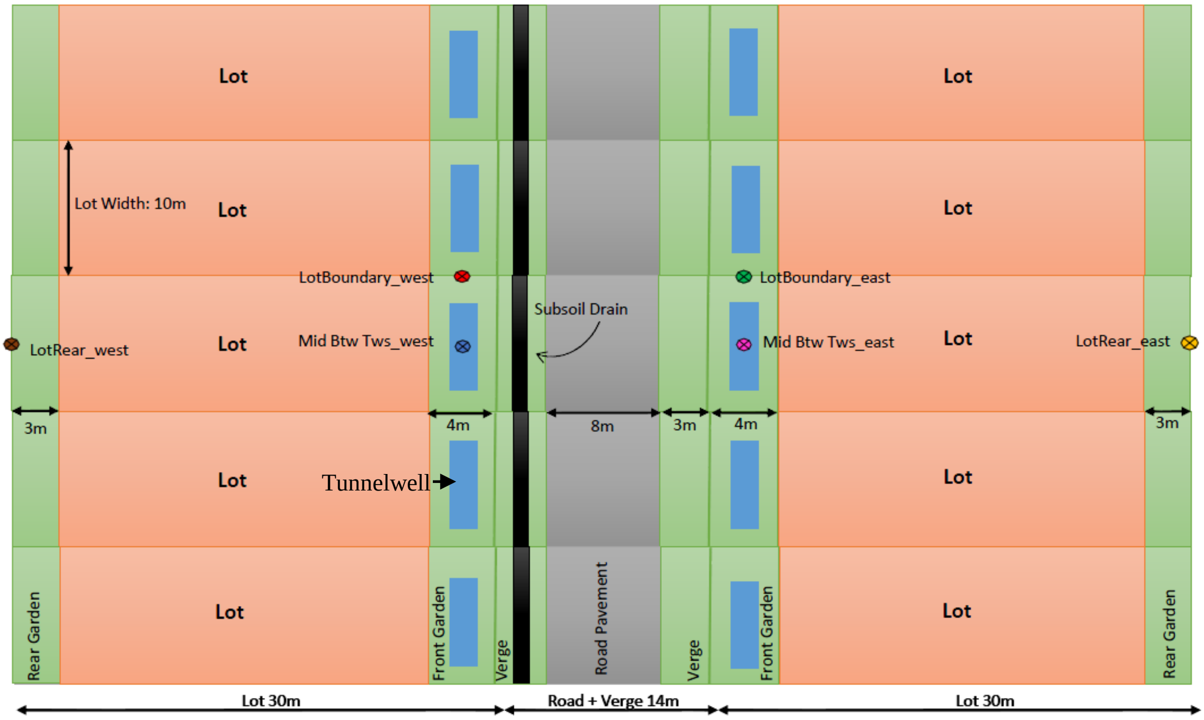


Figure 3: *Tunnelwell® (TW) 1.0m^3/m Arch at the front of the Lots*

Daily rainfall from the standard period 1961 to 1990 was downloaded from BoM Perth Airport Station [2]. Monthly anomalies provided by Department of Water (now DWER) were applied to obtain the predicted daily rainfall for the future period 2016 to 2045 median climate scenario, as recommended in [1,3].

The model has observation bores at the following locations (shown in Figures 2 and 3):

- At the rear of lots (east and west);
- On lot boundaries (east and west);
- In the centre of the soakage devices (east and west); and
- Between the soakage devices (in the case of the soakwell configuration).

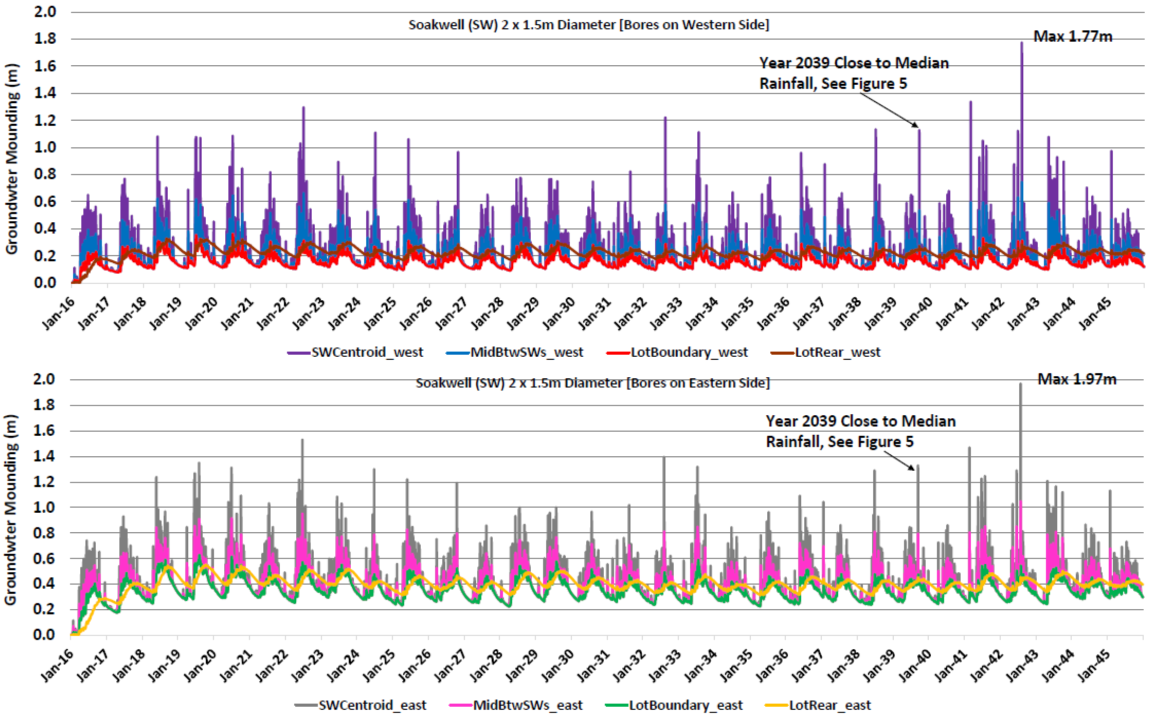


Figure 4: *Groundwater Mounding at Different Observation Bores from 2016 to 2045 for SW Scenario*

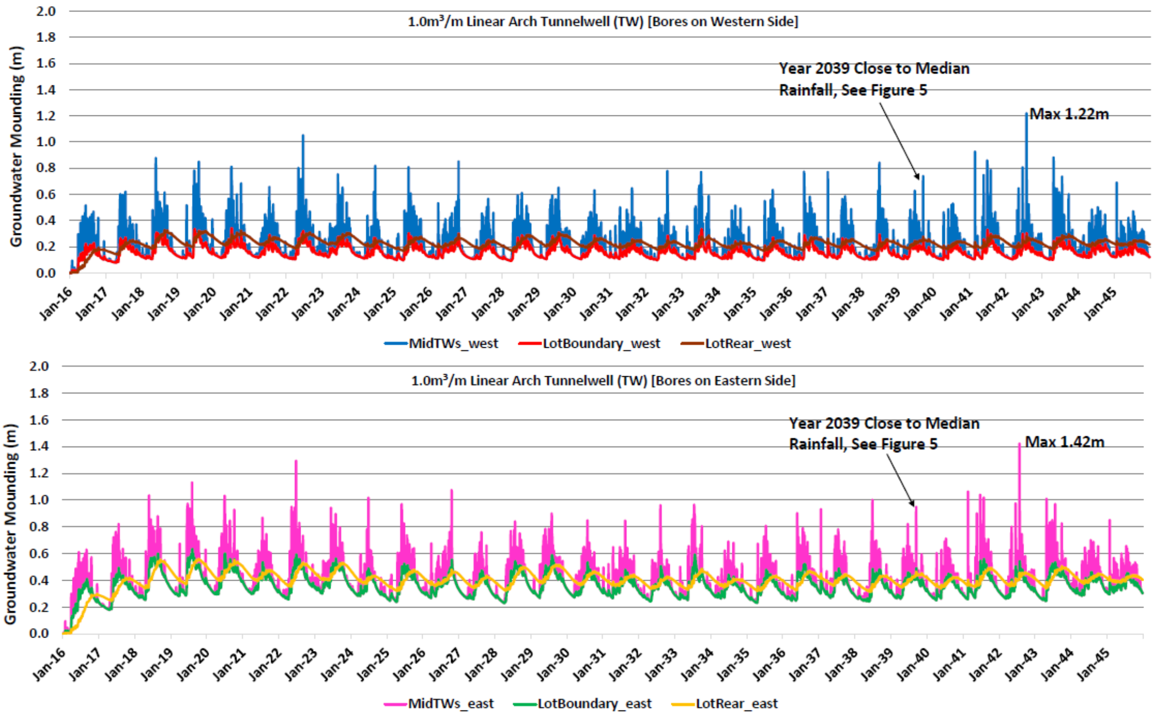


Figure 5: *Groundwater Mounding at Different Observation Bores from 2016 to 2045 for TW Scenario*

3 MODELLING RESULTS

Figures 4 and 5 show the 30 years' time series of daily groundwater levels at observation bores for soakwells and Tunnelwell® respectively. The top panel shows the groundwater mounding for bores located west of the road and bottom panel shows the bores east of the road. The water levels show a seasonal pattern with maximum in September/October and minimum in April/May each year.

Observation bores are colour coded on Figures 4 & 5 corresponding to colouring of bore locations in Figures 2 & 3.

On the eastern side for both soakwell and Tunnelwell® at the corresponding bore locations the groundwater mound water levels are higher than on the western side. This is expected, and is because the western side is closer to the subsoil drain.

The 30 years of annual maxima of groundwater mounding at the front of the lot for both soakwell (SWCentroid_east) and Tunnelwell® (Mid_Btw_Tws_east) are shown in Table 2 below (see locations in Figures 2 and 3), together with 50% Annual Exceedance Probability (AEP) of annual maxima.

Maximum mounding occurs beneath soakwell and Tunnelwell® rather the at rear of lots.

Each year (Table 2) Tunnelwell® has lower groundwater mounding at the front of lots compared to the soakwell configuration. In terms of 50% AEP groundwater mounding, which could potentially determine the finished lot level as outlined in [3], Tunnelwell® has 0.17 m (1.11-0.94m) lower 50% AEP groundwater mounding height, that is, approximately 85% of the soakwells.

As Year 2039 has close to median rainfall over the 30 years, this has been chosen to illustrate groundwater levels over a rainfall year. These single year groundwater results are plotted in Figure 6 to compare groundwater levels in the soakwell and Tunnelwell® scenarios. This further illustrates the groundwater mounding trends described above. The groundwater mounding at the front of the lot for Tunnelwell® is 0.95m, which is 0.38m, about 71% of the equivalent soakwell scenario of 1.33m.

JDA considers that Tunnelwells® results in lower groundwater mounding compared to equivalent soakwells, due to the larger plan area for infiltration of the Tunnelwell® units.

The 1.9 ratio of Tunnelwell to Soakwell plan area, results in 10% to 31% lower groundwater mounding.

Table 2: *Annual Maxima of 30 Yrs Groundwater Mounding (m) at the Front of the Lot*

Year	SW Centroid _east*	Mid_Btw _Tws _east*	Difference in Mound Height	Mound TW/SW (%)
2016	0.74	0.63	0.11	85%
2017	0.93	0.82	0.11	88%
2018	1.24	1.04	0.20	84%
2019	1.35	1.13	0.22	84%
2020	1.31	1.03	0.28	79%
2021	1.03	0.87	0.16	84%
2022	1.53	1.29	0.24	84%
2023	1.08	0.94	0.14	87%
2024	1.30	1.02	0.28	78%
2025	1.22	0.97	0.25	80%
2026	1.19	1.07	0.12	90%
2027	0.86	0.76	0.10	88%
2028	1.00	0.84	0.16	84%
2029	1.00	0.90	0.10	90%
2030	0.97	0.85	0.12	88%
2031	1.02	0.84	0.18	82%
2032	1.39	0.96	0.43	69%
2033	1.32	0.97	0.35	73%
2034	0.84	0.69	0.15	82%
2035	0.96	0.81	0.15	84%
2036	1.09	0.90	0.19	83%
2037	1.04	0.93	0.11	89%
2038	1.29	1.00	0.29	78%
2039	1.33	0.95	0.38	71%
2040	0.86	0.71	0.15	83%
2041	1.47	1.06	0.41	72%
2042	1.97	1.42	0.55	72%
2043	1.21	1.01	0.20	83%
2044	0.86	0.70	0.16	81%
2045	1.13	0.85	0.28	75%
50% AEP	1.11	0.94	0.17	83%
Max	1.97	1.42	0.55	90%
Min	0.74	0.63	0.11	69%

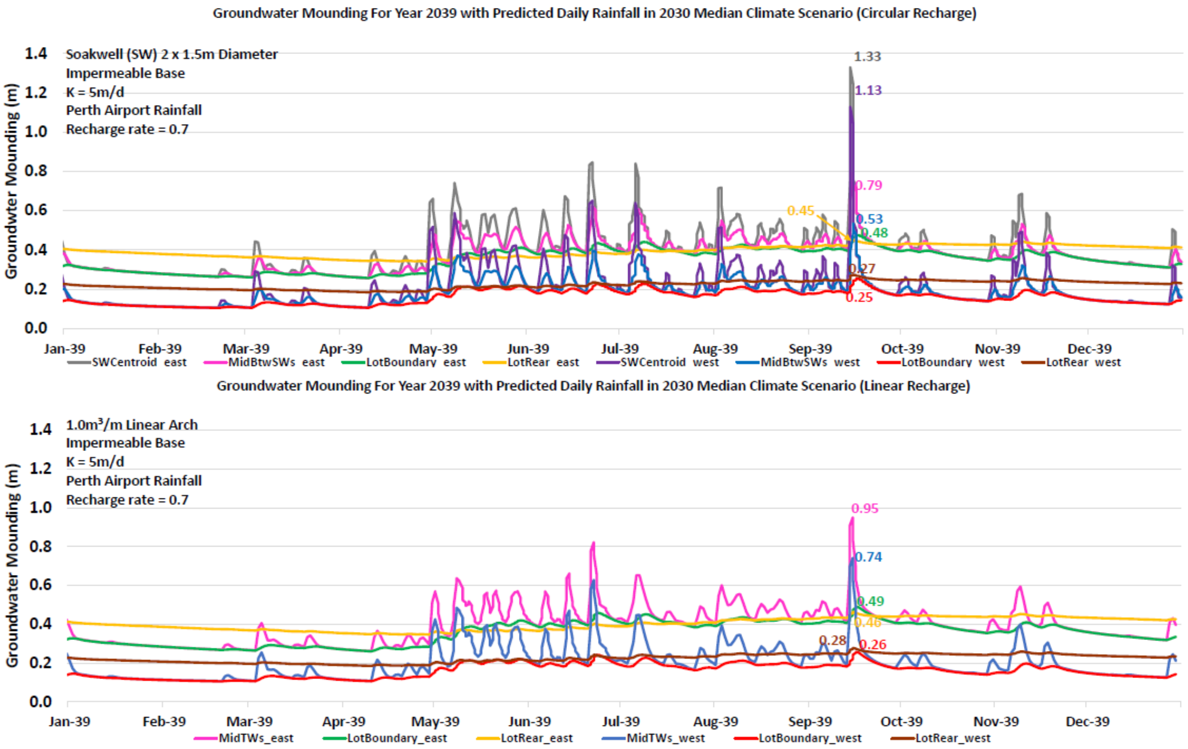


Figure 6: *Groundwater Mounding for SW and TW Scenario for Year 2039*

4 OPTIMUM TUNNELWELL® SPACING

The science of hydrogeology has long established the interference effects associated with groundwater abstraction bores being in close proximity to another.

In particular, in an unconfined aquifer the water table drawdown associated with abstraction from one bore may overlap the water table drawdown associated with an adjacent bore such that the total drawdown is equal to the sum of the drawdowns that would arise from each bore pumped independently.

These same equations of saturated groundwater flow apply equally to groundwater recharge as they do to groundwater discharge from bores.

As such the optimum spacing of infiltration devices, or specifically Tunnelwell® units, can be estimated using groundwater flow equations.

This is shown conceptually in Figure 7.

An experiment was performed for both soakwells and Tunnelwell® [4]. Only Tunnelwell® results are reported here. The tested site was underlain with 3.3 m thickness of sand overlying an impermeable layer of coffee rock. The water-table prior to the test was 1.43 m below natural surface. Water was recharged from a water tanker at 1L/s for 4 hours. At the end of the 4-hour test the water level rise in the monitor bores was 1.03 m at 2 m distance and 0.21 m at 7 m distance [4]. The TW itself was maintained full of water after the initial filling.

Analysis of the water level rise by the Theis Formula indicates Transmissivity in the range of 13 to 26 m^2/day, corresponding to hydraulic conductivity (K) of 4 to 8 m/day, a typical range for compacted sand. Specific yield of the sand, appropriate to its lithology, is assumed to be 0.2.

The Theis Formula can be used to calculate water level rises at a range of distances from a TW, after 4 hours recharging at 1 L/s. From this the minimum spacing to maximise recharge between TW can be calculated, as well as the amount of recharge between TW installed closer than the minimum spacing.

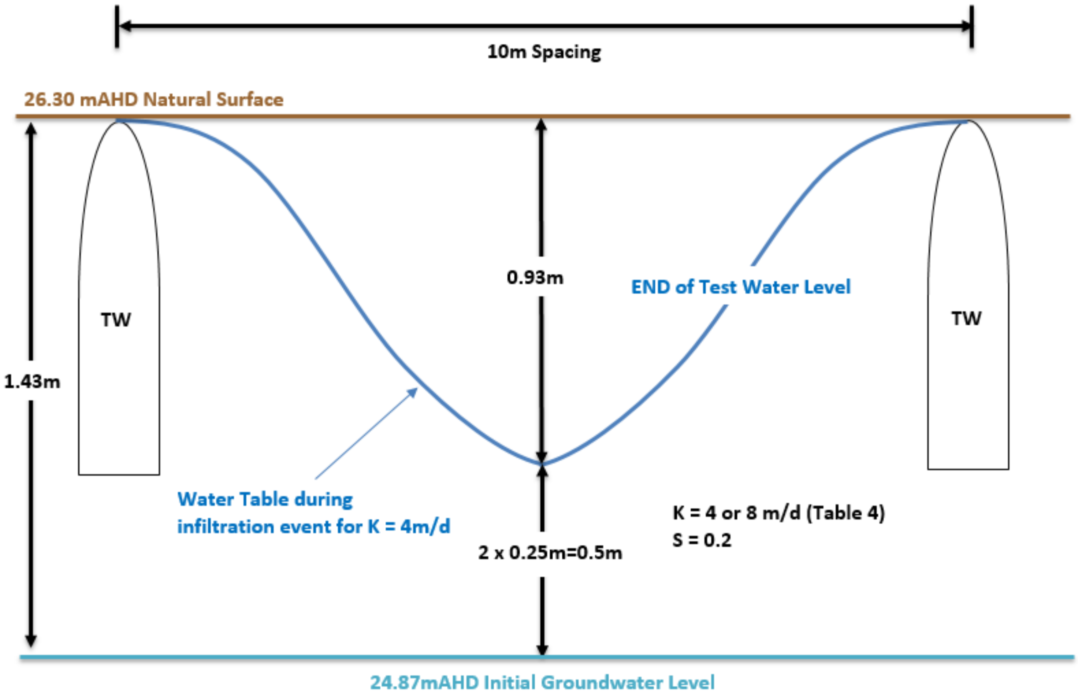


Figure 7: *Schematic Diagram for Water Levels between Two Tunnelwells with Spacing of 10m for 4-hour Recharge at 1L/s*

Calculated water level rises at different distances from TW, for K values of 4 m/day and 8 m/day, are presented in Table 3.

For example, at distance of 5m, the water level rise was 0.25m for both K=4 and 8m/d.

Table 3: Groundwater Level Rise from the TW

Distance from TW (m)	**Water Level Rise for K = 4 m/day**	**Water Level Rise for K = 8 m/day**
2	1.00 m	0.67 m
3	0.63 m	0.47 m
4	0.42 m	0.34 m
5	0.25 m	0.25 m
6	0.16 m	0.18 m
8	0.06 m	0.09 m
10	0.02 m	0.05 m

Using a 0.1m water level rise criterion the desired spacing is approximately 7m. Closer spacing will result in surcharge at the Tunnelwell® infiltration device. Alternatively, additional Tunnelwell® can be installed with reduced spacing and lower recharge rates.

As with groundwater abstraction bores, there is no benefit in having them too close together as the extra bores (or TW in this case) do not produce any more pumped water (recharge water).

5 CONCLUSIONS

JDA completed 3D groundwater modelling using FEFLOW comparing resulting groundwater level mounding for the installation of two 1.5m diameter soakwells or two 1.7m×2.0m×1.1m arch Tunnelwells® at the front of lots, to provide the same storage (based on storing 15mm initial loss) for a 30m×10m residential lot.

With subsoil drainage installed on the western side of the road reserve, the western lots have lower groundwater mounding compared to the eastern lots, due to shorter draining distance to the subsoil drain, as expected.

Maximum mounding occurs at the Tunnelwell® location, rather than at other locations, such as rear of lots.

For the modelling period of year 2016 to 2045 [1], Tunnelwell® units have lower daily groundwater mounding and annual maxima mounding than using soakwells. Taking the median rainfall year 2039 as an example, as shown in Figure 6, the groundwater mounding at the front of lot is about 29% lower for Tunnelwell® than for equivalent soakwells.

JDA considers that Tunnelwells®, with greater plan infiltration and predominantly horizontal storage, results in lower groundwater mounding compared to equivalent soakwells, which have a smaller plan are and predominantly vertical storage.

A separate analysis of overlapping water table mounds indicates that the optimum spacing between rows of Tunnelwells® units (on large sites such as industrial or commercial sites and POS) is approximately 7 m. Alternatively closer spacing can be used with reduced recharge in each Tunnelwell® unit.

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