4 PREDICTIVE MODELLING

4.1 MINE SCHEDULE

A summary of the schedule that was used for the Project in the groundwater model is provided in Figure 26. This figure outlines the stress period setup for the mining period of the transient predictive model run. The prediction period runs for 22 years of active mine life, followed by 1000 years of post-mining recovery. For this preliminary groundwater assessment, the lengths of the first six modelled stress periods were set to match the scheduled longwall extraction in as temporally coarse a manner as was possible without compromising the simulated inflows. The 1000 year recovery period was subdivided into twenty 50-year stress periods, primarily for ease of post-processing given our use of SURFACT's adaptive time-stepping (ATO) package.

4.2 MODELLING APPROACH

The potential impacts of the development were assessed by making comparisons between baseline predictive runs (with no Project) and impacted predictive runs (with the Project simulated using Drain boundaries as per Figure 26). This allows the net impact of the development on the hydrogeological environment to be evaluated separately from the other processes.

As noted in Section 3.8, 180 calibrated realisations of the predictive model were developed for the purposes of assessing predictive model uncertainty for the Gateway process. The uncertainty analysis is presented in Section 6.

4.3 MODEL IMPLEMENTATION

The underground mining and dewatering activity is defined in the model using drain cells within the mined coal seams, with drain elevations set to 0.1 m above the base of the coal seam. These drain cells were applied wherever workings occur, and were progressed through time increments coincident with the stress period durations.

The model setup involved changing the parameters with time in the goaf and overlying fractured zones directly after mining of each panel (see Section 3.5.1), whilst simultaneously activating drain cells along development headings. The main roadway headings were activated in advance of the active mining and subsequent subsidence (see Figure 26). The parameter changes to the goaf and overlying fractured zone rock units were applied to all 180 calibrated model realisations.

4.4 WATER BALANCES

The average water balance (over 1,022 years) for the optimally calibrated predictive model across the entire model area is summarised in Figure 27 for scenarios with and without the Project.

The results for the baseline and impacted scenarios are broadly similar, the key differences being the mine inflows (about 0.07 ML/day (27.2 GL total)), which results in a reduced discharge from the Permian rock aquifer to the Hunter Alluvium, ultimately inducing leakage of water from the Hunter River into the Hunter Alluvium (0.03 ML/day). This accounts for about 42% of the predicted mine inflow. A further 20% (0.007 ML/day) of mine inflow is due to depletion of aquifer storage, which the model suggests will not recover because of the fracture zone changes in aquifer storage and hydraulic conductivity. The remaining mine inflows are derived from reductions in evapotranspiration (20%; 0.007 ML/day), reduced bore yields (11%; 0.004 ML/day), and reductions in down-basin groundwater flow (7%; 0.003 ML/day).

The increased stream leakage into the alluvials is caused by a mining-induced reduction in discharge from the Permian strata into the alluvials, which peaks approximately 250 years after mine cessation, at a maximum depletion rate of 0.046 ML/day (16.7 ML/year). This level of stream flow impact is below detectable limits on a large river such as the Hunter, and below model accuracy limits. Further discussion of this potential impact and its uncertainty is presented in Section 5 and Section 6.

For both scenarios, the total inflow (recharge) to the model is approximately 53 ML/day, primarily comprising rainfall recharge (36%), and leakage from streams into the aquifer (64%). In both cases, groundwater discharge is dominated by evapotranspiration (74%), with lesser roles played by groundwater use (less than 26%), and, in the case of the mining-impacted model, mine inflows (0.1%).

4.5 PREDICTED MINE INFLOWS

Throughout the predictive period, the fracture zones invoked in the model above the underground mine were progressed in accordance with the mine plans.

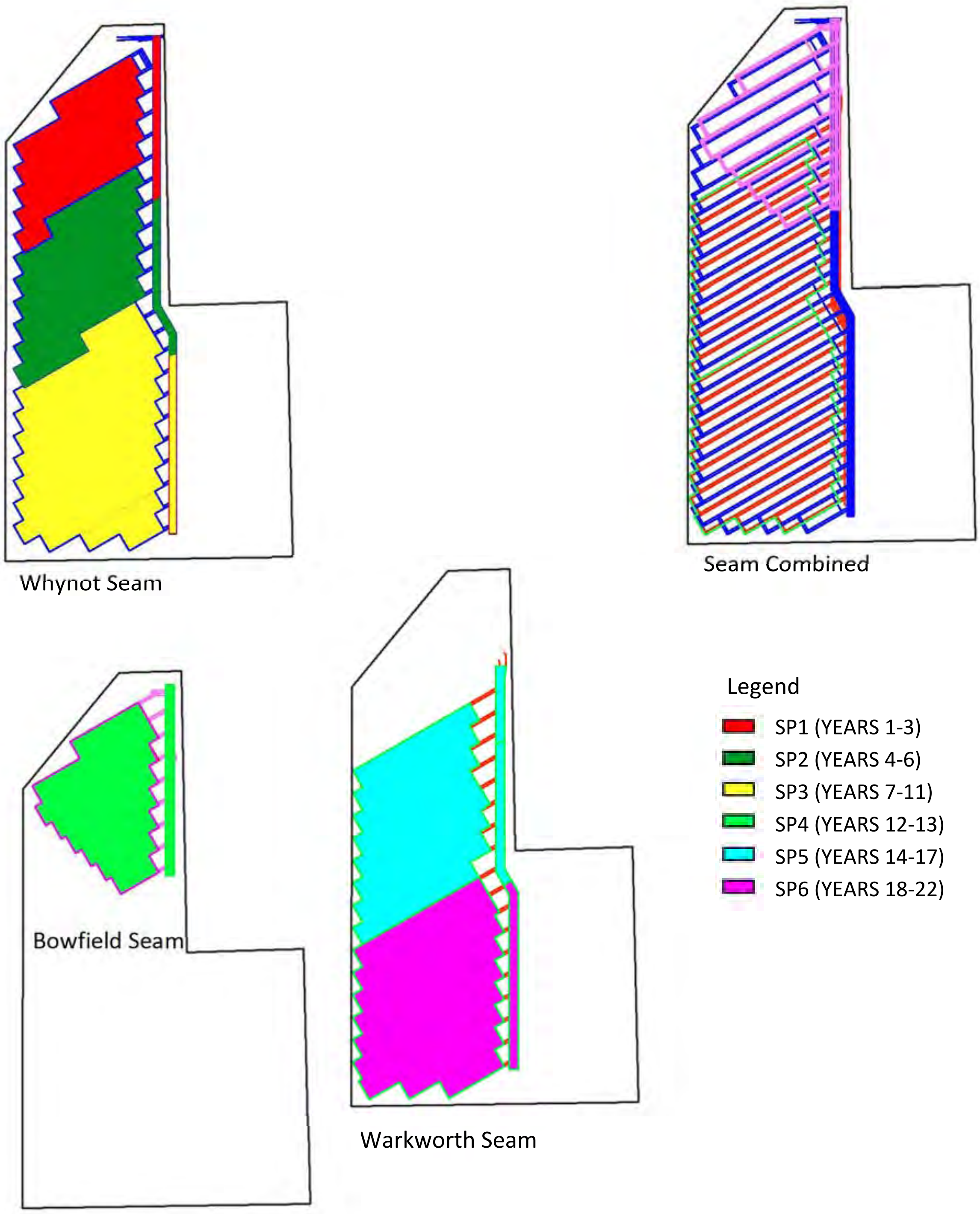
Model predicted inflows are shown in Figure 28 for the Project. The inflow rates are predicted to increase fairly linearly over the first 14 years of operation from about 1 ML/day at the start of underground mining activities to a peak of about 4.8 ML/day in years 14-17.

In years 4, 7 and 14 there are significant jumps in predicted inflows; these correspond to the initiation of the various seam longwalls (Drain boundaries) in the model. In reality, these sudden jumps are not likely to occur - they are largely a reflection of the coarse temporal discretisation of the predictive models adopted for the Gateway assessment (see Figure 26).

Beyond year 14 of operations, simulated inflows taper off marginally at around 4.5 ML/day.

Over the life of the mine, these simulated inflows total 27 GL. In annual terms, this Permian rock aquifer water take averages about 1230 ML/year over the 22 years of mining and peaks at about 1750 ML/year in years 14 through 17 of mine operation.

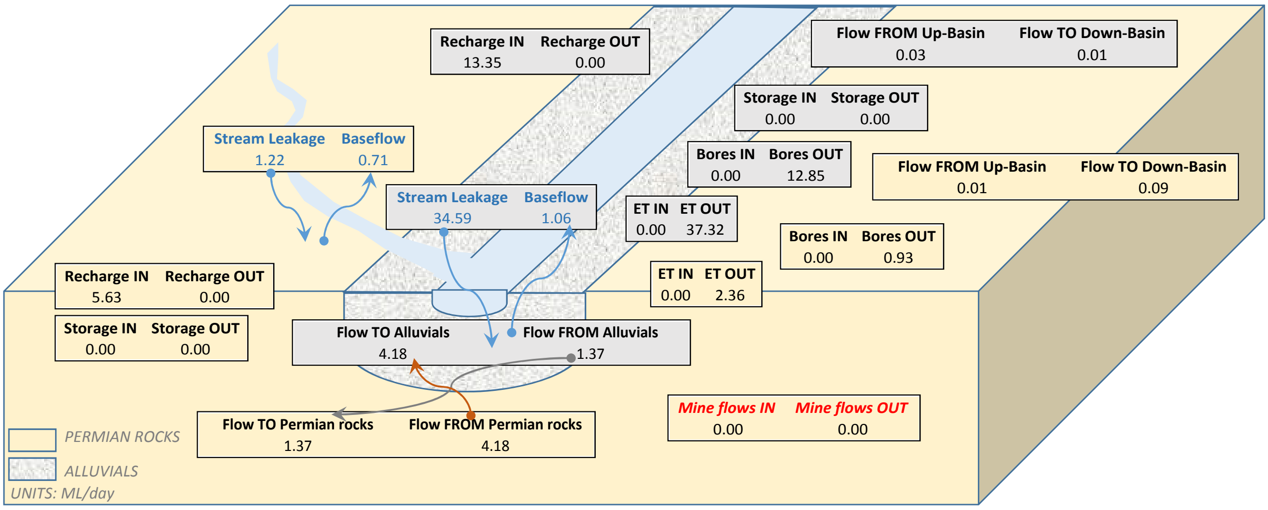
Uncertainty in these predictions is presented in Section 6.1.



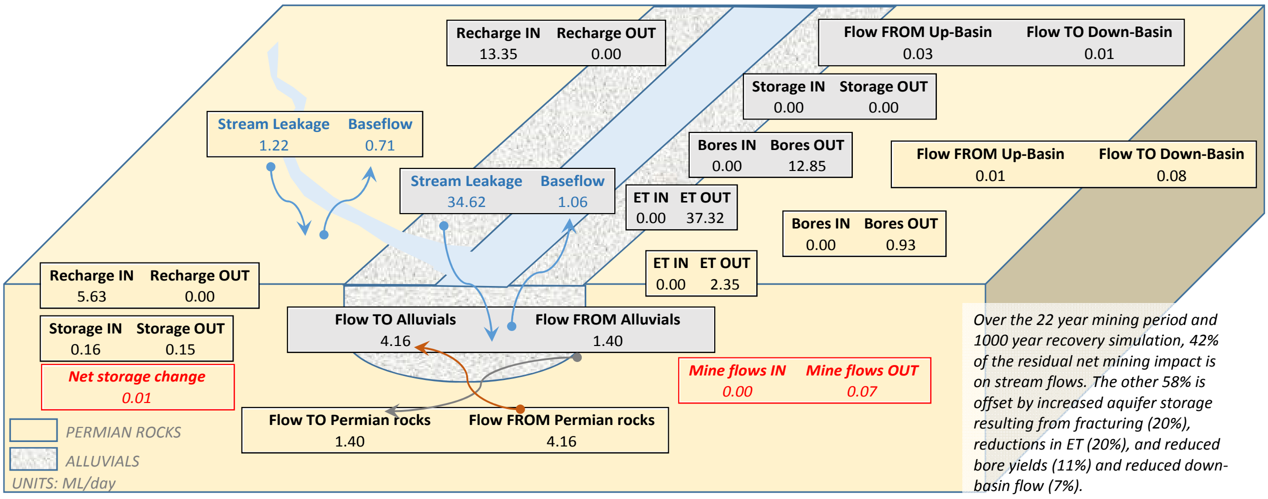
HYDRO SIMULATIONS

Figure 26 Modelled Spur Hill Mine Schedule

PRE-MINE DEVELOPMENT MODELLED WATER BALANCE



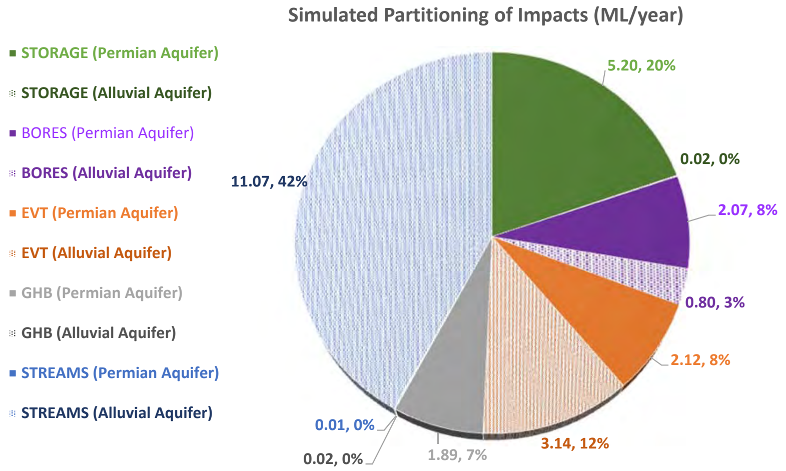
POST-MINE DEVELOPMENT MODELLED WATER BALANCE



Over the 22 year mining period and 1000 year recovery simulation, 42% of the residual net mining impact is on stream flows. The other 58% is offset by increased aquifer storage resulting from fracturing (20%), reductions in ET (20%), and reduced bore yields (11%) and reduced down-basin flow (7%).

Modelled Impacts on Permian Aquifer		
Net storage impact	-0.014	
Bore use impact	-0.006	
Mine inflow impact	0.072	*Increased mine flows*
Recharge impact	0.000	
ET Impact	-0.006	
Stream leakage Impact	0.000	
Flow to alluvials impact	-0.042	*Reduced flow to alluvials*
Down-basin flow impact	-0.005	

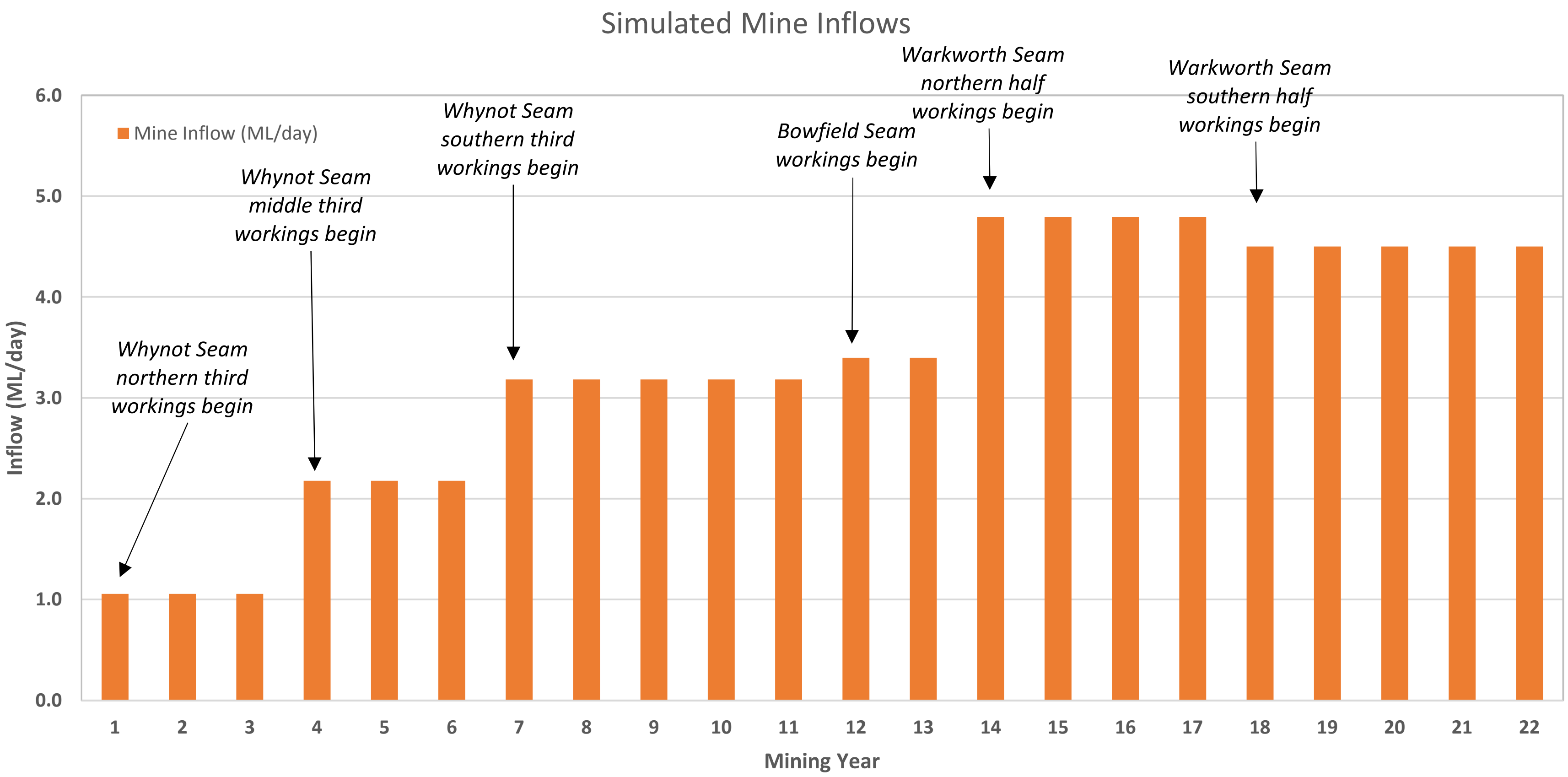
Modelled Impacts on Alluvial Aquifer		
Net storage impact	0.000	
Bore use impact	-0.002	
Mine inflow impact	0.000	
Recharge impact	0.000	
ET Impact	-0.009	
Stream leakage Impact	-0.030	*Increased stream leakage into alluvials*
Flow from bedrock impact	0.042	*Reduced flow from bedrock*
Down-basin flow impact	0.000	



Notes: Detailed water balance component impacts are provided elsewhere for modelled mine inflows and stream flow impacts.
Averaged over 1020 year predictive model.

HYDRO SIMULATIONS

Figure 27 Modelled Average Water Balance Impacts (averaged over 1022 years)



Model Run: SHv02TR010.

HYDRO SIMULATIONS

Figure 28 Modelled Spur Hill Mine Groundwater Inflows

5 POTENTIAL IMPACTS

5.1 FRAMEWORK FOR ASSESSMENT

This assessment focuses on the requirements of the AI Policy and the Gateway process (Table 1).

5.2 POTENTIAL IMPACTS ON GROUNDWATER

The main potential impacts on the groundwater regime due to underground mining arise from changes in bulk rock mass permeability caused by the fracturing associated with longwall subsidence, and the pumping out of groundwater that enters the mine as a consequence. This caving, and associated extraction of groundwater, has a number of effects on the hydrogeological system during and after mining operations that have been evaluated as part of the impact assessment. These can be summarised as follows:

- Inflow of water to the underground mine and the management of that mine water (Section 5.3);
- Impacts on groundwater levels during and after operational mining, both within the Permian hard rock strata and the alluvium associated with Hunter River and tributaries (Section 5.6);
- Impacts on baseflow and stream leakage to and from the Hunter River and tributaries during and after operational mining. This could also impact upon groundwater quality around streams (Sections 5.3 and 5.8); and
- Impacts on groundwater quality via mining-induced mixing of groundwater from different strata (Section 5.8).

5.3 TEMPORAL PARTITIONING OF WATER BALANCE IMPACTS

The simulated ultimate sources of water taken by the Project (Section 4.4) are the Hunter River, and the Permian (Sydney Basin) porous rock aquifer (Hunter EMU/ Jerrys and Muswellbrook Management Zones).

The simulated total annual take of water from the Permian rock aquifer as mine inflows is derived from a range of depletion sources (as described in Section 4.4). Figure 29 (upper chart) presents the breakdown of modelled annual water takes for the Hunter Alluvium and the Permian rock aquifer over the full predictive model period (1022 years), including the operational mining period, and the post-mining period (i.e. “whole of mine life”). These are also further partitioned into the various depletion sources (Figure 29 [lower time series chart]).

Corresponding charts focussing solely on the operational mining period, and the post-mining period are presented in Figure 30 and Figure 31, respectively.

5.3.1 Whole of Mine Life Partitioning

The largest ultimate depletion source is the Hunter Alluvium and River (57% of total water take of the Project; Figure 27 [hatched components of pie chart]), which are depleted via a reduction in groundwater discharge from the Permian rock aquifer (classified as a less productive groundwater source) to the Hunter Alluvium (classified as a highly productive groundwater source). This depletion is largely (73%) balanced by a corresponding increase in leakage from the river into the Hunter Alluvium (11 ML/year; see Section 4.4, Figure 27 and Figure 29). Hunter River flow depletion peaks at around 250 years post-mine operation at a rate of 16.7 ML/year, averaging 11 ML/year over the long term (which is around 0.004% of average flow in the Hunter River at Denman, Table 5) (Figure 29).

Uncertainty and partitioning of stream flow impacts are discussed in Section 6.2.

The remaining 27% (4 ML/year average) of reduced Permian rock aquifer discharge into the Hunter Alluvium (that is not balanced by increased river leakage) therefore comprises a net take from the highly productive groundwater source of the Hunter Alluvium. The model simulates this as being primarily comprised of a reduction in evapotranspiration from the alluvium (3.1 ML/year), with a negligible reduction in bore yields (0.8 ML/year) (Figure 29).

Figure 29 also shows that water takes from the Permian rock aquifer are ultimately derived from reduced aquifer storage (due to fracturing above longwalls; 5.2 ML/year on average), followed by reduced evapotranspiration and well yields (2.1 ML/year each), and reduced down-basin groundwater flow (1.9 ML/year).

The modelled negative water “takes” in years 1 through 22 (i.e. during the operational mining period) evident in Figure 29 are discussed in the following sub-section.

5.3.2 Operational Mine Period Partitioning

Inspection of the modelled depletion sources during the operational mining period only (Figure 30) reveals negative water “takes”. During mine operation, mining-induced fracturing (increased specific yield (Sy) and hydraulic conductivity (K) of bedrock) results in temporary watertable rises in areas of shallow cover (i.e. where fracturing reaches the near-surface). This is caused by the watertable equilibrating with deeper bedrock aquifer heads. These localised areas of watertable rise result in the following water balance impacts (negative water "takes"):

1. A corresponding net increase in evapotranspiration from the Permian aquifer (due to the shallower watertable); and
2. A corresponding net increase in discharge from the Permian aquifer into the Hunter Alluvium (due to higher Permian watertable heads and the resulting larger hydraulic gradients); resulting in

3. A net increase in alluvial aquifer storage; which results in
4. A net decrease in leakage from the Hunter River into the alluvium (due to reduced hydraulic gradients from the river into the alluvium, in which the watertable has locally risen).

The lower chart in Figure 30 shows that during the operational mine life, the groundwater flowing into the mine voids is almost exclusively derived from Permian aquifer storage.

5.3.3 Post-Mine Closure Partitioning

In the post-mine operation period, Figure 31 shows that the impacts of the previous mine depressurisation manifest themselves through aquifer storage recovery (rebounding pressures (50%)), which results in depletion of other water balance discharge components (alluvial and Permian evapotranspiration (12%), groundwater bore yields (7%), Permian down-basin groundwater flow (5%)), and enhancement of recharge (leakage from the Hunter River (26%)).

Figure 31 also shows that whilst enhanced leakage from the Hunter River into the alluvium peaks at around 250 years post-mine closure, total impacts on the alluvial aquifer peak 50-100 years later, because of lagged impacts on reduced bore yields and evapotranspiration.

5.4 GROUNDWATER DEPENDENT ECOSYSTEMS

At the time of writing there were no high priority GDEs listed in the relevant Water Sharing Plan, i.e. 'Hunter Unregulated and Alluvial Water Sources' (version current for 8 March 2013). Hence there are no known risks of mine development to such ecosystems.

In addition, flora surveys have determined that there is no groundwater dependent vegetation within EL7429 (Dr Colin Bower, FloraSearch, pers. comm., 14 June 2013).

5.5 CULTURALLY SIGNIFICANT SITES

At the time of writing there were no Culturally Significant Sites listed in the relevant Water Sharing Plan, i.e. 'Hunter Unregulated and Alluvial Water Sources' (version current for 8 March 2013). Hence there are no known risks of mine development to such sites.

5.6 SIMULATED IMPACTS ON GROUNDWATER LEVELS

The Project will cause depressurisation of the Permian strata. The Permian coal measures within the mine footprint are predicted to be essentially dewatered during mining of the target coal seams. Outside the mine footprint, depressurisation impacts on potentiometric pressures within Permian strata will occur.

The modelled drawdown impacts of the proposed mine development are presented in Figure 32 to Figure 36 for all model layers. Each of these figures presents:

- The maximum modelled drawdown in each model layer at any given time throughout the predictive modelling period. As such this is a composite temporal drawdown map; and
- The end of predictive model drawdown (i.e. simulated drawdown 1000 years after the cessation of mining). This illustration provides an indication of the degree of recovery of groundwater levels in the long term.

On each of these figures, the optimal calibrated model drawdowns are presented, including the modelled 2 m drawdown contour, which is a key criterion of the AI Policy in terms of bore interference. Following is a discussion of the simulated drawdowns in each model layer. Uncertainty in these drawdown estimates is discussed in Section 6.

Simulated maximum shallow drawdowns (in alluvium and regolith) due to the proposed mining operation (Figure 32) are expected to be limited in extent to localised areas within and immediately adjacent the lease. There are no simulated drawdowns on the highly productive Hunter Alluvium – all modelled drawdowns in layer 1 are in the Permian regolith, and these are focused in the lower lying areas where the regolith is saturated. Further upslope, the regolith is largely unsaturated, and hence no drawdowns are simulated.

Maximum modelled regolith drawdowns are less than 5 m and are focused in the northern end of EL7429. In lower lying areas, the modelled regolith drawdown is generally less than 1 m.

Recovery of regolith drawdown is slow, with around 3 m drawdown remaining in the northern end of the lease 1000 years after mining (Figure 32)). Full recovery will not occur due to mining-induced fracturing and the resulting increase in rock permeabilities (see Section 3.5). This results in a short-term greater rate of groundwater flow through the system and equilibration of groundwater pressures (to lower levels) under this altered hydraulic regime.

Within the deeper strata, drawdown is simulated to reach its maximum in the deepest layers (Layers 7 through 10 – Bowfield Seam down to the Permian underburden beneath the Warkworth Seam; Figure 35 and Figure 36); similarly the spatial extent of maximum drawdown is greatest in these deeper strata, and diminishes gradually up into the shallower units.

In the shallower strata (down to layer 6), drawdown is simulated to reach its maximum around the northwestern lease boundary (Figure 32 – Figure 34). To the east and north, where these units thin and pinch out, the simulated drawdown diminishes rapidly, whilst down-basin to the west simulated drawdowns spread beneath the Hunter River and fall to approximately 10 m within 5-6 km of the western lease boundary in the shallowest rock units (layer 2; Figure 32). In the strata down to layer 6, drawdown propagation to the south is similarly limited, albeit to a lesser extent, by the thinning and pinching out of these units to the south of the Hunter River (west of the Mt Ogilvie Structure). Simulated maximum drawdowns of 2 m (or more) spread out to approximately 8 km to the north and south from the northern and southern lease boundaries in the shallowest Permian strata (layer 2; Figure 32).

As noted for the regolith, modelled drawdown recovery is slow in the deeper strata, with up to approximately 26 m maximum drawdown remaining in the Permian (Whybrow) Overburden (layer 2) in the north of the lease 1000 years post-mining. Regional drawdowns have however recovered to at least approximately 5-10 m of baseline groundwater levels within this unit. Interestingly, drawdowns in the deepest strata (layers 7 through 10; Figure 35 and Figure 36) recover most quickly, with proportional drawdown recovery (relative to the maximum) being greatest in these units, and lowest (slowest) in layers 1 through 6. This is due to immediate replenishment by gravity drainage down to the deepest layers, with water being drawn away from the middle and higher layers.

5.7 POTENTIAL IMPACTS ON EXISTING GROUNDWATER USERS

The simulated maximum drawdown impacts of the Project, in addition to the cumulative impacts of surrounding mines on existing groundwater users in the region are presented in Table 11 and Table 12. It should be noted that the drawdown values in these tables are the maximum impact at any given point in time in the predictive model. These tables are restricted to listing those bores that were modelled as being potentially impacted upon (cumulative or otherwise) in excess of the AI Policy criterion of 2 m maximum cumulative drawdown.

As noted in Section 5.6, no appreciable drawdown impacts are simulated for the highly productive Hunter Alluvium. All listed drawdown impacts in Table 11 and Table 12 are modelled as occurring in the less productive Permian porous rock units.

Table 11 Modelled Impacts on Registered NOW Groundwater Bores

Work No	Site ID	Licence	Easting	Northing	Depth	Completion Date	Model Layer	Ownership	Modelled Maximum Drawdown (at any time; m)	
									Best Estimate	Cumulative Best Estimate
GW029654	200067000	20BL023411	289354	6412999	95.1	1/01/1921	6	Private	98.5	98.5
GW029660	200067000	20BL023412	290316	6413266	74.7	1/01/1938	**6**	Private	54.9	56.6
GW062557	200004000	20BL134254	286836	6417106	45	1/04/1986	2	**SHM**	54.3	54.3
GW050849	200048000	20BL112920	287508	6417459	27	1/05/1980	2	**SHM**	49.2	49.2
GW040550	200040000	-	286497*	6413582*	N/A	-	2	Private	26.5	26.5
GW078709	200068000	20BL167443	290853	6412568	50	-	6	Private	34.5	35.8
GW078708	200068000	20BL167442	290993	6413403	43	-	6	Private	34.1	36.9
GW029650	200067000	20BL023416	286443	6409733	67.1	1/04/1957	2	Private **(Not in Use)**	32.9	32.9
GW029651	200067000	20BL023415	286490	6410011	54.9	1/04/1957	2	Private **(Not in Use)**	31.6	31.6
GW029652	200067000	20BL023414	286511	6410227	91.4	1/04/1957	2	Private **(Not in Use)**	24.0	24.0
GW201830[+]	-	20BL167445	287315	6413665	40	1/07/1930	2	Private	~24	~24
GW029653	200067000	20BL023413	286532	6410474	48.8	1/04/1957	2	Private **(Not in Use)**	20.6	20.6
GW080338	1000010000	**20CA212307**[‡]	280038	6412295	N/A	7/11/2002	2	Private	10.0	10.0
GW029658	200067000	20BL023408	289566	6414113	55.8	1/01/1957	4	Private	8.9	11.5
GW033193	200011000	20BL026154	293790	6417220	46.9	1/04/1971	6	**HVEC**	7.5	34.7
GW029661	200067000	20BL023406	293158	6414865	42.7	1/01/1914	6	Private	6.9	9.7
GW078707	200068000	20BL167441	289653	6413714	43	-	4	Private	6.5	9.9

Work No	Site ID	Licence	Easting	Northing	Depth	Completion Date	Model Layer	Ownership	Modelled Maximum Drawdown (at any time; m)	
									Best Estimate	Cumulative Best Estimate
GW031623	200006000	20BL023652	294226	6417630	38.1	1/06/1969	6	**HVEC**	5.4	18.2
GW032077	200008000	20BL024716	294371	6416955	53.3	1/11/1969	6	**HVEC**	5.3	22.3
GW031622	200006000	20BL024276	294545	6416126	91.4	1/10/1969	6	**HVEC**	5.1	18.4
GW078013	200067000	20BL145078	281060	6418122	18.28	16/12/1991	2	Private	5.2	5.2
GW031859	200007000	20BL024674	294738	6415637	61	1/10/1969	6	**HVEC**	4.0	16.3
GW016888	200036000	20BL007696	283160	6420171	28.3	1/01/1957	2	**Mangoola**	3.9	3.9
GW022416	200060000	20BL014928	279843	6418743	17.7	1/01/1965	2	Private	3.2	3.2
GW018000	200037000	20BL010703	284272	6420780	20.7	-	2	**Mangoola**	3.0	3.0
GW078026	200067000	-	294455	6420158	N/A	-	2	**HVEC**	2.7	8.3
GW037616	200009000	20BL028439	280007	6418407	13.7	1/02/1973	2	Private	2.8	2.8
GW032512	200009000	20BL024338	294490	6418806	33.5	1/01/1969	6	**HVEC**	2.5	8.4
GW033915	200013000	20BL024261	294289	6419686	39.6	1/06/1971	6	**HVEC**	2.4	10.4
GW043796	200041000	20BL101583	279336	6419194	28.9	1/10/1974	2	Private	2.5	2.5
GW013114	200032000	**20WA208861**ǂ	278430	6404536	42.2	1/01/1957	2	Private	2.3	2.3
GW047762	200045000	**20WA208869**ǂ	283449	6400732	76.2	1/11/1980	2	Private	2.2	2.2
GW045469	200043000	20BL103870	295654	6420709	49.1	1/05/1976	6	**HVEC**	2.0	62.0
GW049223	200046000	20BL106334	298225	6413859	67.1	1/01/1979	6	**HVEC**	<2	2.3
GW073576	200019000	20BL166372	291700	6424852	20	6/08/1995	6	**Rio Tinto (Bengalla)**	<2	4.3

Work No	Site ID	Licence	Easting	Northing	Depth	Completion Date	Model Layer	Ownership	Modelled Maximum Drawdown (at any time; m)	
									Best Estimate	Cumulative Best Estimate
GW030745	200004000	-	296157	6423031	220	1/06/1979	10	**Government**	<2	127.0
GW061636	200002000	20BL133914	292086	6426306	42.7	1/04/1986	6	**Rio Tinto (Bengalla)**	<2	6.7
GW200003	200067000	20BL166521	291137	6425991	21	-	6	Private	<2	6.0
GW011295	200030000	**20WA212203[‡]**	290640	6425321	29	1/08/1955	6	Private	<2	4.6

[+] This bore was identified following the completion of the modelling and the predicted maximum drawdown has been estimated based on drawdown contours. Analysis of this bore will be addressed in the EIS (incorporation into water level mapping and the geological model), along with confirmation of the location and condition.

* Updated based on field-validated bore census.

[‡] Water Management Act licence indicates this bore is located in the alluvial aquifer and therefore would not be subject to drawdown impact.

SOURCE: D:\Heritage\Spur_Hill\GWModel\SHv02TR\Processing\Prediction\Drawdowns\SHv02TR010_RegisteredBore_Census_Drawdowns.xlsx

Table 12 Modelled Impacts on Users' Groundwater Bores Identified in the Project Bore Census

Census Ref No	Plan No	Lot No	Description	NOW Work No	Easting	Northing	In Use	Purpose	Year Drilled	Drill Depth	Modelled Maximum Drawdown (at any time; m)	
											Best Estimate	Cumulative Best Estimate
26	279967	4	Inverted 1.2 m Concrete Pipe	GW040550	286497	6413582	Yes	Stock / Irrigation	Unknown	Unknown	26.5	26.5
3	752441	49	Windmill	GW029657	288491	6411304	No	Stock	1966	8	<2	<2
2	752441	33	Windmill	GW029659	289107	6411477	Yes	Stock	1936	Unknown (Shallow)	<2	<2

SOURCE: D:\Heritage\Spur_Hill\GWModel\SHv02TR\Processing\Prediction\Drawdowns\SHv02TR010_RegisteredBore_Census_Drawdowns.xlsx

It should be noted that bores were assigned to model layers (and aquifers) based on recorded bore location, mapped geological outcrop (i.e. the extent of the alluvial aquifer), and recorded bore depths where possible. For these reasons it is possible that some bores might have been incorrectly assigned to aquifers. This issue is considered to affect some bores in Table 11 based on the known licensed aquifer, in which case the listed impacts are over-estimates (given no modelled drawdown in the alluvium, and these bores' likely incorrect location information resulting in the bore being located on Permian outcrop).

The optimally calibrated model simulates 12 privately-owned bores in use as being impacted upon by the Project in excess of the 2 m drawdown criterion of the AI Policy (Table 11 and Table 12). Accounting for cumulative impacts of surrounding mines by using the simplifying assumption of the Principle of Superposition, the number of impacted bores increases to 13.

Uncertainty in these modelled drawdown impacts is discussed in Section 6.4.

SHM is committed to "make good" provisions for any groundwater users adversely affected by mine operations and associated impacts – i.e. provision of alternative water supply or remedial works (e.g. deepening of existing wells or bores).

5.8 POTENTIAL IMPACTS ON GROUNDWATER QUALITY

Mining-induced changes to the hydraulic properties and depressurisation of the strata in the mined area will result in mixing of potentially chemically different groundwater between overlying and underlying units. Electrical conductivity data for the coal measures from surrounding mines' publicly available reports suggests a mean EC of around 5200 uS/cm, with a standard deviation of approximately 2900 uS/cm (from 114 measurements). As such, it is considered unlikely that mining-induced mixing of groundwater will result in changes to the beneficial uses of groundwater in the Permian rock units in or around the Project area during or following mining. The risk of these impacts decreases with distance from the active mining area and enhanced rock mass fracturing.

In the long-term, mining-induced leakage of surface water into the Hunter Alluvium will result in a reduction in the salinity of the alluvial aquifer, which has an EC range of 1187-6490 uS/cm (Section 2.6.2), whilst the gauged Hunter River EC averages around 500 uS/cm at Denman.

In the short-term, during mine operation, the model simulates a minor increase in groundwater discharge from the bedrock into the alluvium (see Section 5.3.2). This could potentially result in localised areas of changed groundwater quality in the alluvium. However, it is considered an insignificant risk because:

- It is a short-lived impact;
- It only affects small localised areas of the alluvial aquifer; and
- It is unlikely to alter the beneficial use of groundwater in these areas, as:
    - Groundwater around the alluvial margins is of similar quality to that of the porous rock aquifer (see Section 2.6.2); and

- The rates of increased Permian groundwater discharge into the alluvium are very low (around 5 ML/year maximum increase from approximately 1023 ML/year total baseline Permian discharge, i.e. around 0.5%).

There are therefore no significant simulated risks of reduced beneficial uses of the Hunter Alluvium or the Hunter River as a result of the Project.

5.9 OTHER IMPACTS OF MINING

For the highly productive water source of the Hunter Alluvium, the AI Policy requests that:

- There be no mining activity below the ground surface within 200 m laterally from the high bank, or 100 m vertically beneath the alluvial water source (whichever is the lesser); and
- Not more than 10% cumulatively of the three dimensional extent of the alluvial material to be excavated by mining activities beyond 200 m laterally from the high bank, or 100 m vertically beneath the alluvial water source.

The proposed underground mining would be more than 100 m below the ground surface. At its closest point, the Hunter river channel is located more than 200 m (approximately 550 m) from the northwestern limit of EL7429. No alluvial material will be excavated.

Consequently, neither of the above criteria is compromised by the proposed mining activity.

5.10 SUMMARY OF ASSESSMENT IN TERMS OF THE AQUIFER INTERFERENCE POLICY

Table 13 and Table 14 summarise the preceding discussion of potential impacts of the Project in terms of the AI Policy Minimal Impact Considerations.

Given the simulated potential impacts on existing groundwater users' bores within the Permian strata, the Project falls within the AI Policy Level 2 classification of the minimal impact considerations for less productive groundwater and Level 1 classification for highly productive groundwater. No minimal impact considerations other than exceeding the 2 m drawdown criteria at existing bores in the Permian rock have been identified in this assessment.

As such, the Project will require risk mitigation, prevention or avoidance strategies to be identified in this preliminary groundwater assessment. A Groundwater Management Plan will require development and approval. This will need to define a groundwater monitoring strategy, groundwater level triggers, and a trigger exceedance action plan.

It is recommended that the Project instate a groundwater monitoring network designed to monitor for the potential drawdown risks to existing users' water works.

Furthermore, the Project will require a volumetric take (total mine inflow) metering program. These water takes should be reported on an annual basis to the NOW, and periodically used, in conjunction with the monitoring network data, to verify the numerical modelling and the potential risks of mining activity identified in this assessment. This should include revision of the modelling and identified risks as required.

The simplest means of addressing and managing the identified potential bore impacts is to 'make good' on the impacted users' water sources. SHM is committed to this 'make good' process. This could involve deepening and/or replacing bores and wells, and/or providing an alternative water source to affected users (possibly derived from mine inflows). Before such a process is instigated it is recommended that all water works identified as being potentially adversely affected in this assessment are surveyed for their existence, location, use, and construction details. Subsequent to this, remedial action can be planned and undertaken as required.

Table 13 Summary of AI Policy Assessment – Hunter Alluvium

Aquifer	Alluvial aquifer (Hunter Unregulated and Alluvial Water Sources)	
Category	Highly Productive	
Level 1 Minimal Impact Consideration		**Assessment**
Water Table Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan. **OR** A maximum of a 2 m water table decline cumulatively at any water supply work.		At the time of writing there were no Culturally Significant Sites or high priority GDEs in the study area listed in the relevant Water Sharing Plan, i.e. 'Hunter Unregulated and Alluvial Water Sources' (version current for 8 March 2013). Hence there are no known risks of mine development to such sites. No drawdown in excess of the criterion within the Hunter Alluvium. **Level 1 minimal impact consideration classification.**
Water pressure A cumulative pressure head decline of not more than 40% of the "post-water sharing plan" pressure head above the base of the water source to a maximum of a 2m decline, at any water supply work.		N/A (only unconfined conditions in alluvial aquifer).
Water quality Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity. No increase of more than 1% per activity in long-term average salinity in a highly connected surface water source at the nearest point to the activity. No mining activity to be below the natural ground surface within 200m laterally from the top of high bank or 100m vertically beneath (or the three dimensional extent of the alluvial water source - whichever is the lesser distance) of a highly connected surface water source that is defined as a "reliable water supply". Not more than 10% cumulatively of the three dimensional extent of the alluvial material in this water source to be excavated by mining activities beyond 200m laterally from the top of high bank and 100m vertically beneath a highly connected surface water source that is defined as a "reliable water supply".		Mining is predicted to induce leakage of surface water into the Hunter Alluvium. This will, if anything, have a beneficial impact on EC of the alluvial aquifer. There are therefore no simulated risks of reduced beneficial uses of the Hunter Alluvium as a result of the Project. Nor is there any predicted increase in the salinity of the Hunter River. No proposed mining activity within these specified proximities to the Hunter Alluvium. No proposed excavation of alluvial material proposed. **Level 1 minimal impact consideration classification.**

Table 14 Summary of AI Policy Assessment – Permian Porous Rock

Aquifer	Permian (Sydney Basin) Porous rock (Hunter Extraction Management Unit / Jerrys Management Zone)	
Category	Less Productive	
Level 1 Minimal Impact Consideration		**Assessment**
Water Table Less than or equal to a 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40 m from any: (a) high priority groundwater dependent ecosystem; or (b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan. **OR** A maximum of a 2 m water table decline cumulatively at any water supply work.		At the time of writing there were no Culturally Significant Sites or high priority GDEs known in the study area or listed in Water Sharing Plans for the area, i.e. 'Hunter Unregulated and Alluvial Water Sources' (version current for 8 March 2013). Hence there are no known risks of mine development to such sites. Drawdown in excess of the water supply work drawdown criterion (2 m) within the Permian strata. **Level 2 minimal impact consideration classification.**
Water pressure A cumulative pressure head decline of not more than a 2m decline, at any water supply work.		Drawdown in excess of the criterion (2 m) within the Permian strata at private water supply works. **Level 2 minimal impact consideration classification.**
Water quality Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity.		Mining-induced changes to the hydraulic properties and depressurisation of the strata in the mined area will result in mixing of potentially chemically different groundwater between overlying and underlying units. However, it is considered unlikely that this will result in changes to the beneficial uses of groundwater in the Permian rock units in or around the exploration licence. The risk of these impacts decreases with distance from the active mining area and enhanced rock mass fracturing. **Level 1 minimal impact consideration classification.**

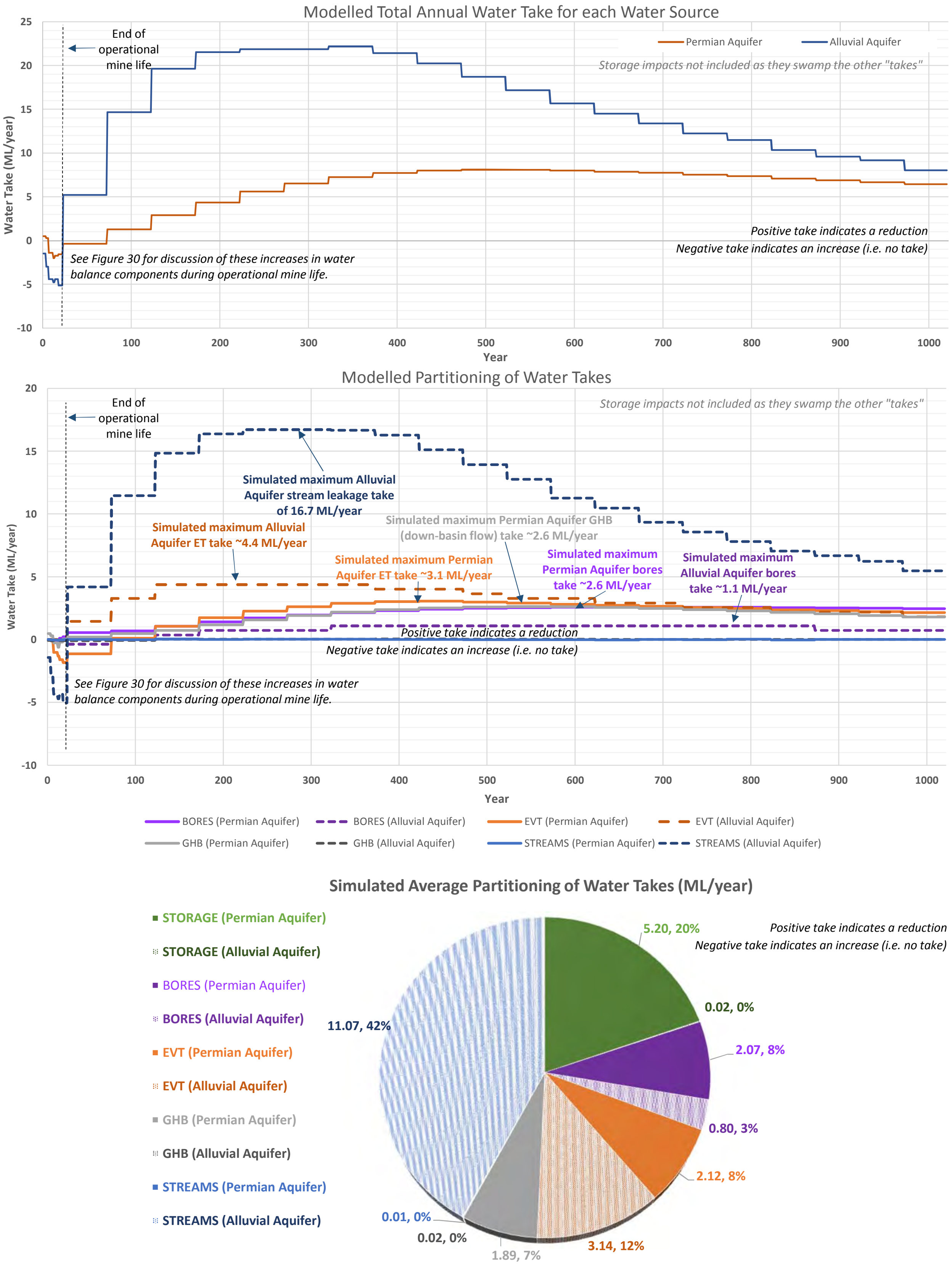
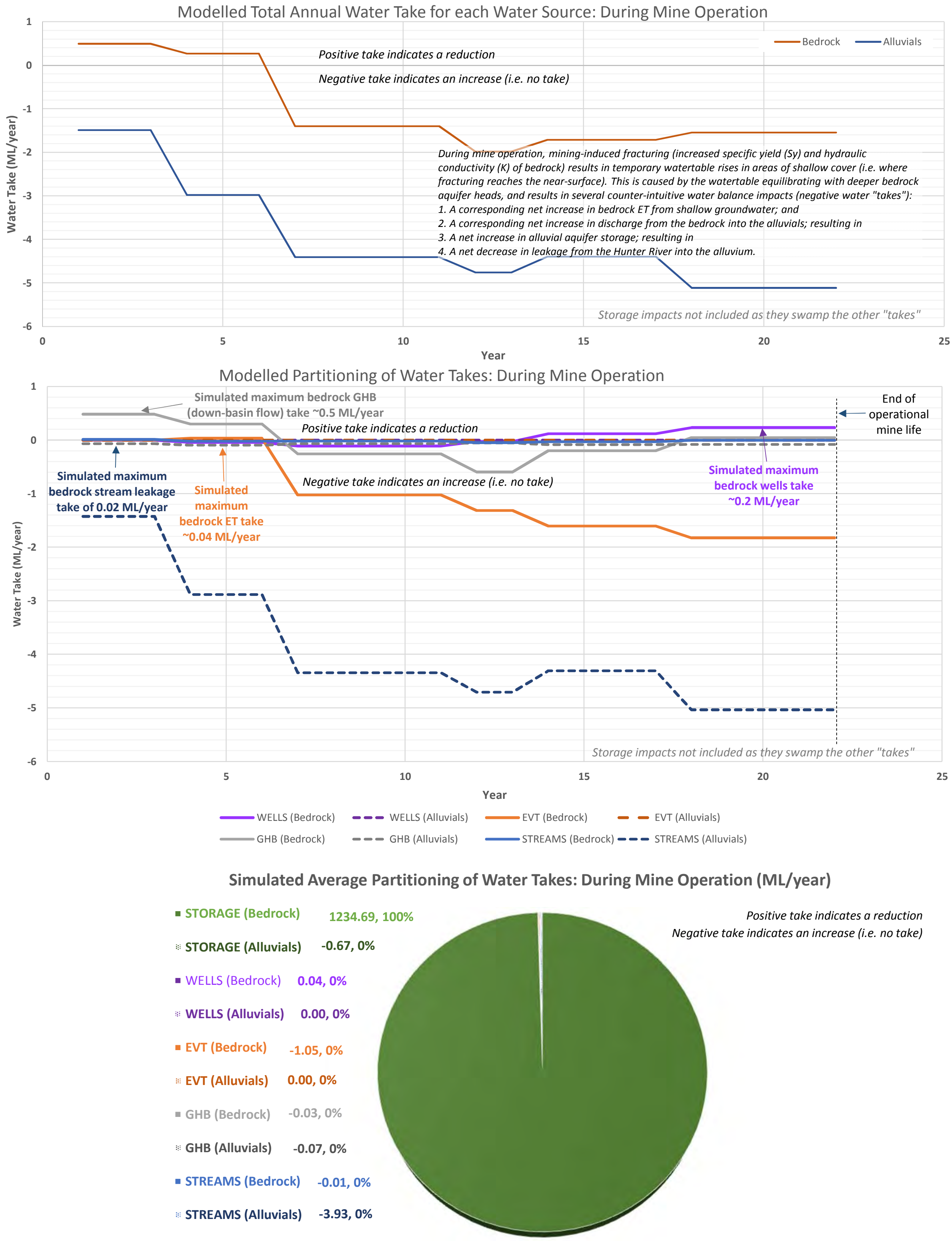
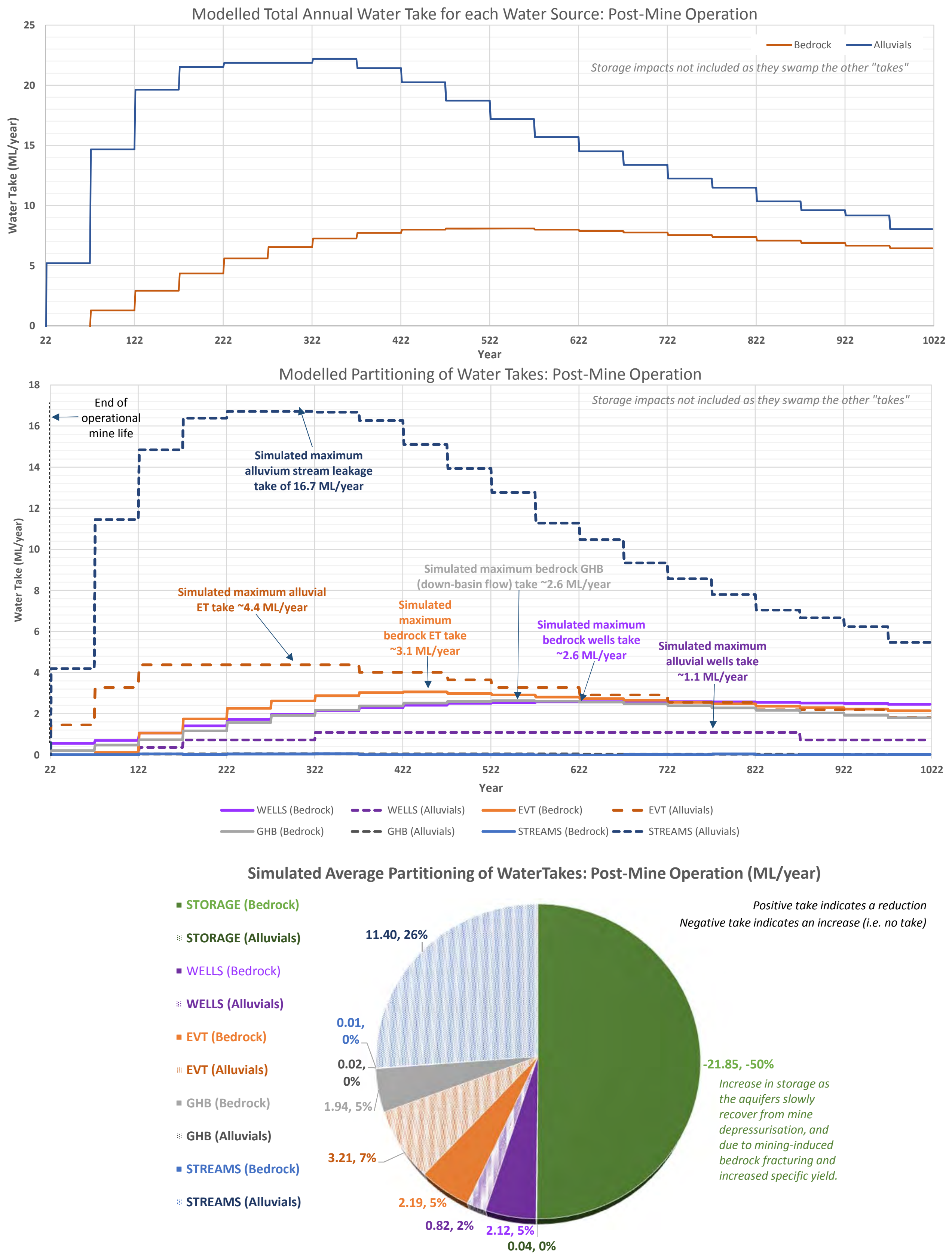


Figure 29 Modelled Total Annual Water Takes



HYDROSIMULATIONS

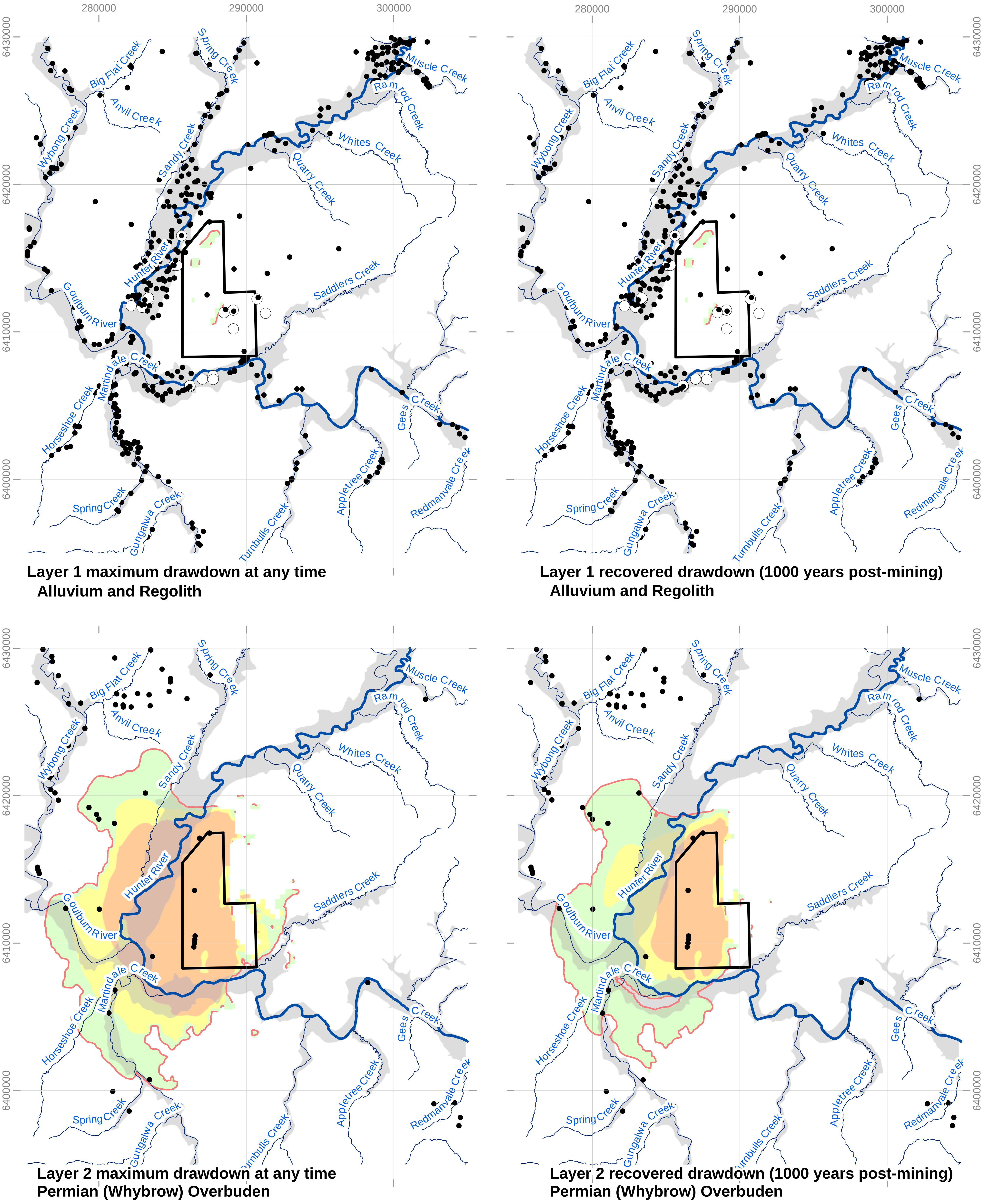
Figure 30 Modelled Total Annual Water Takes: During Mine Operation



HYDRO SIMULATIONS

Figure 31 Modelled Total Annual Water Takes: Post-Mine Operation

D:\Heritage\Spur_Hill\GWModel\SHv02TR\Processing\Prediction\Budget\SHv02TR010v2zbud_out.xlsxSHv02TR010v2zbud_out.xlsx (Figure 31)



Layer 1 maximum drawdown at any time
Alluvium and Regolith

Layer 1 recovered drawdown (1000 years post-mining)
Alluvium and Regolith

Layer 2 maximum drawdown at any time
Permian (Whybrow) Overbuden

Layer 2 recovered drawdown (1000 years post-mining)
Permian (Whybrow) Overbuden

Legend

- NOW Registered Bores
- Census Bores
- 2m Drawdown Contour
- Watercourse
- Exploration Lease 7429
- Alluvials

Maximum Drawdown (metres)

- 0 - 2
- 2.01 - 5
- 5.01 - 10
- 10.1 - 100
- 101 - 251

Spur Hill Management
Spur Hill Underground Coal

Figure 32

Simulated Drawdown and Recovery Model Layers 1 and 2

DrawingNo: SHC002-013
Rev: D.
Created by: CNicol
Date: 20/11/2013.

Scale: 250,000 at A3
GDA 1994 MGA Zone 56

0 1.25 2.5 5 7.5 10 Kilometers

HYDROSIMULATIONS

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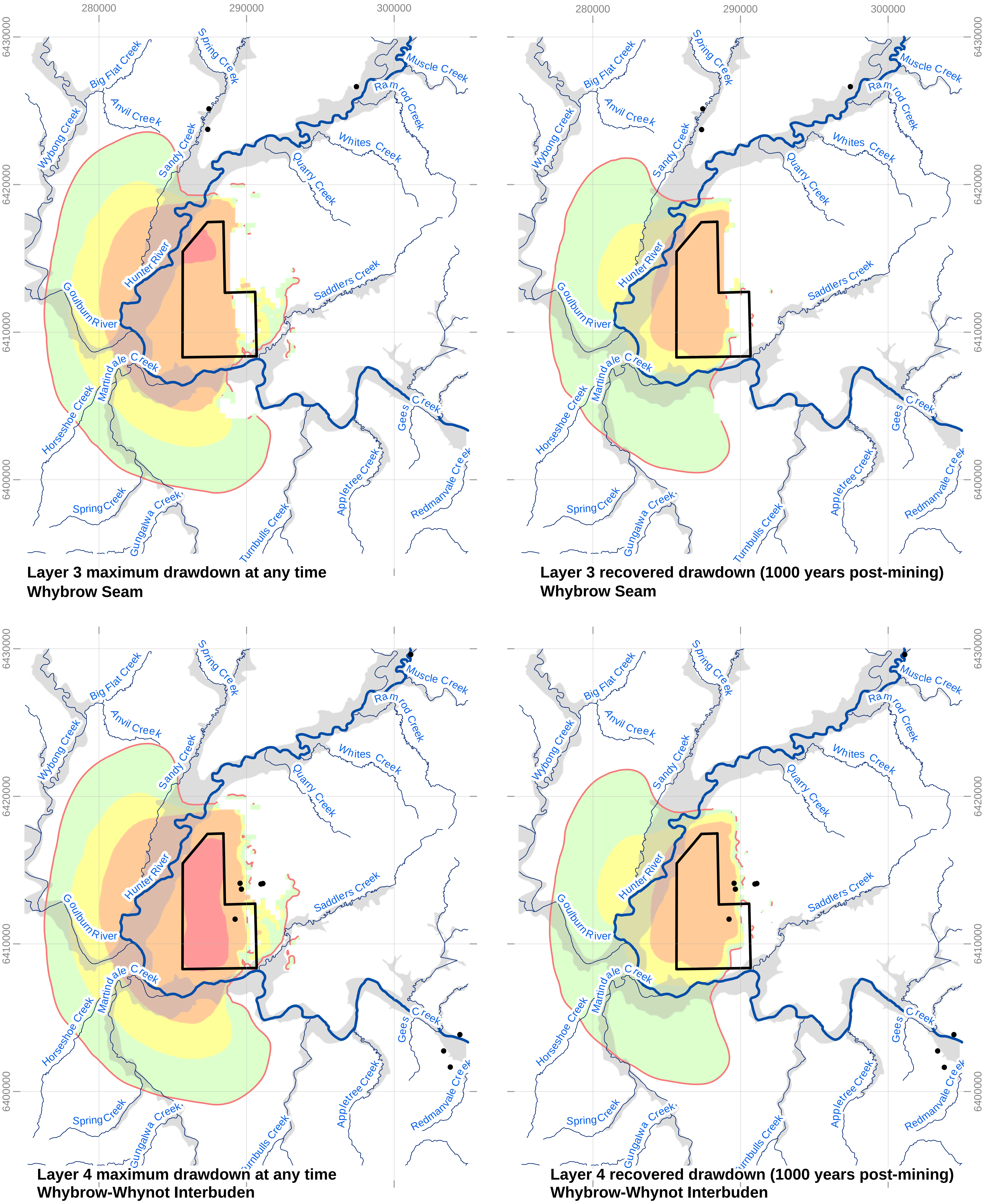

Legend

• NOW Registered Bores	Alluvials	2.01 - 5
2m Drawdown Contour	**Maximum Drawdown (metres)**	5.01 - 10
Watercourse		10.1 - 100
Exploration Lease 7429	0 - 2	101 - 251

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DrawingNo: SHC002-014
Rev: C.
Created by: CNicol
Date: 16/11/2013.

HYDROSIMULATIONS

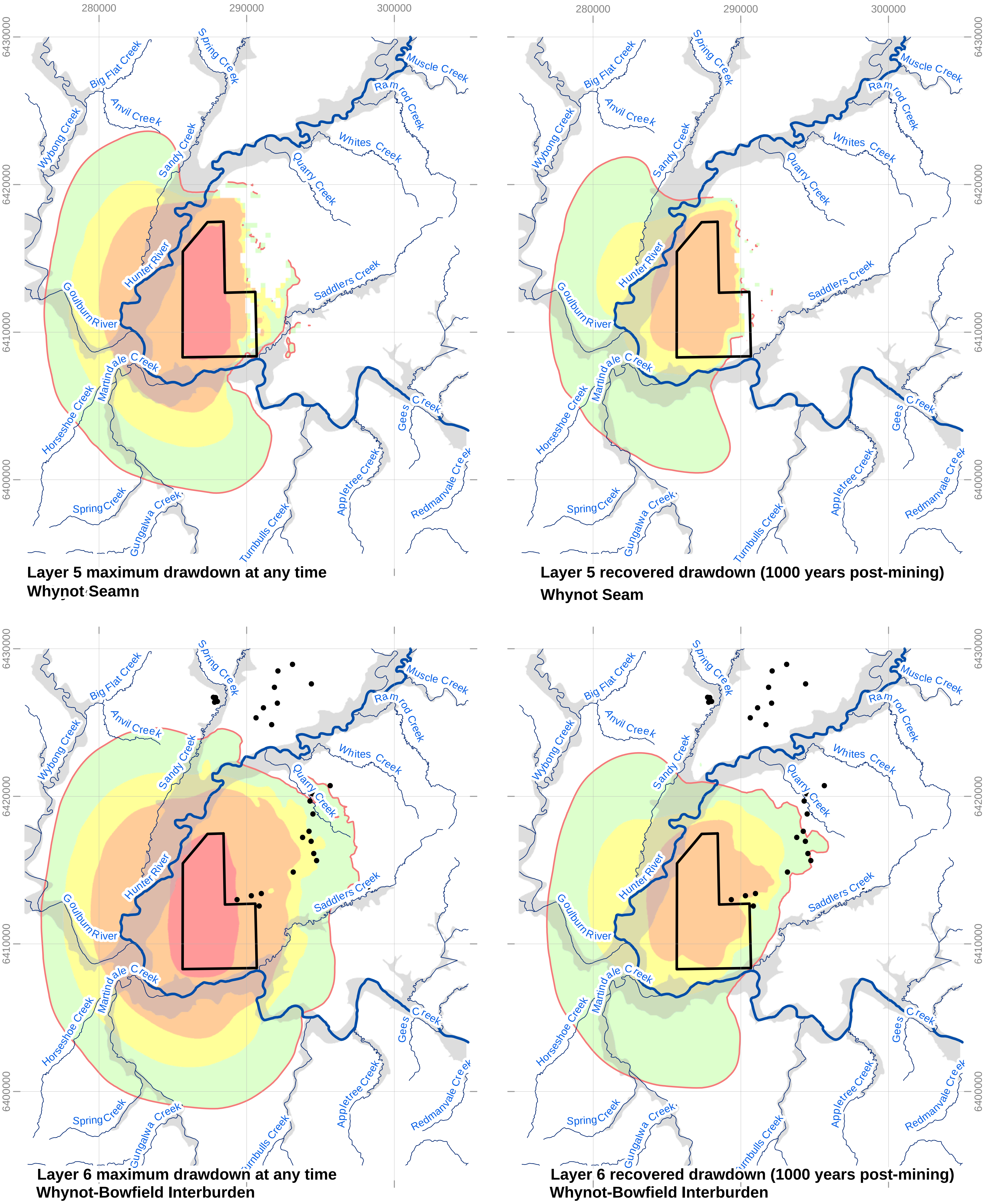
Spur Hill Management
Spur Hill Underground Coal

Figure 33

Simulated Drawdown and Recovery Model Layers 3 and 4

Scale: 250,000 at A3
GDA 1994 MGA Zone 56

0 1.25 2.5 5 7.5 10 Kilometers



Spur Hill Management

Spur Hill Underground Coal

Legend

• NOW Registered Bores	Alluvials	2.01 - 5
2m Drawdown Contour	**Maximum Drawdown (metres)**	5.01 - 10
Watercourse		10.1 - 100
Exploration Lease 7429	0 - 2	101 - 251

Figure 34

Simulated Drawdown and Recovery Model Layers 5 and 6

DrawingNo: SHC002-015
Rev: C.
Created by: CNicol
Date: 16/11/2013.

HYDROSIMULATIONS

Scale: 250,000 at A3
GDA 1994 MGA Zone 56

0 1.25 2.5 5 7.5 10 Kilometers

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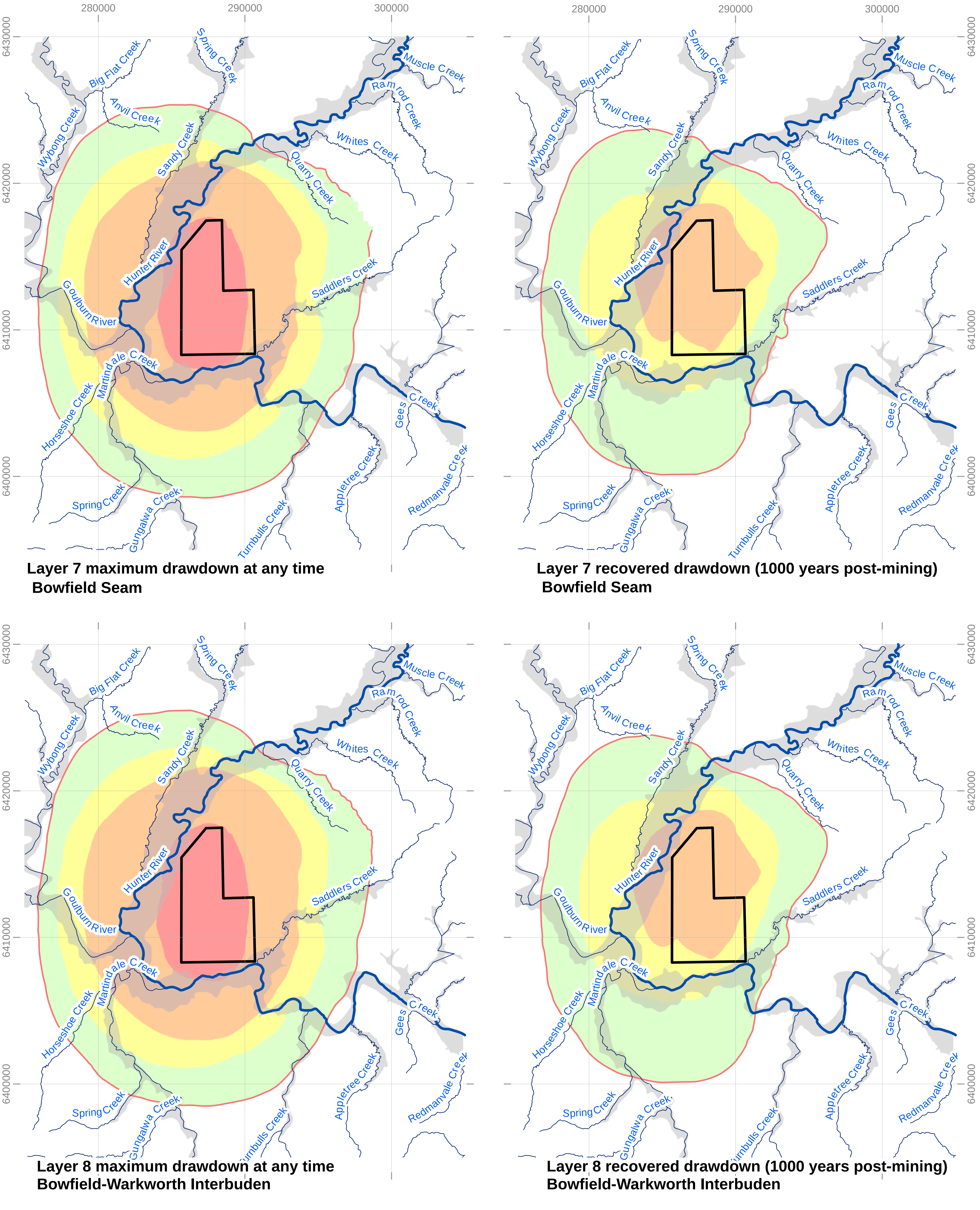

Spur Hill Management
Spur Hill Underground Coal

Legend

- NOW Registered Bores
- 2m Drawdown Contour
- Watercourse
- Exploration Lease 7429
- Alluvials

Maximum Drawdown (metres)

- 0 - 2
- 2.01 - 5
- 5.01 - 10
- 10.1 - 100
- 101 - 251

Figure 35

Simulated Drawdown and Recovery Model Layers 7 and 8

DrawingNo: SHC002-016
Rev: C.
Created by: CNicol
Date: 16/10/2013.

HYDROSIMULATIONS

Scale: 250,000 at A3
GDA 1994 MGA Zone 56

0 1.25 2.5 5 7.5 10 Kilometers

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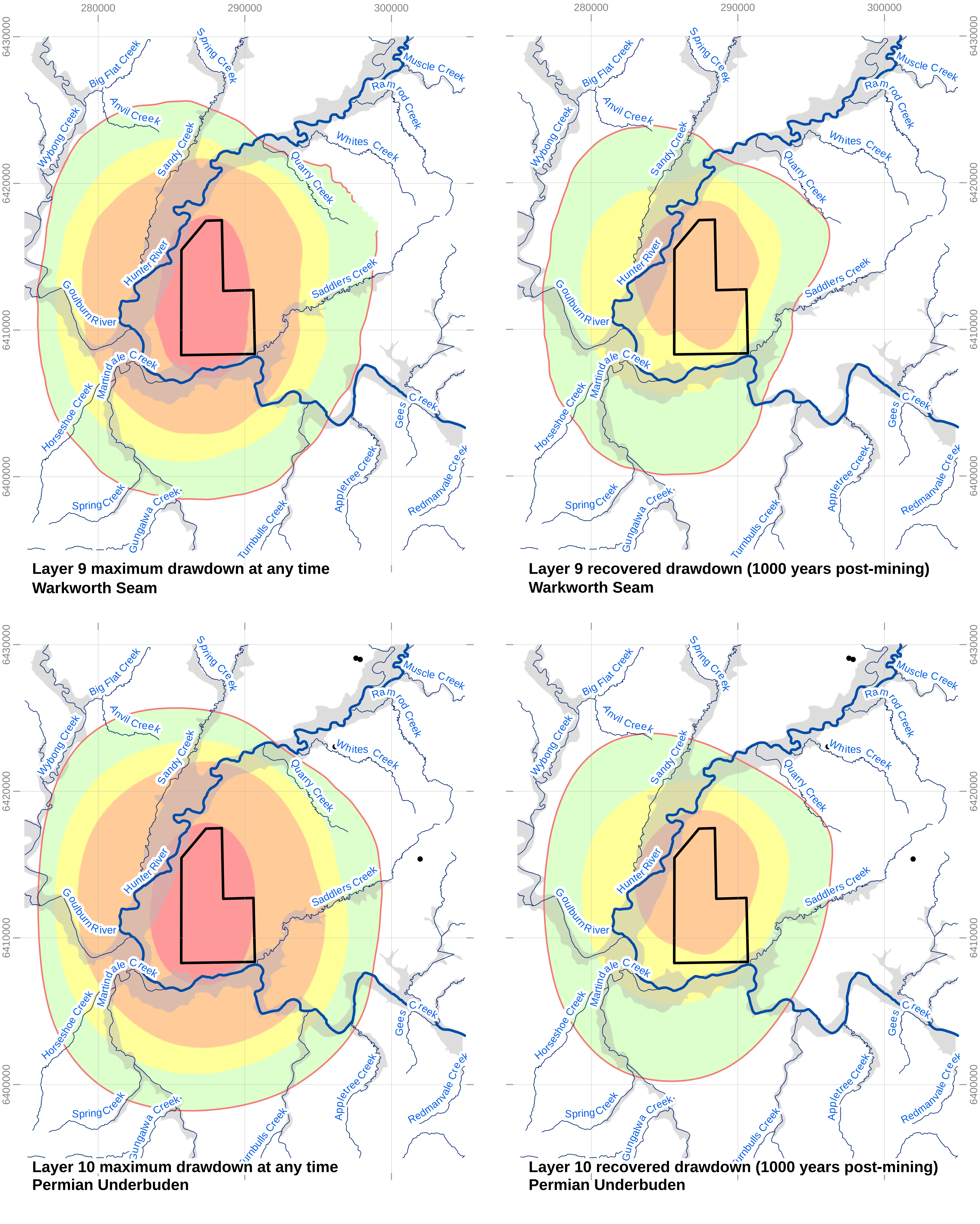

Layer 9 maximum drawdown at any time
Warkworth Seam

Layer 9 recovered drawdown (1000 years post-mining)
Warkworth Seam

Layer 10 maximum drawdown at any time
Permian Underbuden

Layer 10 recovered drawdown (1000 years post-mining)
Permian Underbuden

Legend

● NOW Registered Bores	Alluvials		2.01 - 5
2m Drawdown Contour	**Maximum Drawdown (metres)**		5.01 - 10
Watercourse			10.1 - 100
Exploration Lease 7429	0 - 2		101 - 251

Spur Hill Management
Spur Hill Underground Coal

Figure 36

Simulated Drawdown and Recovery Model Layers 9 and 10

DrawingNo: SHC002-017
Rev: C.
Created by: CNicol
Date: 16/11/2013.

Scale: 250,000 at A3
GDA 1994 MGA Zone 56

0 1.25 2.5 5 7.5 10 Kilometers

HYDROSIMULATIONS

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6 PREDICTIVE UNCERTAINTY

6.1 UNCERTAINTY IN PREDICTED MINE INFLOWS

Uncertainty in modelled mine inflows has been assessed using the suite of 180 recalibrated predictive model realisations.

The base case inflow is shown in Figure 28. Within 95% confidence limits, inflow rates are predicted to increase from about 0.4-2.6 ML/day (median 1.7 ML/day) at the start of underground mining activities to a peak of about 2.5-5.8 ML/day in years 14-17 (median 3.9 ML/day in year 22).

Over the life of the mine, simulated total inflows are expected to be about 28 GL (median), with a range between about 13 GL and about 40 GL within 95% confidence limits.

6.2 PARTITIONING AND UNCERTAINTY OF SIMULATED MAXIMUM STREAM FLOW IMPACTS

The result of enhanced leakage into the alluvium from the Hunter River (discussed in Sections 4.4 and 5.3) is a reduction in flows in the Hunter River.

The modelling estimates an approximate 75% probability that there will be no appreciable maximum flow impact on the Hunter River (<0.1 ML/day), whilst there is 100% probability of no appreciable maximum flow impact to the Goulburn River and Saddlers Creek, the latter appearing to be a largely ephemeral, runoff-dominated stream. The vast majority of maximum simulated stream flow impact is on the Hunter River (less than 0.3 ML/day at the 95% confidence limit), via mining-induced increases in stream leakage (see Section 5.3.2).

Comparison of the simulated maximum Hunter River flow impact with the stream flow exceedance curve of the Hunter River at Denman gauge (Figure 8) shows that this level of impact is not appreciable: 0.3 ML/day maximum impact, compared to the 99th percentile gauged flow of 32 ML/day derived from around 50 years of gauge records.

It is noted that the Hunter River is a regulated river and any impact on Hunter River flows would be offset by the purchase of adequate licences.

6.3 UNCERTAINTY IN SIMULATED IMPACTS ON GROUNDWATER LEVELS

In model layers 1 through 4, the 95% confidence limit 2 m drawdown contour is no more than 1-3 km broader than the ‘best estimate’ 2 m drawdown contour. In the deeper model layers the 2 m drawdown contour uncertainties become larger, particularly where drawdowns do not significantly intersect the model boundaries (to the south, north and east). The expansion of the drawdown extent is generally 1-6 km.

Given that the majority of existing groundwater users extract water from model layer 1 (the Hunter Alluvium), these uncertainties are considered to be of limited concern. This is assessed in greater detail in the following subsection.

6.4 UNCERTAINTY IN POTENTIAL IMPACTS ON EXISTING GROUNDWATER USERS

The number of privately-owned bores in use that are cumulatively impacted in excess of the drawdown criterion within 95% confidence limits is 24, as opposed to 12 based upon the optimally calibrated model. Most of these additionally impacted bores are located to the northeast of the Project area, around Mt Arthur mine (mostly intersecting model layer 6).

The location and predicted drawdown on privately-owned bores would be refined as part of the EIS modelling process.

7 LICENSABLE WATER TAKES

Table 15 presents the indicative Project groundwater licensing summary, which is based upon the base model simulated water balance impacts presented and discussed in Sections 4.4, 4.5 and 5.3.

Table 15 Project Groundwater Licensing Summary

Water Sharing Plan	Management Zone/ Water Source	Predicted Interim Annual Water Takes requiring Licensing (ML/year)	
		During Mine Operation	Post-Mine Operation
Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009	Hunter Regulated River Alluvial Water Source	Avg. 0 Max. 0	Avg. 4 Max. 6
Water Sharing Plan for the Hunter Regulated Water Source 2003	Hunter River Management Zone 1	Avg. 0 Max. 0	Avg. 11 Max. 17
Water Act 1912	Porous Rock (Hunter Extraction Management Unit / Jerrys Management Zone)	Avg. 1230^ (Drain (mine) inflow) Max. 1750#	Avg. 0.01 (reduced baseflow) Max. 0.05

Notes: ^ The median of the uncertainty simulations is 1260 ML/year.
The median of the uncertainty simulations is 1450 ML/year.

The Gateway Application is required to include a strategy for obtaining appropriate water licences based on the initial estimate of water take. It is therefore appropriate to consider whether the initial estimates of water take indicate that there are sufficient water licences on hand or on the open market to an order of magnitude. These licence volumes would be refined as part of the EIS model predictions.

SHM would ensure that prior to the commencement of mining operations it holds the appropriate licences for the predicted EIS water take.

SHM currently holds aquifer access licences (WAL 18196 and WAL 18201) under Part 2 of the *Water Management Act 2000*, which have a combined entitlement of 125 unit shares under the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009*. SHM also holds regulated river (general security) licences (WAL 1143, WAL 1220, WAL 770 and WAL 771) under Part 2 of the *Water Management Act 2000*, which have a combined entitlement of 1,222 unit shares under the *Water Sharing Plan for the Hunter Regulated River Water Source 2003*. SHM holds regulated river (high security) licence WAL 769 with an entitlement of 3 unit shares.

It is considered by HydroSimulations that these licences would be adequate to account for the potential take of water from the alluvial aquifer associated with the Project. The predicted take would be refined during the development of the EIS and over the progression of the Project life to more accurately predict potential take.

Clause 39 of the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009* includes rules (specifically distance restrictions) for granting water supply works approvals. Relevantly for the Project, the distance restrictions in clause 39 do not apply where:

(a) a hydrogeological study undertaken by the applicant, and assessed as adequate by the NOW, demonstrates that the water supply work will have no more than minimal impacts on the existing licensed taking of water from the water source,

(b) all potentially affected persons in the near vicinity of the water supply work, holding an access licence or having a right to take water under the *Water Management Act 2000*, have been notified by the applicant, and

(c) any approval granted contains conditions setting out a process for remediation in the event that any more than minimal impact on existing extraction from the water source occurs in the future (see clause 39(6)).

The above three listed conditions would be satisfied for the Project, thereby excluding the Project from the restrictions contained in clause 39 of the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009*.

There are no flow classes established for the Hunter Regulated River Alluvial Water Source under the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009.*

There is no embargo on licences in the Hunter EMU under the *Water Act 1912*. SHM will apply for adequate licences for take associated with the porous rock aquifer prior to Project commencement.

8 CONCLUSIONS

The Project Groundwater Model developed for this preliminary groundwater assessment for the Gateway process was designed to address the following:

- Data analysis and conceptualisation of the groundwater system, including assessment of HSUs and their properties, and groundwater recharge and discharge through the flow systems;
- Development of a simple regional-scale 3-dimensional numerical groundwater flow model. This was based on data analysis and development of a conceptual hydrogeological model;
- Steady-state model calibration to observed groundwater level data, using only a single parameter zone for each hydrostratigraphic unit;
- Transient model verification against observed groundwater level fluctuation data;
- Transient prediction for the mine plan conducted with coarse temporal resolution of the extraction schedule, followed by a minimum 100 year simulation of the post-mining recovery period (1000 years post-mining was simulated);
- Preparation of this Preliminary Groundwater Assessment report for inclusion in the Spur Hill Gateway submission documents that includes assessment of potential underground mine groundwater impacts and cumulative impacts with other existing and approved mines in the area associated with the development. This assessment focussed on the criteria specified by the AI Policy and the Gateway process; and
- Proposed measures to avoid, mitigate and/or offset (if necessary) potential impacts on groundwater resources and recommendations for future groundwater monitoring to measure actual impacts on groundwater resources associated with the development.

A review of the data, literature and conceptual hydrogeology associated with other mines in the area, and other hydrogeological studies was carried out as a basis for model development. This was supported by a review of currently available information on geology, rock mass hydraulic properties, neighbouring mine workings and strata geometry for the area. Due consideration was given to the setup and creation of model boundaries and surface water/groundwater interaction processes. Justification for all of the modelling approaches that were used has been given within this report. Care was taken to ensure that hydraulic parameters within the model were maintained within realistic ranges that were based on actual measured data or published information for this region. Recharge rates were based largely on estimates (and model calibration), but the zones and values used within the model reflect the conceptual hydrogeology for the study area.

The Project comprises underground coal mine workings in three seams (Whynot, Bowfield and Warkworth), using the longwall method of extraction. This assessment focussed on the risks of the proposal within the framework of the 'minimal impact considerations' of the AI Policy.

These impacts were to be assessed for the highly productive Hunter Alluvial aquifer, and the less productive Permian (Sydney Basin) porous rock aquifer.

The key findings of this assessment are:

- The simulated total annual take of water from the Permian rock aquifer as mine inflows is derived from a range of depletion sources.
- The post-mining average total water take from the Hunter River and Alluvium is 15.6 ML/year (11.4 from the Hunter River (via induced leakage)). The maximum depletion rate at any point in time from these sources is 22.3 ML/year. During mining, the simulated take from this source is zero.
- The average total water take from the Permian porous rock aquifer during operational mining is 1229 ML/year. The maximum depletion rate at any point in time from this source is 1749 ML/year (during years 14-17 of mine operation). Post-mining, the simulated take from this source is zero.
- The mining-induced leakage of surface water into the Hunter Alluvium would have a beneficial impact on the salinity of the alluvial aquifer. Short-term minor increases in bedrock groundwater flux into the alluvial margins are simulated to occur. However alluvial groundwater quality in these margin areas is similar to that of the bedrock. There are therefore no simulated risks of reduced beneficial uses of the Hunter Alluvium as a result of the Project. Nor is there any predicted increase in the salinity of the Hunter River.
- Mining-induced changes to the hydraulic properties and depressurisation of the Permian porous rock strata will result in mixing of potentially chemically different groundwater between overlying and underlying units. However, it is considered unlikely that this will result in changes to the beneficial uses of groundwater.
- Neither high value GDEs nor culturally significant sites are identified in the relevant water sharing plan. Hence the proposal is not considered a risk to such sites.
- There is no proposed mining activity within the AI Policy's specified proximities to the Hunter Alluvium, nor is there any proposed excavation of alluvial material. Hence the proposal poses no risks in this regard.
- The optimally calibrated model simulates 12 privately-owned bores in use as being impacted upon by the Project in excess of the 2 m drawdown criterion of the AI policy. Accounting for cumulative impacts of surrounding mines by using the simplifying assumption of the Principle of Superposition, the number of impacted bores increases to 13.
- The noted drawdown impacts on the Permian porous rock aquifer mean that the proposal is classified within Level 2 of the AI Policy's minimal impact considerations.
- No minimal impact considerations other than exceeding the 2 m drawdown criteria at existing bores have been identified in this assessment.

- These simulated risks will require monitoring and mitigation measures. The latter will likely comprise deepening and/or replacing bores and wells, and/or providing an alternative water source to affected users. SHM is committed to 'make good' provisions for affected groundwater users.
- A Groundwater Management Plan will require development and approval. This will need to define groundwater level triggers, and a trigger exceedance action plan.

8.1 RECOMMENDATIONS FOR FUTURE WORK

Following determination of the Project's Gateway Application, it is recommended that this preliminary assessment and its supporting numerical model are updated and expanded upon in greater detail for the purposes of a full EIS, as outlined in Table 16. The scope of this (Gateway) model is included for comparison.

Table 16 Proposed Scope for a Full Environmental Impact Assessment

Model Feature	*Gateway Process*	Environmental Impact Statement
Spatial Scale	*Coarse*	Fine
Temporal Scale	*Coarse*	Fine
Model Extent	*30 km x 35 km*	30 km x 35 km
Stratigraphy	*10 Layers*	>10 Layers
Spatial Parameter Variability	*No*	Yes
Steady-State Calibration	*Yes*	Yes
Transient Calibration	*No (verification only)*	Yes
Prediction Period	*22 years*	22 years
Representation of Fractured Zone	*Yes*	Yes
Tracking of First Workings	*No*	Yes
Sensitivity Analysis	*Limited*	Extensive
Uncertainty Analysis	*Extensive*	Limited
Recovery Analysis	*Yes*	Yes
Cumulative Assessment	*Law of Superposition*	Simulation
Mitigation Measures	*No*	Yes
Monitoring Program	*Yes*	Yes
Outputs	*Focused on AI Policy*	Extensive spatial and time-series plots and tables
Licensing Volumes	*Indicative*	Firm recommendations
Software	*MODFLOW-SURFACT*	MODFLOW-SURFACT
Report	*Condensed*	Substantial

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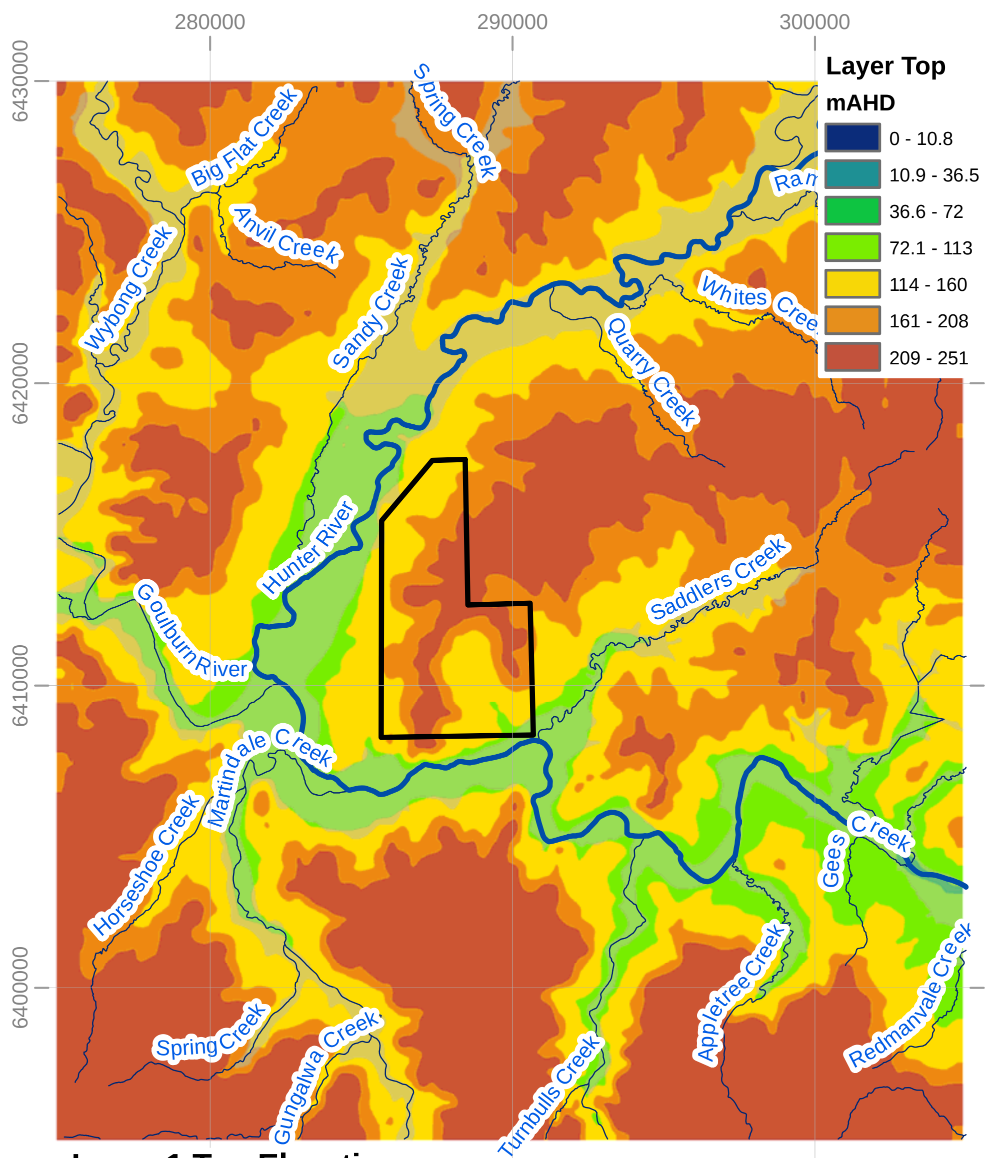
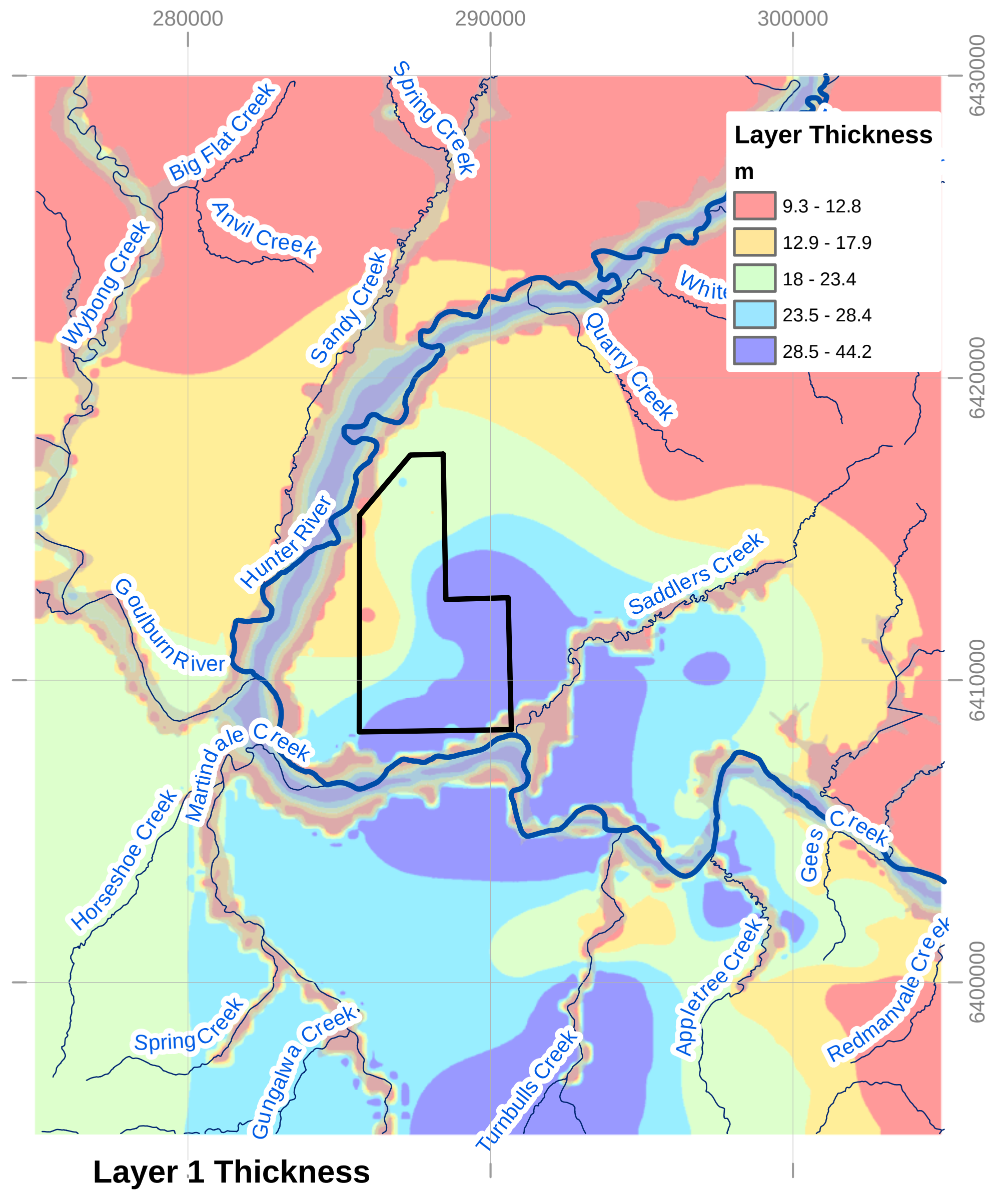
ATTACHMENT A

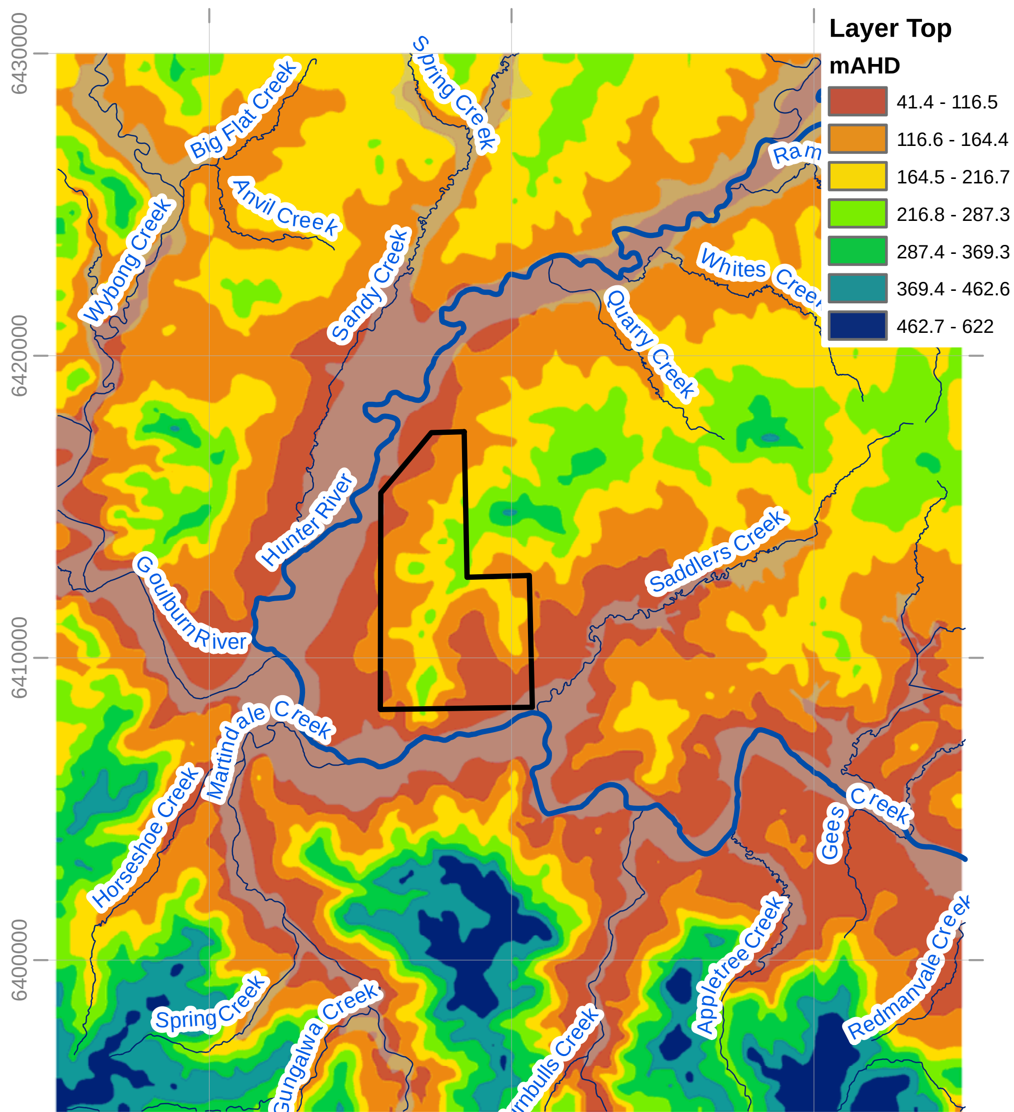
Modelled Geological Surfaces



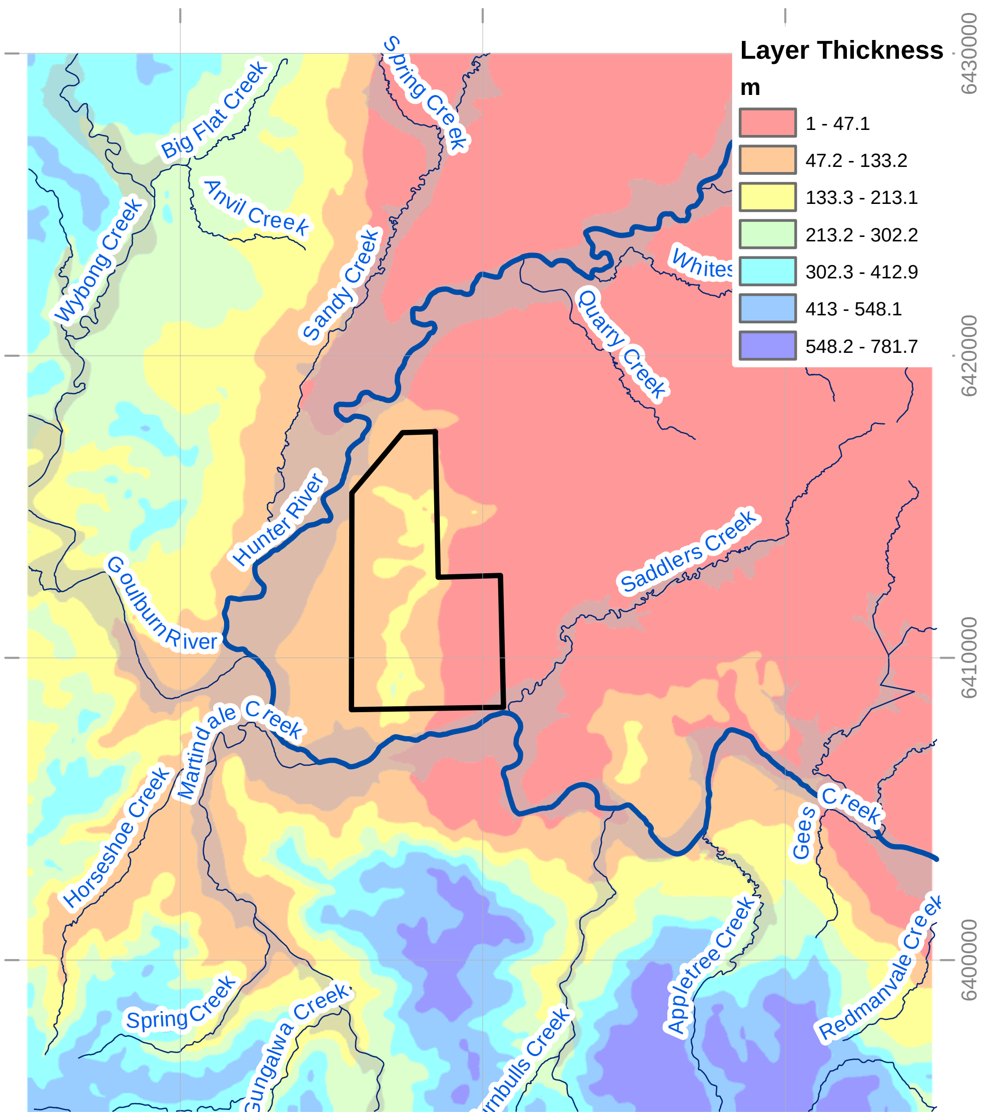
Layer 1 Top Elevation
Alluvium and Regolith



Layer 1 Thickness
Alluvium and Regolith



Layer 2 Top Elevation
Permian (Whybrow) Overbuden



Layer 2 Thickness
Permian (Whybrow) Overbuden

Spur Hill Management
Spur Hill Underground Coal

Figure A1

Tops and Thicknesses
Model Layers 1 and 2

Legend

Watercourse
Alluvials
Spur Hill Mine Lease

DrawingNo: SHC-001-018
Rev: A.
Created by: CNicol
Date: 04/08/2013.

Scale: 250,000 at A3
GDA 1994 MGA Zone 56

0 1.25 2.5 5 7.5 10 Kilometers

HYDROSIMULATIONS

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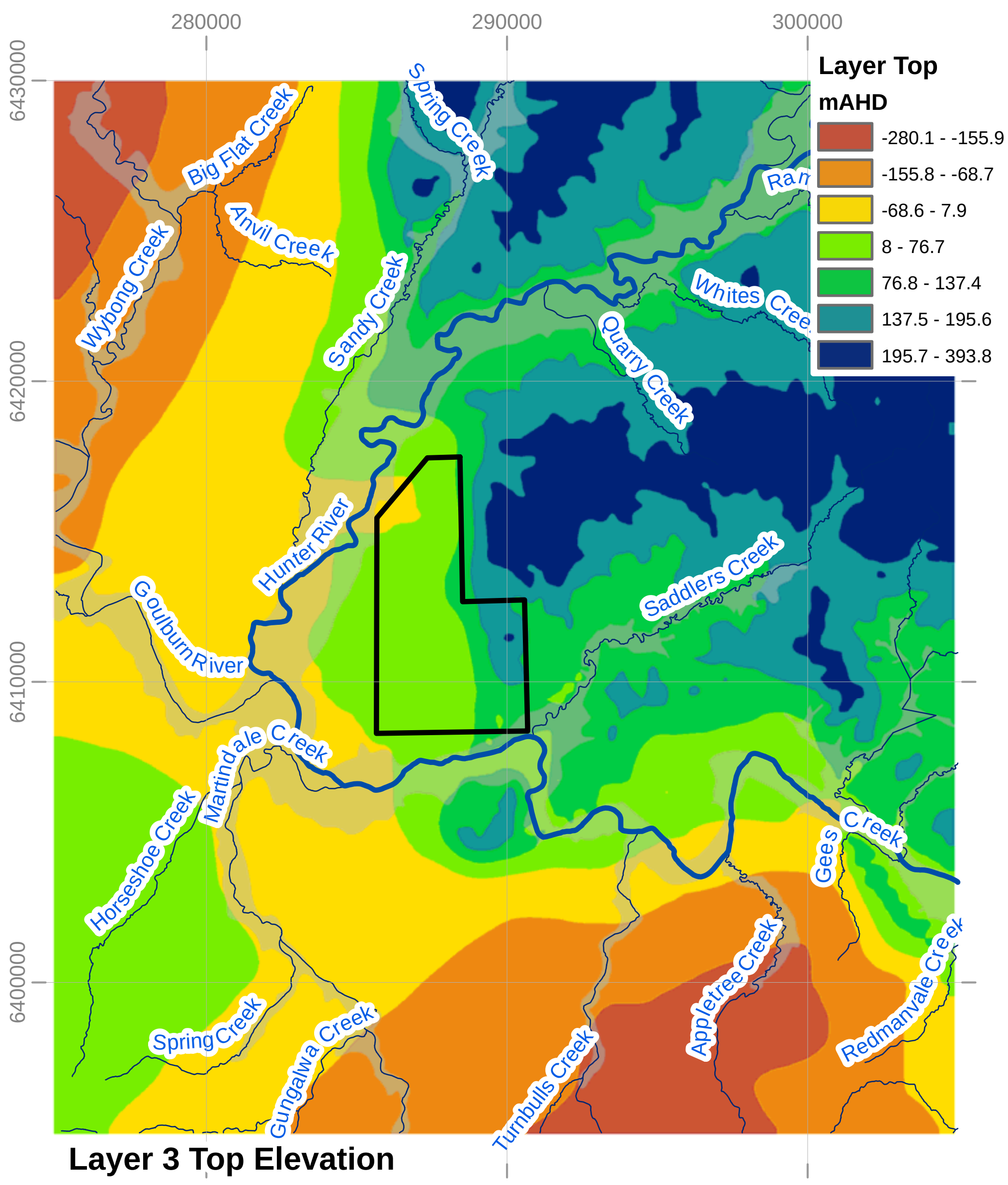
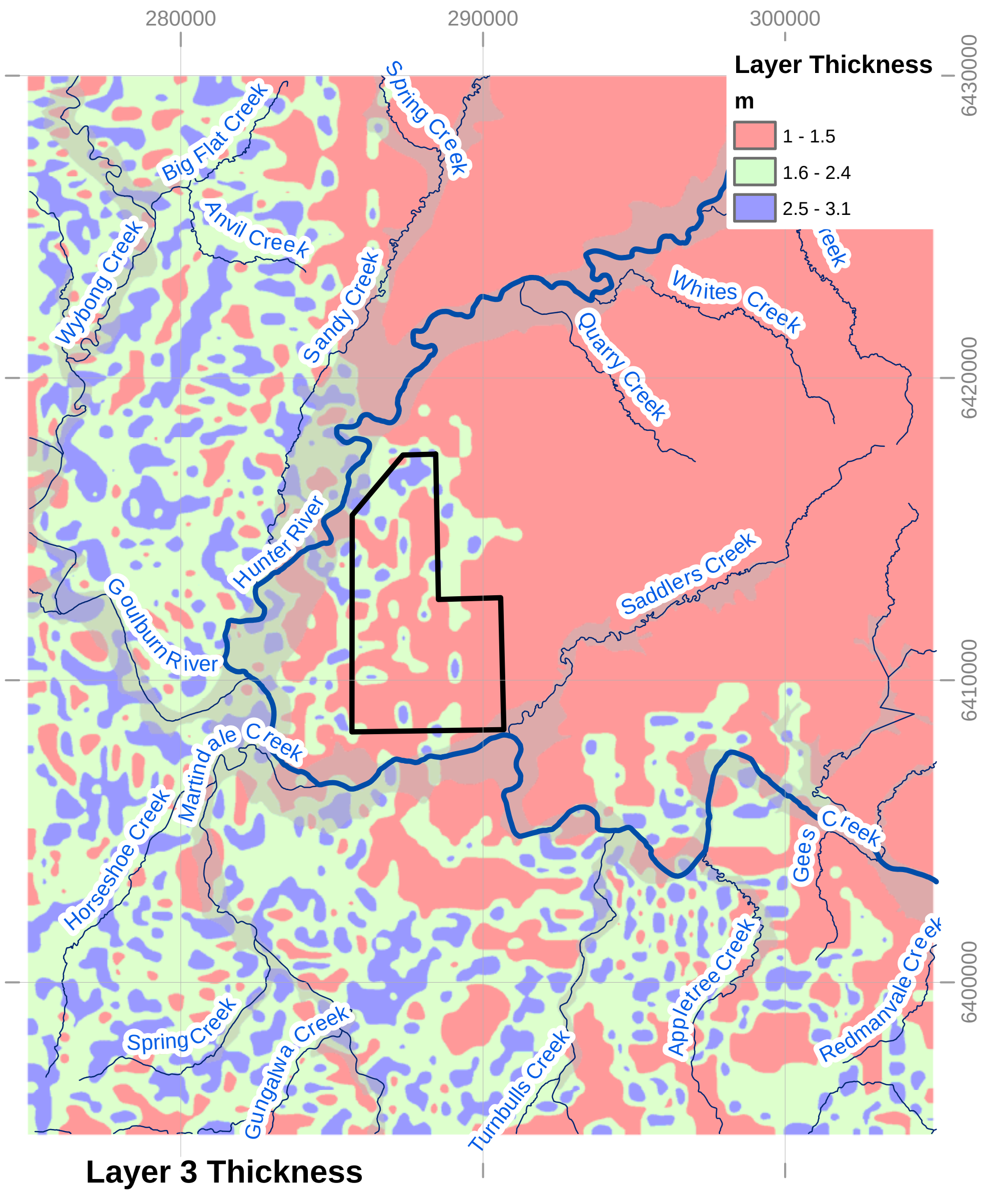
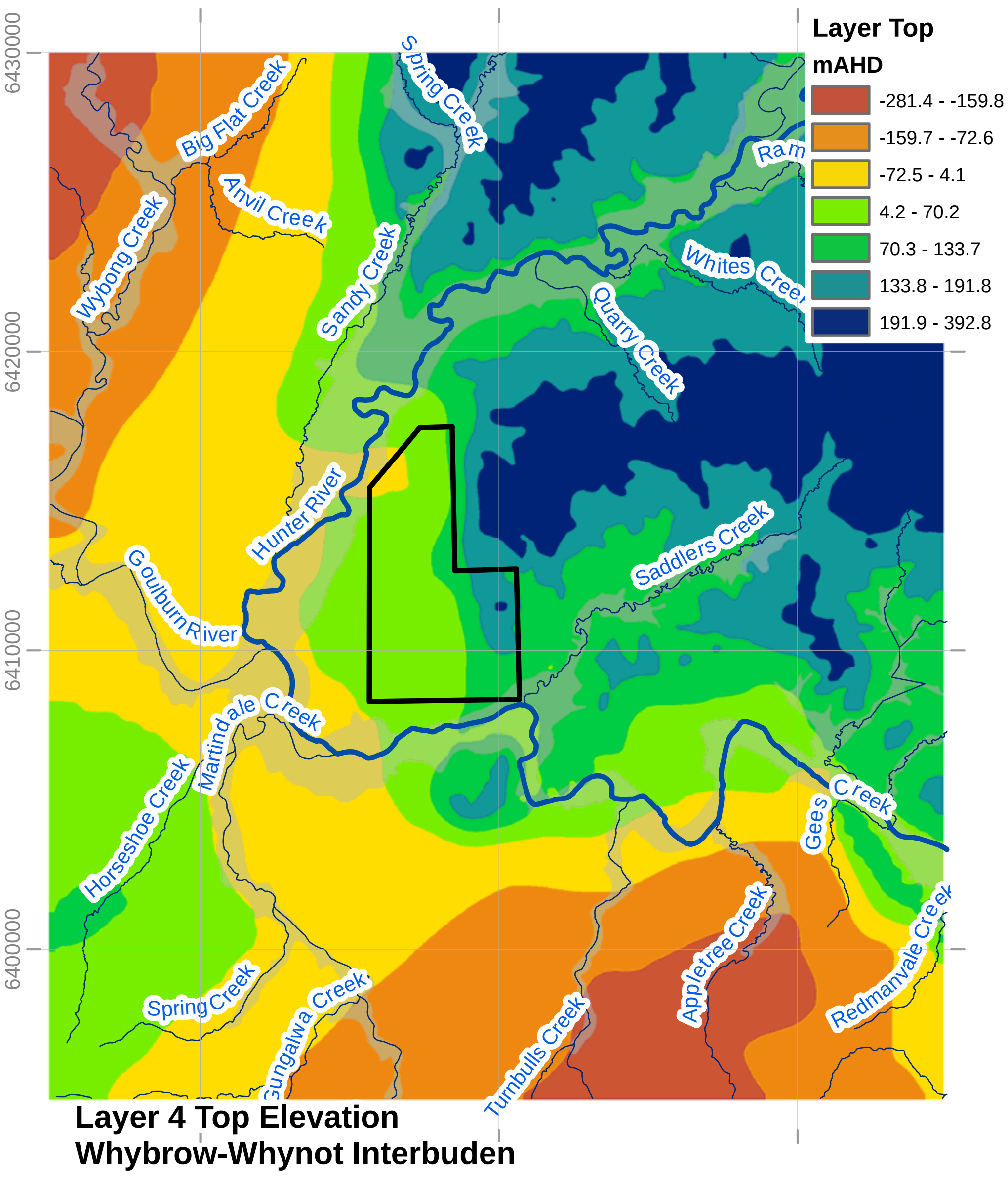


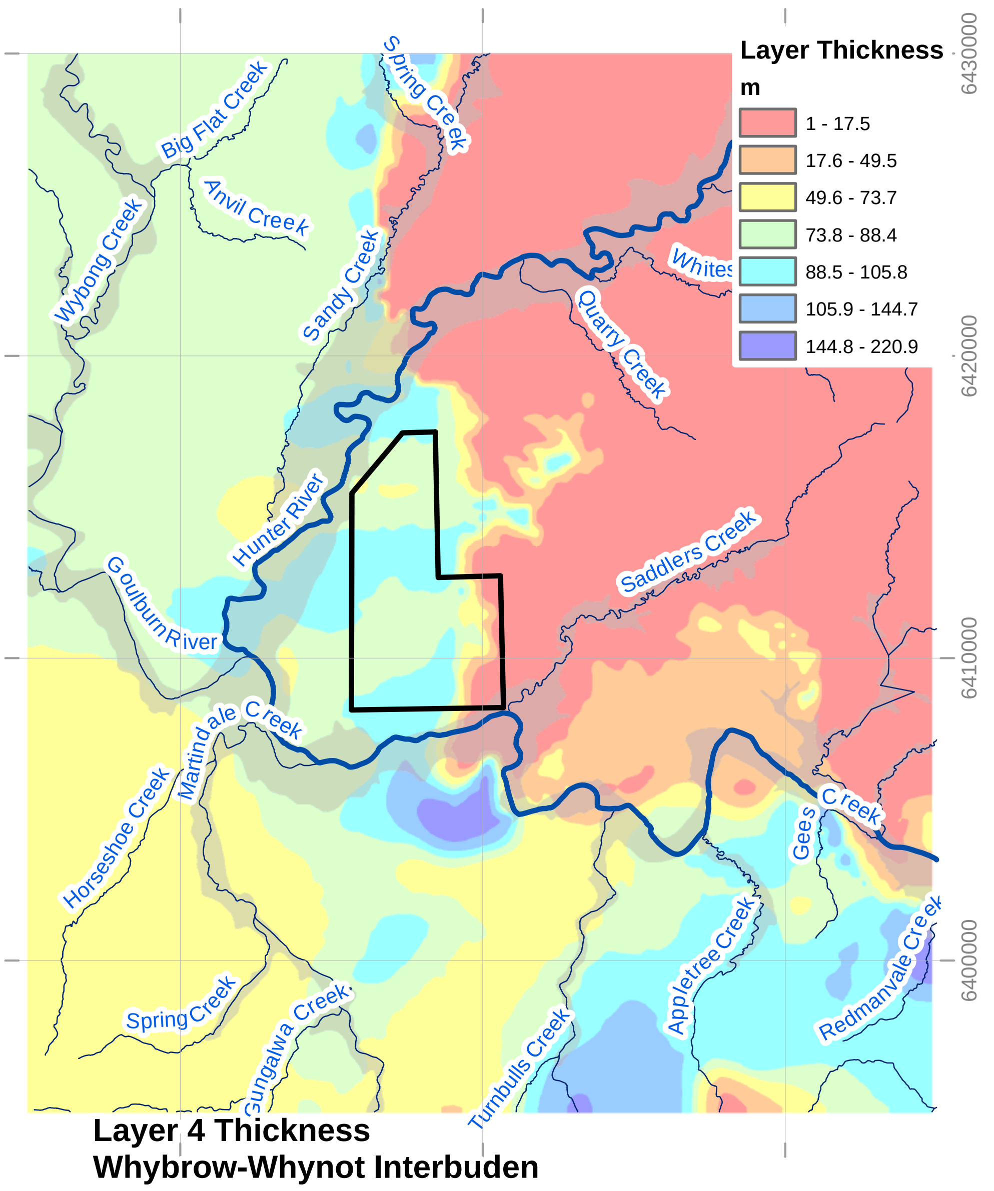
Layer 3 Top Elevation
Whybrow Seam



Layer 3 Thickness
Whybrow Seam



Layer 4 Top Elevation
Whybrow-Whynot Interbuden



Layer 4 Thickness
Whybrow-Whynot Interbuden

Spur Hill Management
Spur Hill Underground Coal

Figure A2

Tops and Thicknesses
Model Layers 3 and 4

Legend

Watercourse
Alluvials
Spur Hill Mine Lease

DrawingNo: SHC-001-019
Rev: A.
Created by: CNicol
Date: 04/08/2013.

Scale: 250,000 at A3
GDA 1994 MGA Zone 56

0 1.252.5 5 7.5 10 Kilometers

HYDROSIMULATIONS

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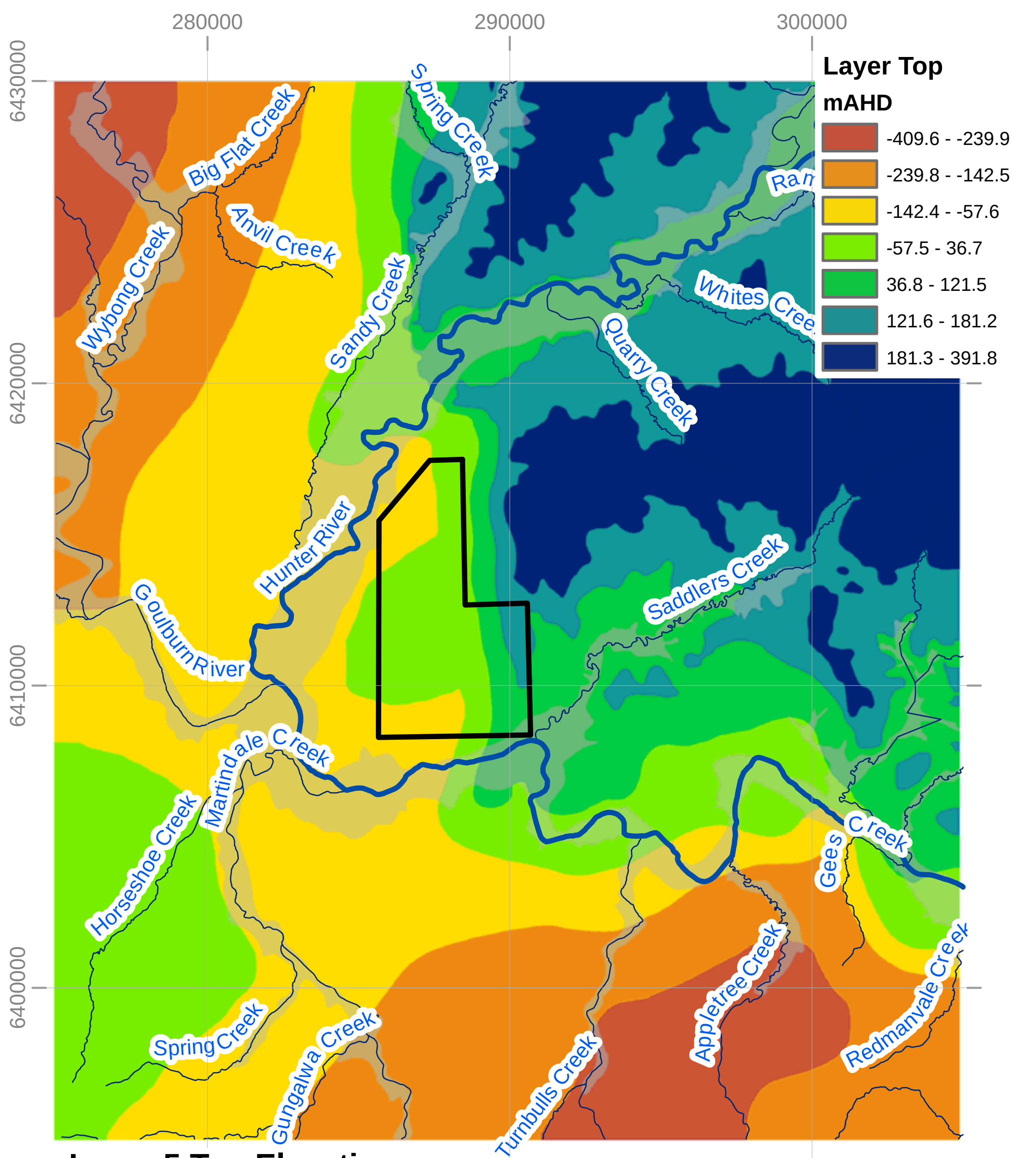
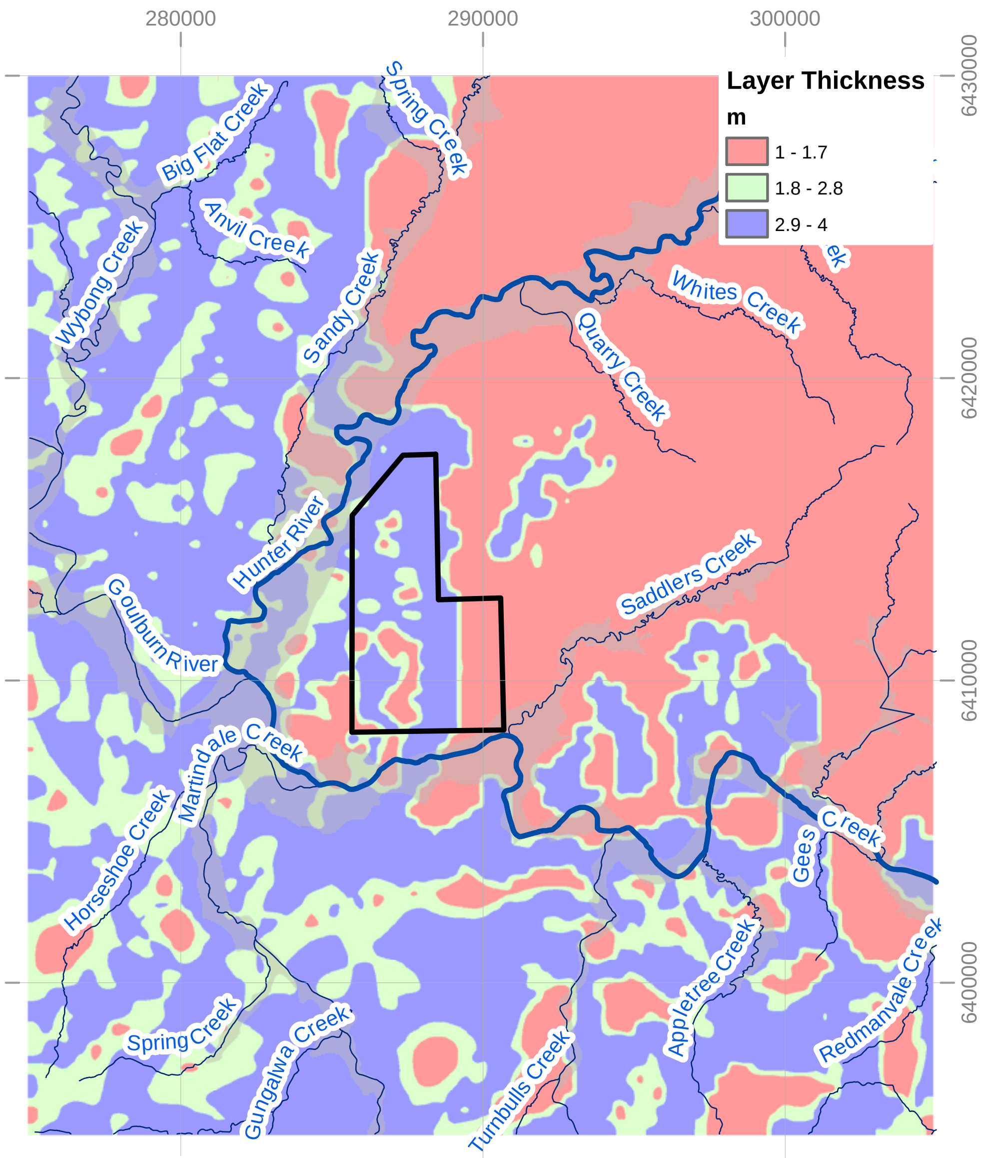
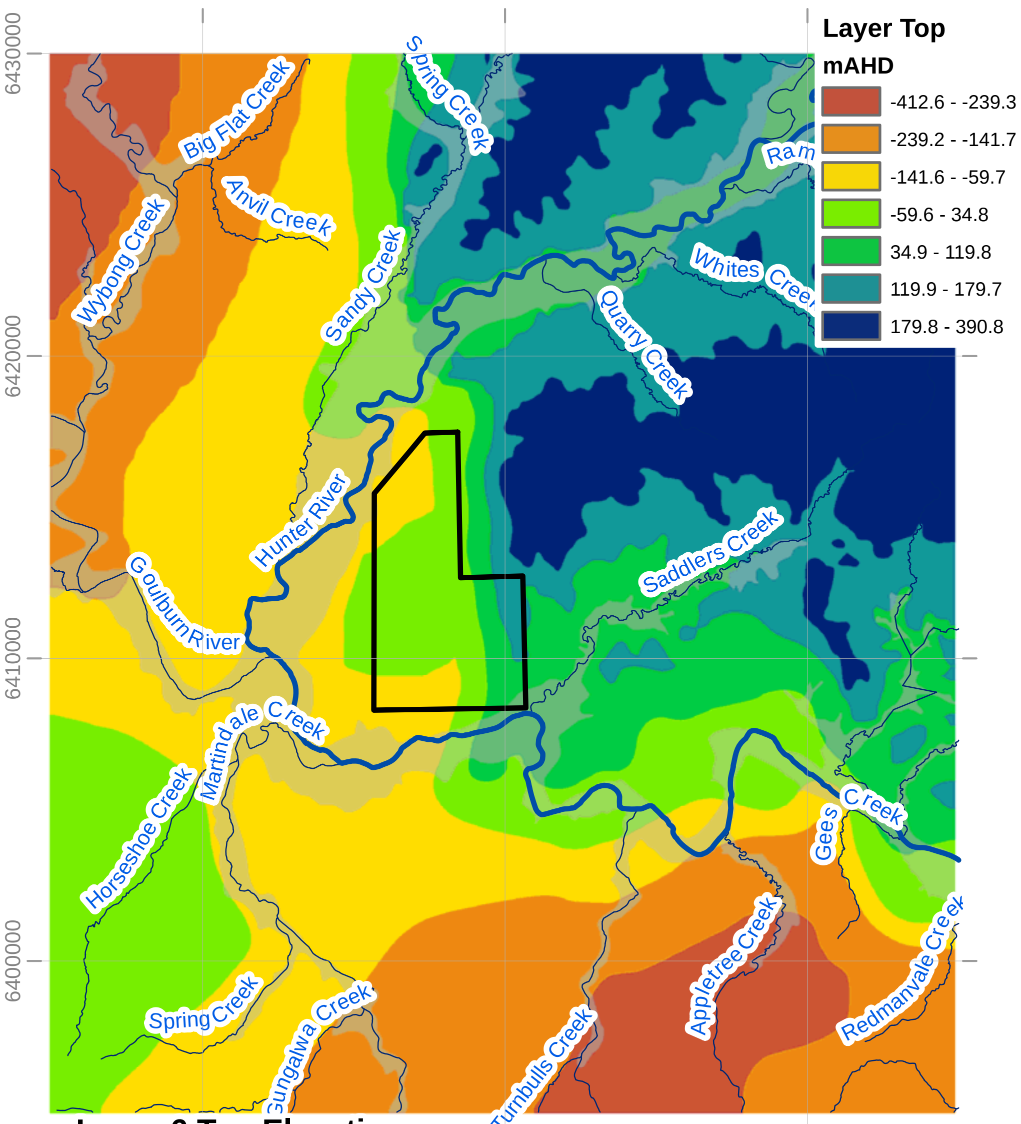


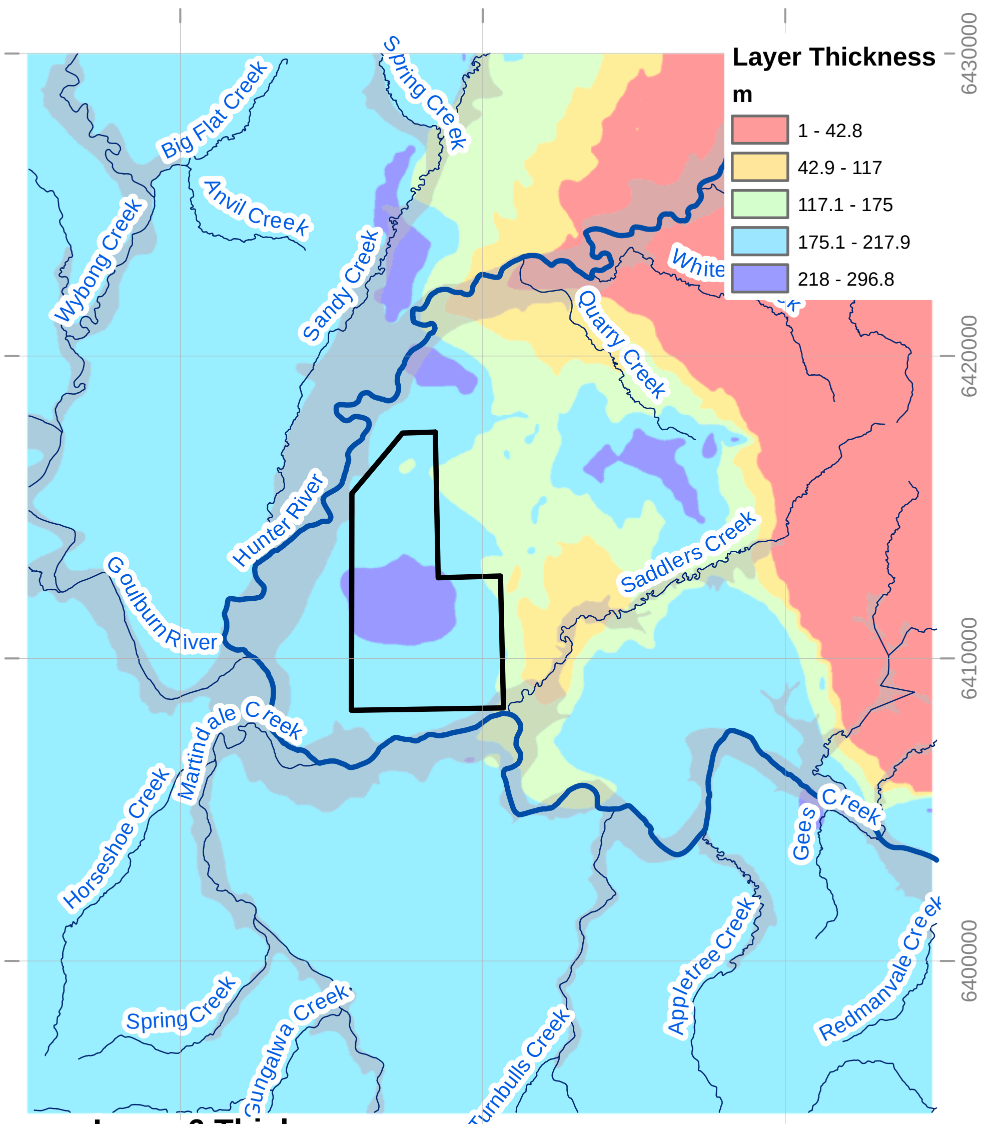
Layer 5 Top Elevation
Whynot Seam



Layer 5 Thickness
Whynot Seam



Layer 6 Top Elevation
Whynot-Bowfield Interburden



Layer 6 Thickness
Whynot-Bowfield Interburden

Spur Hill Management
Spur Hill Underground Coal

Figure A3

Tops and Thicknesses
Model Layers 5 and 6

Legend

Watercourse
Alluvials
Spur Hill Mine Lease

DrawingNo: SHC-001-020
Rev: A.
Created by: CNicol
Date: 04/08/2013.

Scale: 250,000 at A3
GDA 1994 MGA Zone 56

0 1.25 2.5 5 7.5 10
Kilometers

HYDROSIMULATIONS

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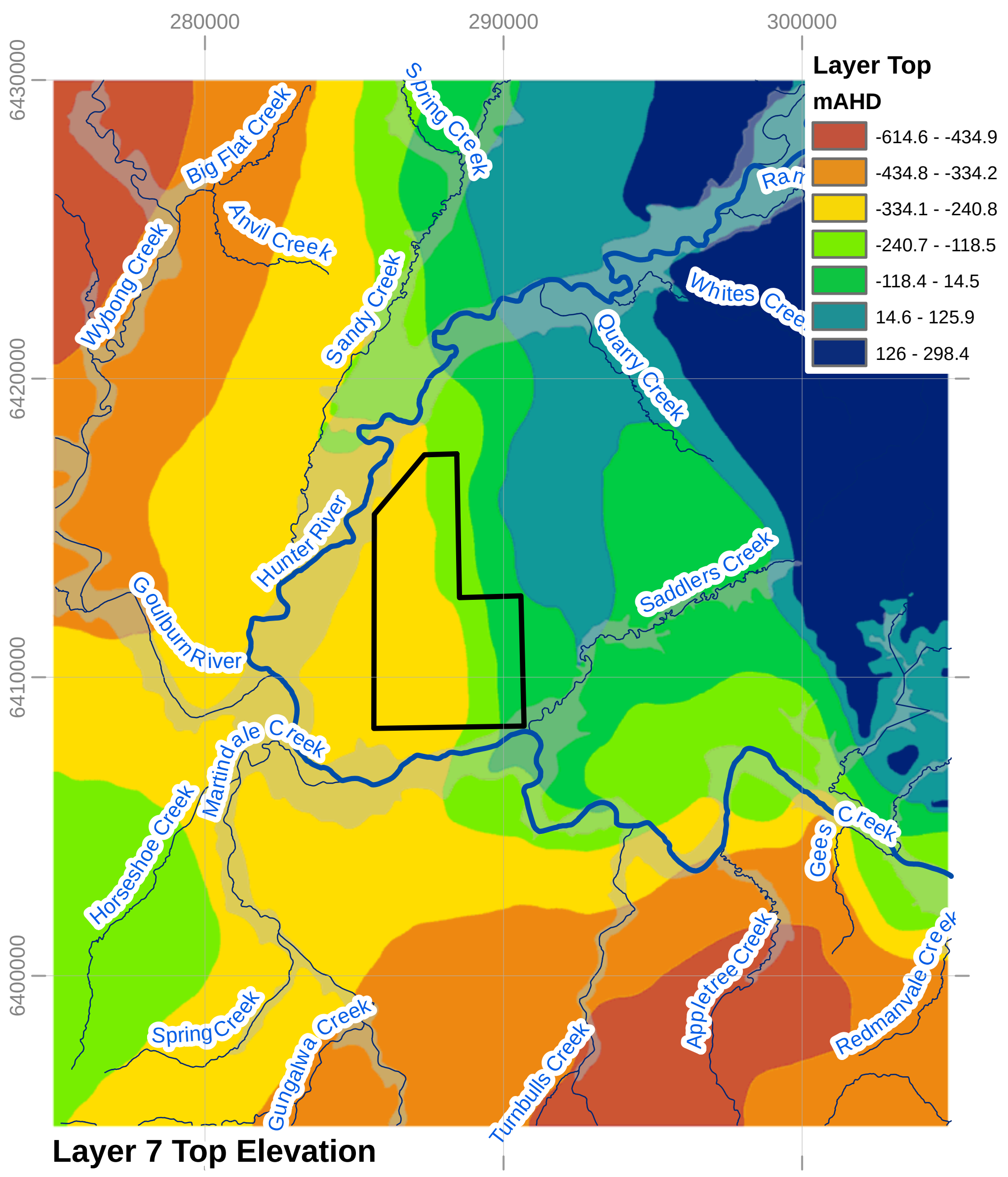
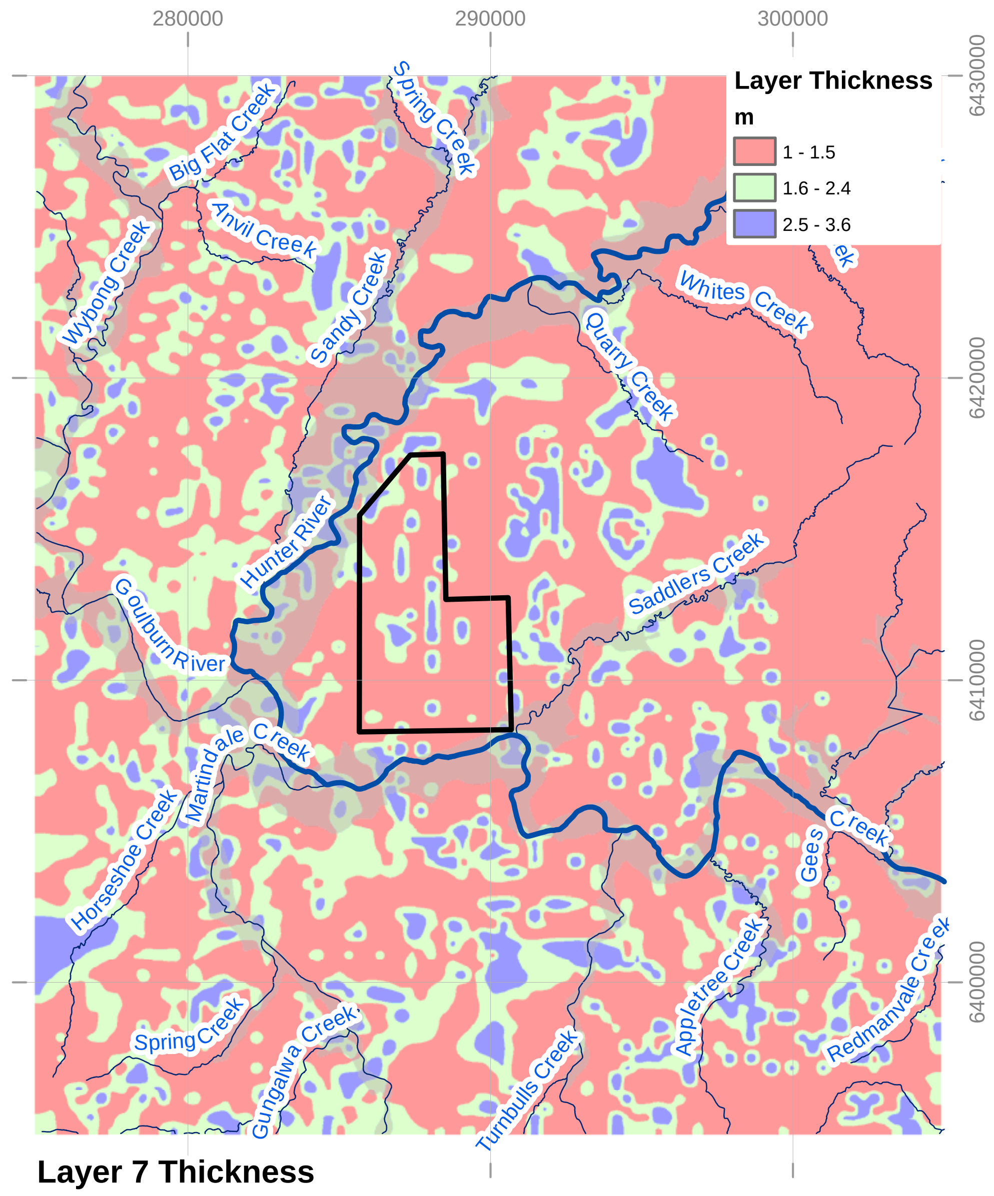
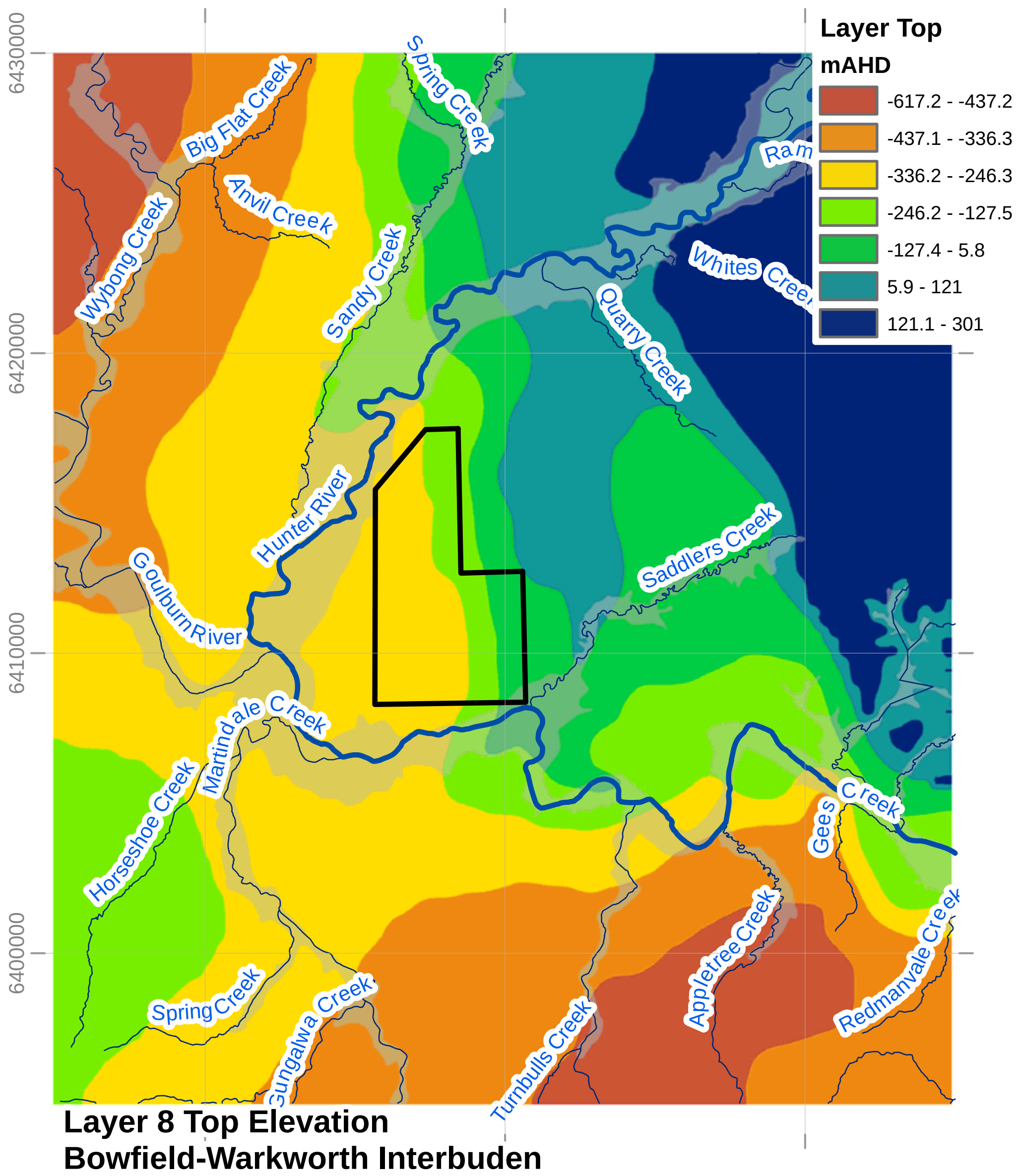


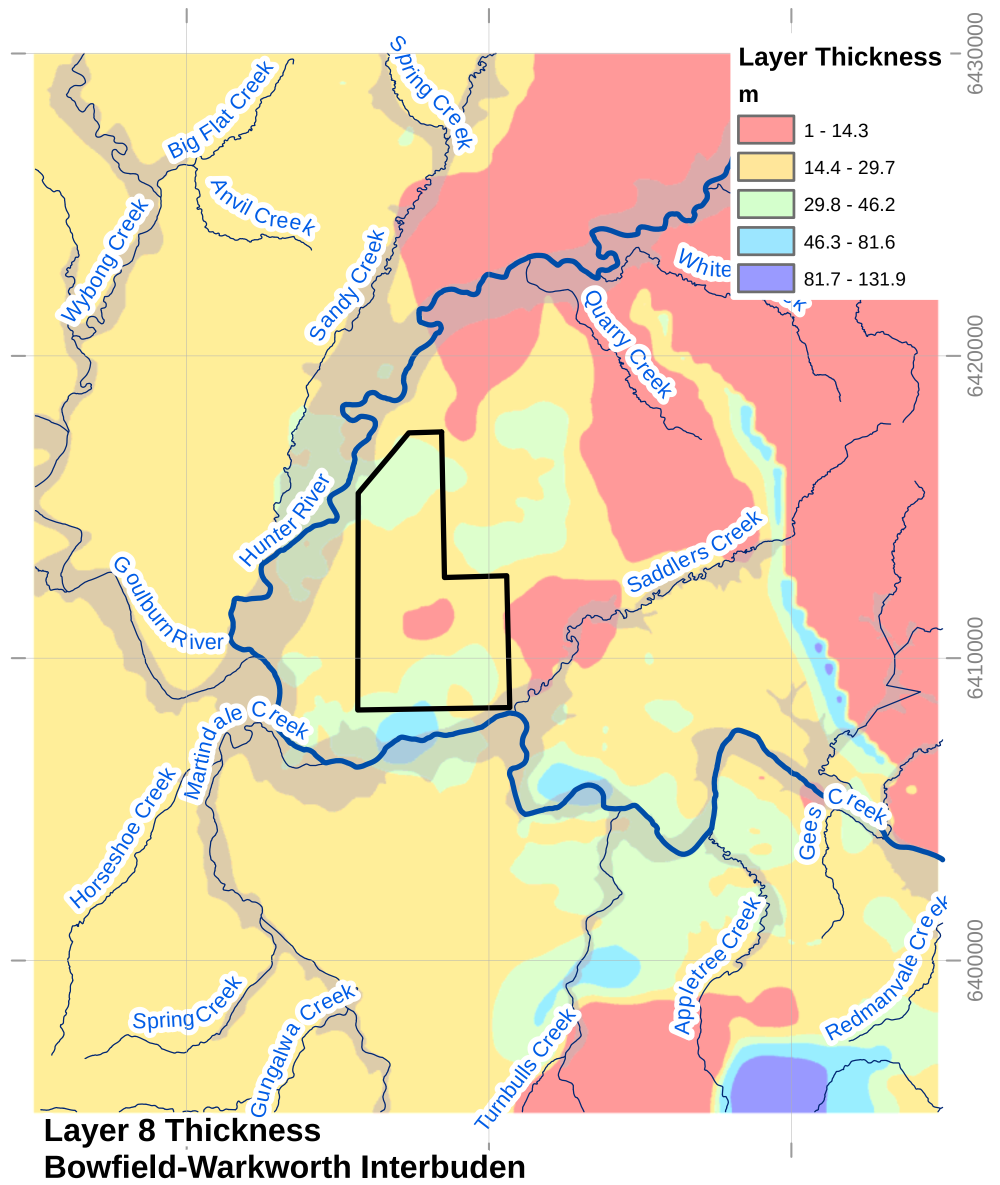
Layer 7 Top Elevation
Bowfield Seam



Layer 7 Thickness
Bowfield Seam



Layer 8 Top Elevation
Bowfield-Warkworth Interbuden



Layer 8 Thickness
Bowfield-Warkworth Interbuden

Spur Hill Management
Spur Hill Underground Coal

Figure A4

Tops and Thicknesses Model Layers 7 and 8

Legend

Watercourse
Alluvials
Spur Hill Mine Lease

DrawingNo: SHC-001-021
Rev: A.
Created by: CNicol
Date: 04/08/2013.

Scale: 250,000 at A3
GDA 1994 MGA Zone 56

0 1.25 2.5 5 7.5 10 Kilometers

HYDROSIMULATIONS

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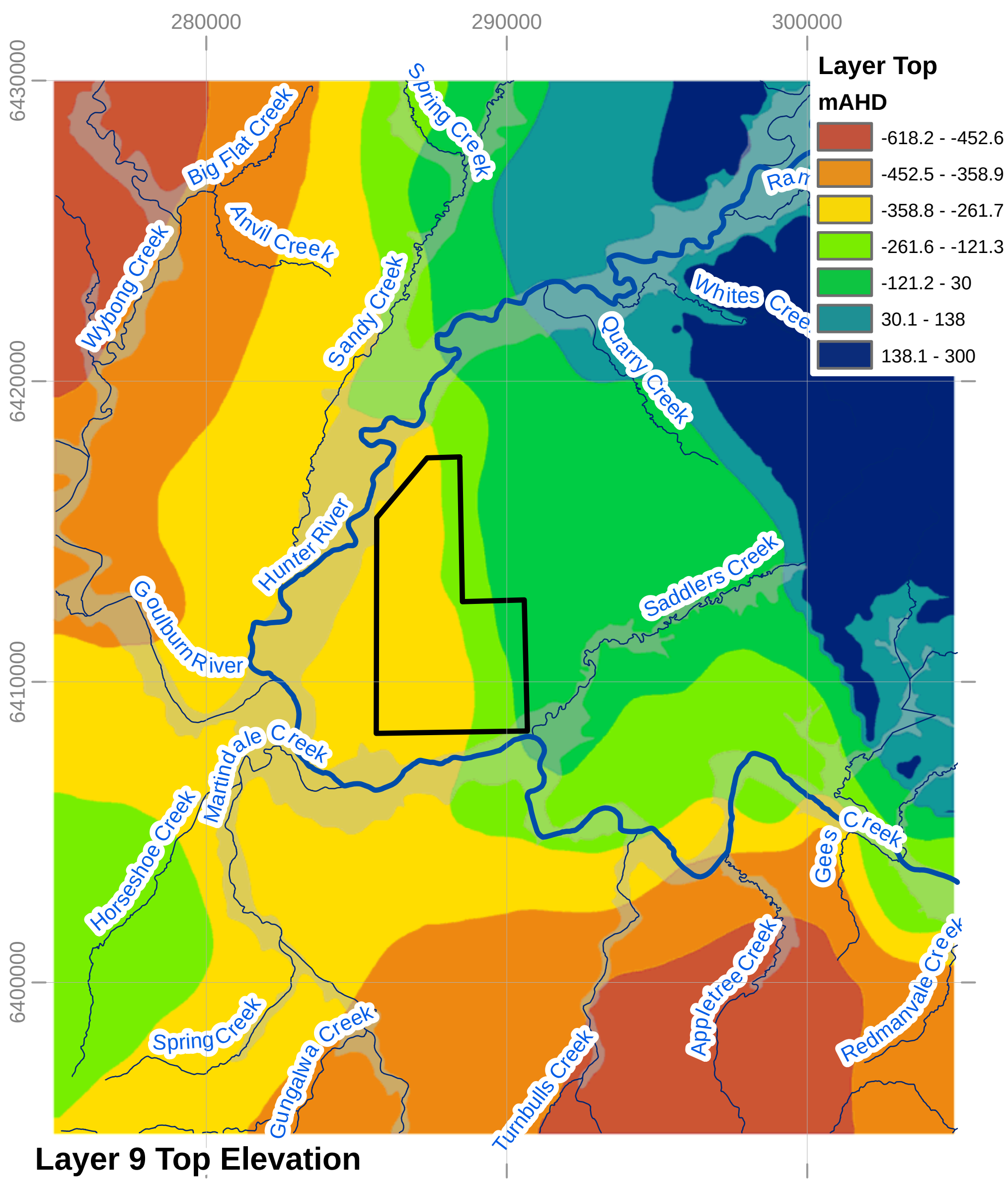
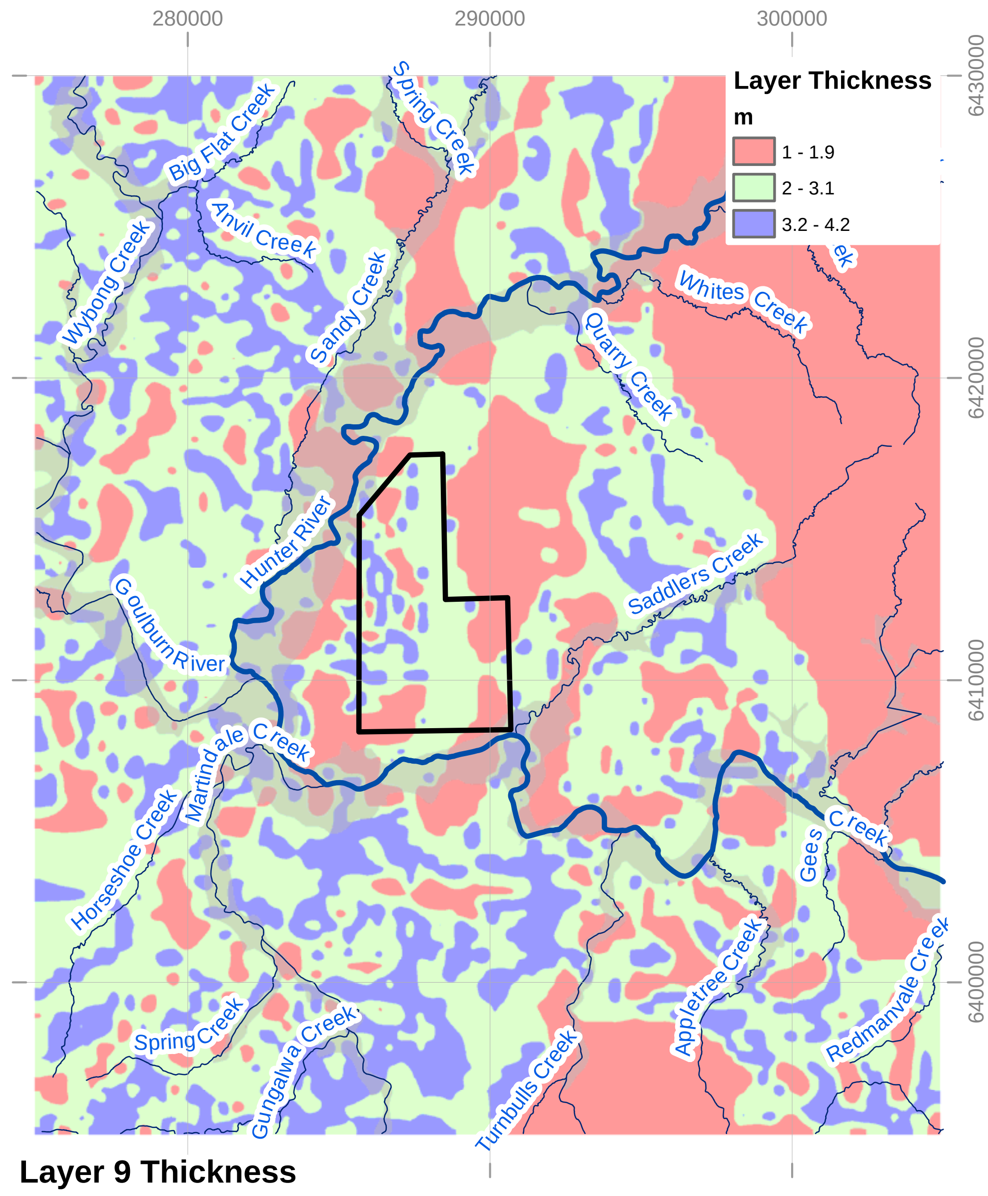
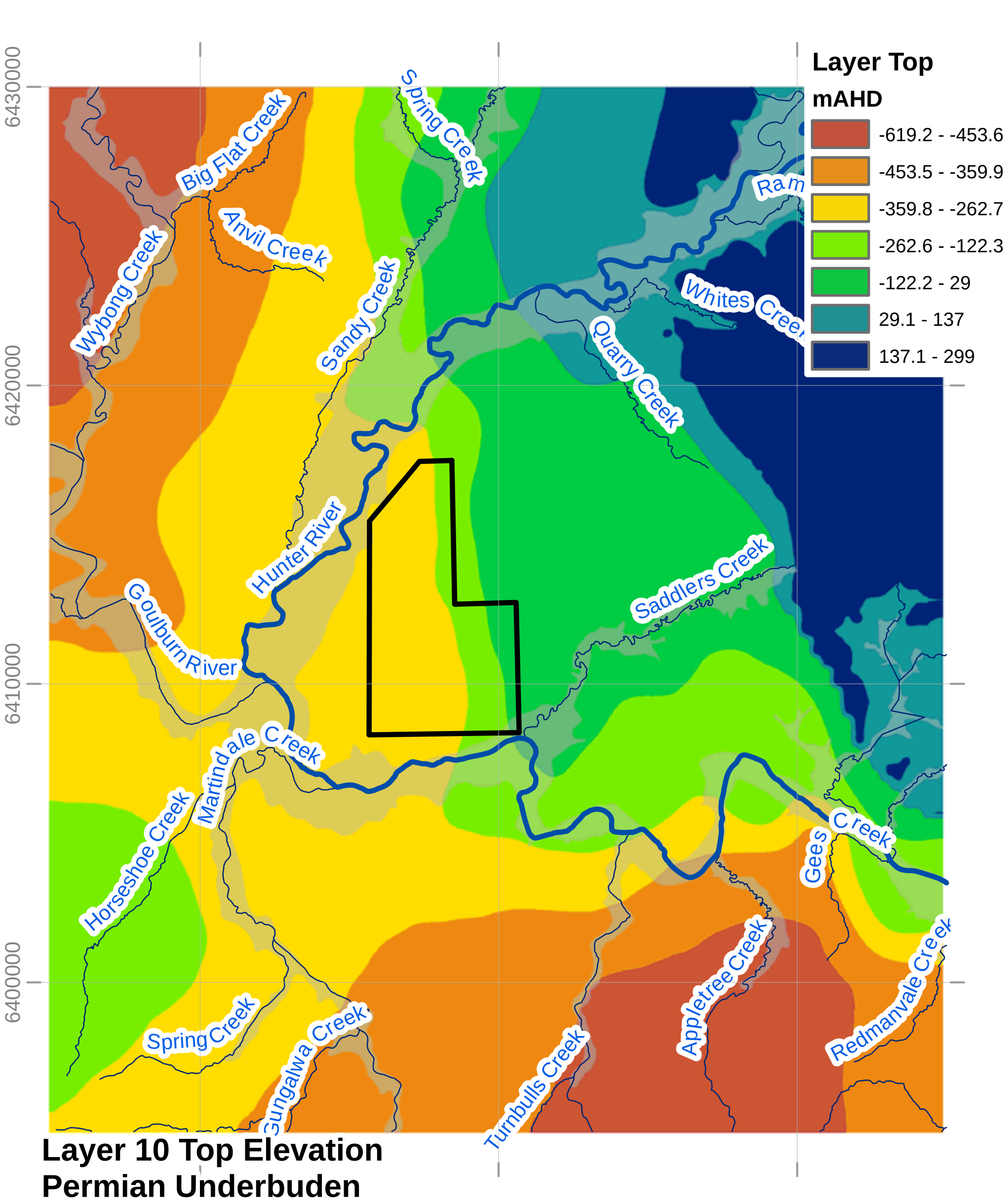


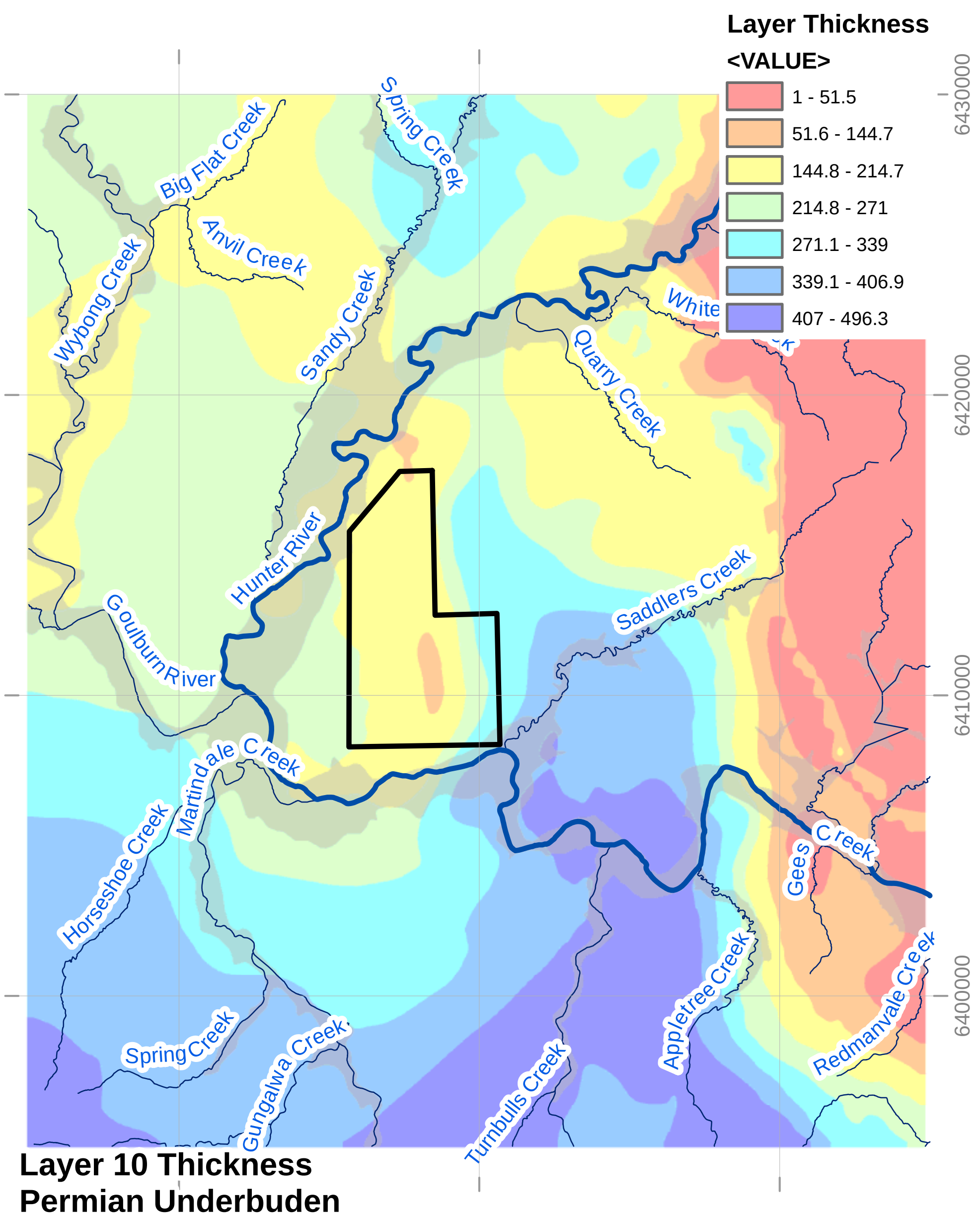
Layer 9 Top Elevation
Warkworth Seam



Layer 9 Thickness
Warkworth Seam



Layer 10 Top Elevation
Permian Underbuden



Layer 10 Thickness
Permian Underbuden

Spur Hill Management
Spur Hill Underground Coal

Figure A5

Tops and Thicknesses
Model Layers 9 and 10

Legend

Watercourse
Alluvials
Spur Hill Mine Lease

DrawingNo: SHC-001-022
Rev: A.
Created by: CNicol
Date: 04/08/2013.

Scale: 250,000 at A3
GDA 1994 MGA Zone 56

0 1.25 2.5 5 7.5 10 Kilometers

HydroSimulations

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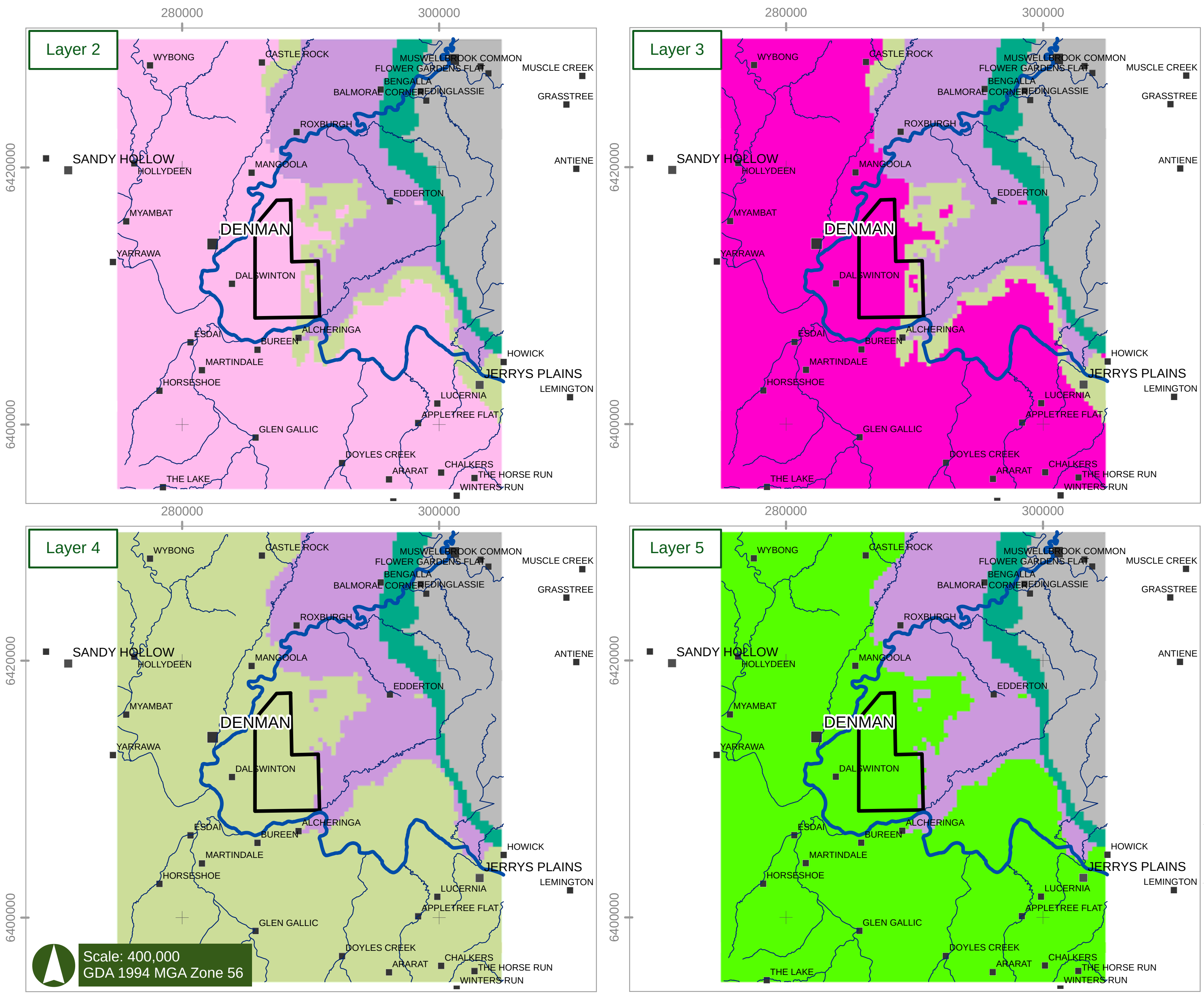
HYDRO SIMULATIONS

ATTACHMENT B

Hydraulic Property Zonation



Legend

Watercourse

Spur Hill Mine Lease

Hydrogeological units (HGUs)

Layer 2 HGUs
- 2
- 4
- 6
- 10
- 11 (inactive)

Layer 3 HGUs
- 3
- 4
- 6
- 10
- 11 (inactive)

Layer 4 HGUs
- 4
- 6
- 10
- 11 (inactive)

Layer 5 HGUs
- 5
- 6
- 10
- 11 (inactive)

Zone	Description
101	Alluvium
102	Regolith
2	Whybrow overburden
3	Whybrow seam
4	Whynot overburden
5	Whynot seam
6	Bowfield overburden
7	Bowfield seam
8	Warkworth overburden
9	Warkworth seam
10	Underburden to Ramrod Ck Seam

Spur Hill Management
Spur Hill Underground Coal

Figure B1

Aquifer parameter zones (HGUs) for Model layers 2-5

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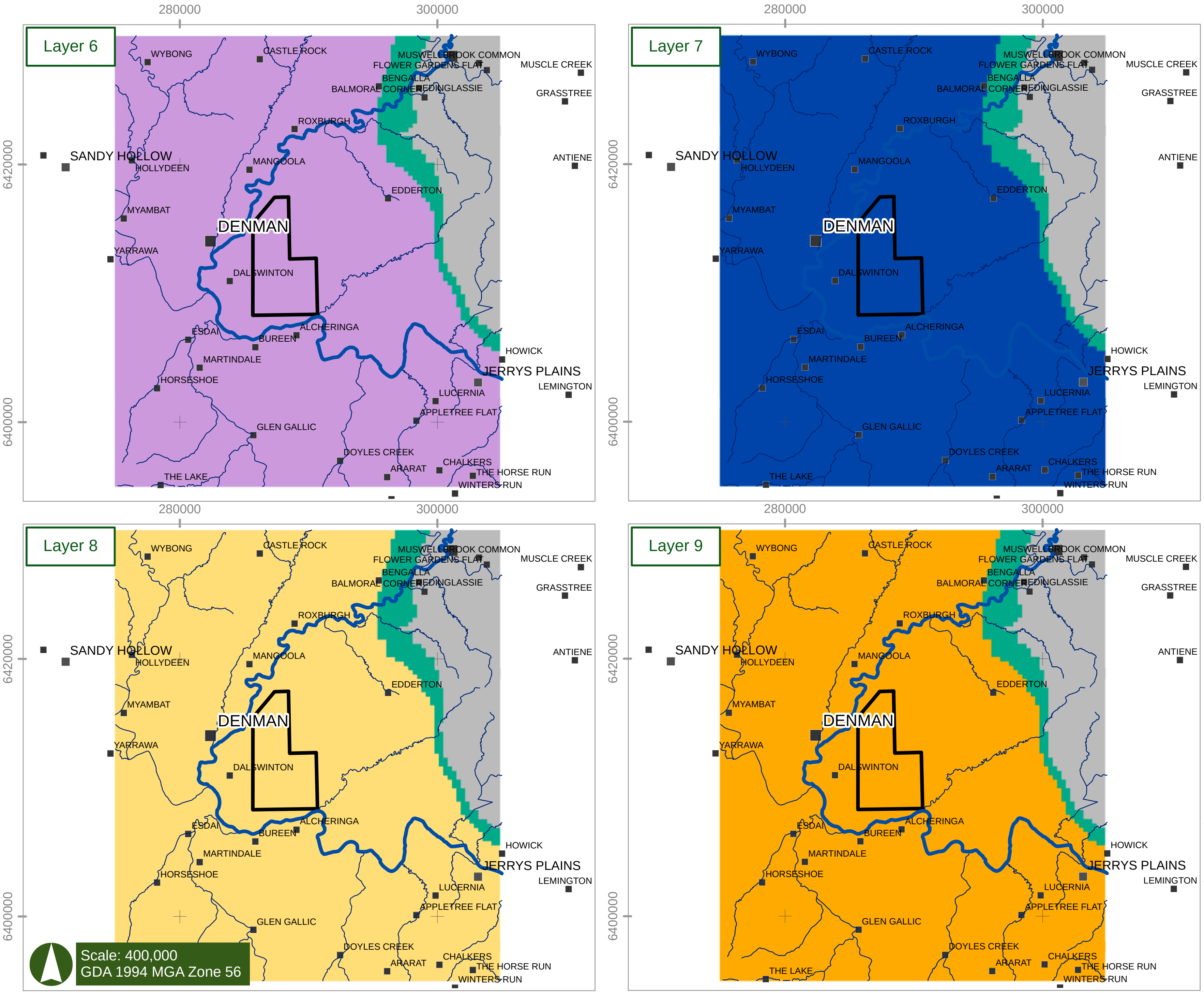
DrawingNo: SHC-001-020
Rev: B.
Created by: CNicol
Date: 06/08/2013.

HYDROSIMULATIONS



Legend

Watercourse

Spur Hill Mine Lease

Hydrogeological units (HGUs)

Layer 6 HGUs	Layer 8 HGUs
6	8
10	10
11	11 (inactive)

Layer 7 HGUs	Layer 9 HGUs
7	9
10	10
11 (inactive)	11 (inactive)

Zone	Description
101	Alluvium
102	Regolith
2	Whybrow overburden
3	Whybrow seam
4	Whynot overburden
5	Whynot seam
6	Bowfield overburden
7	Bowfield seam
8	Warkworth overburden
9	Warkworth seam
10	Underburden to Ramrod Ck Seam

Spur Hill Management
Spur Hill Underground Coal

Figure B2

Aquifer parameter zones (HGUs) for Model layers 6-9

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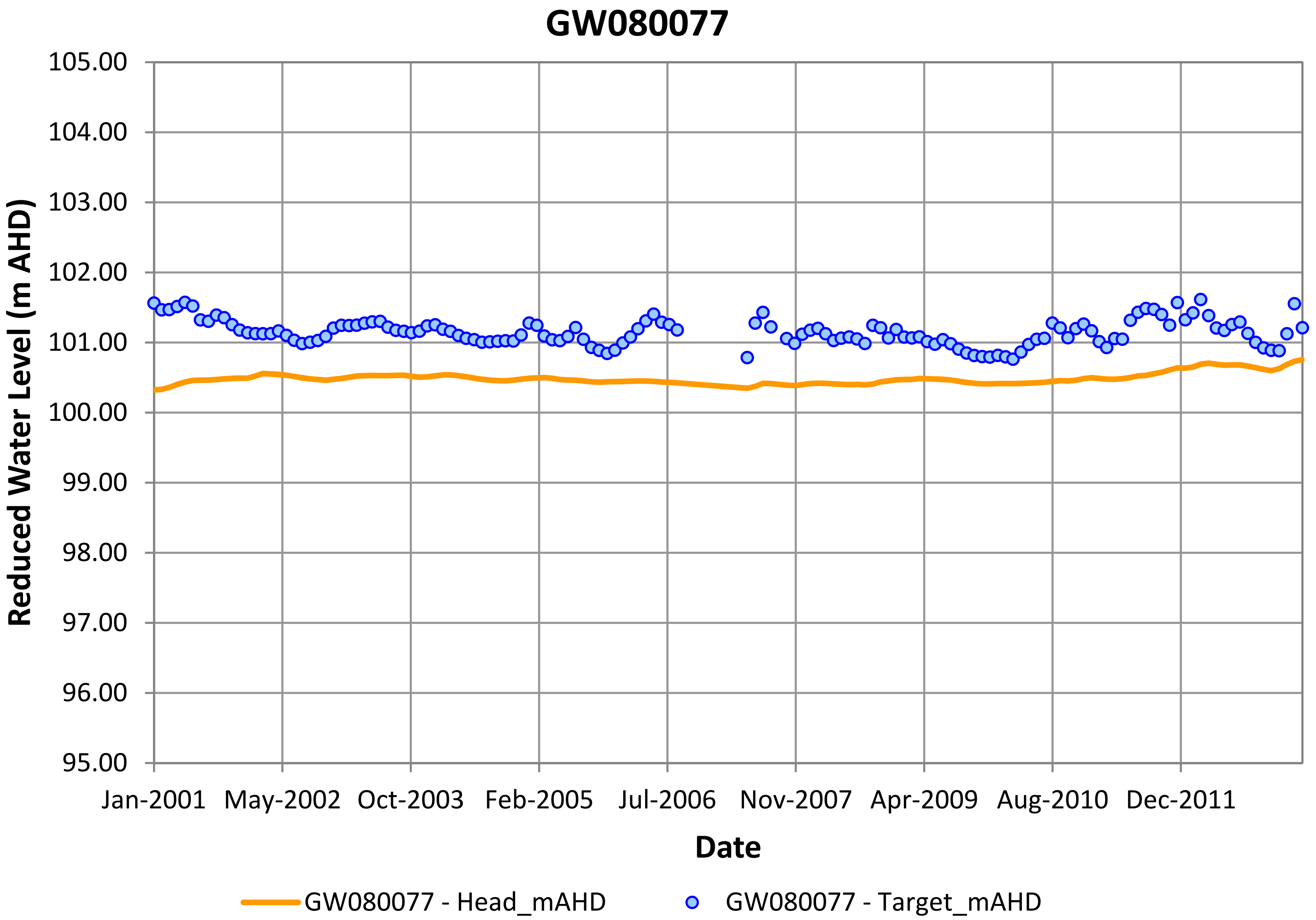
DrawingNo: SHC-001-021
Rev: B.
Created by: CNicol
Date: 06/08/2013.

HYDROSIMULATIONS

HYDRO SIMULATIONS

ATTACHMENT C

Verification Hydrographs



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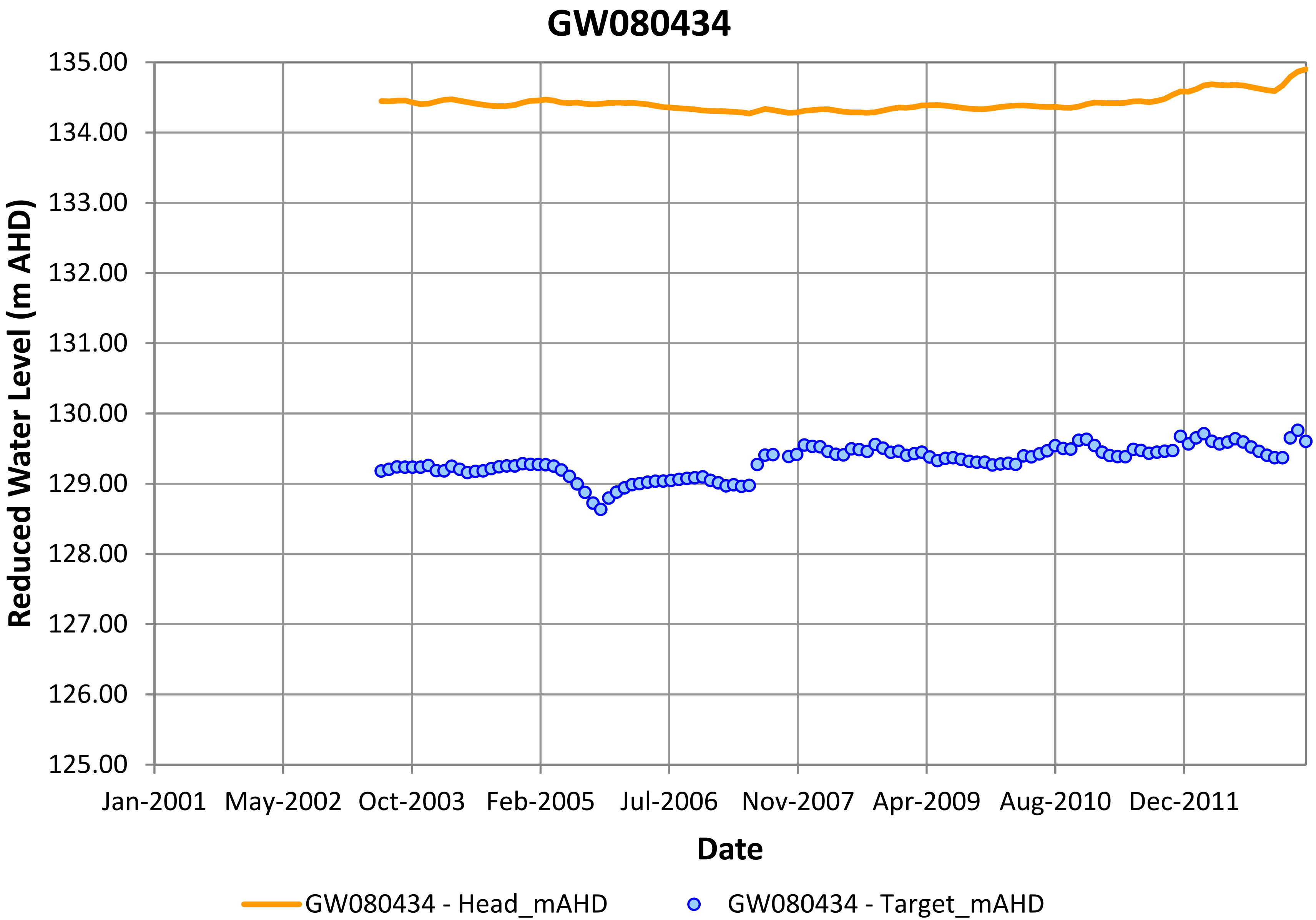

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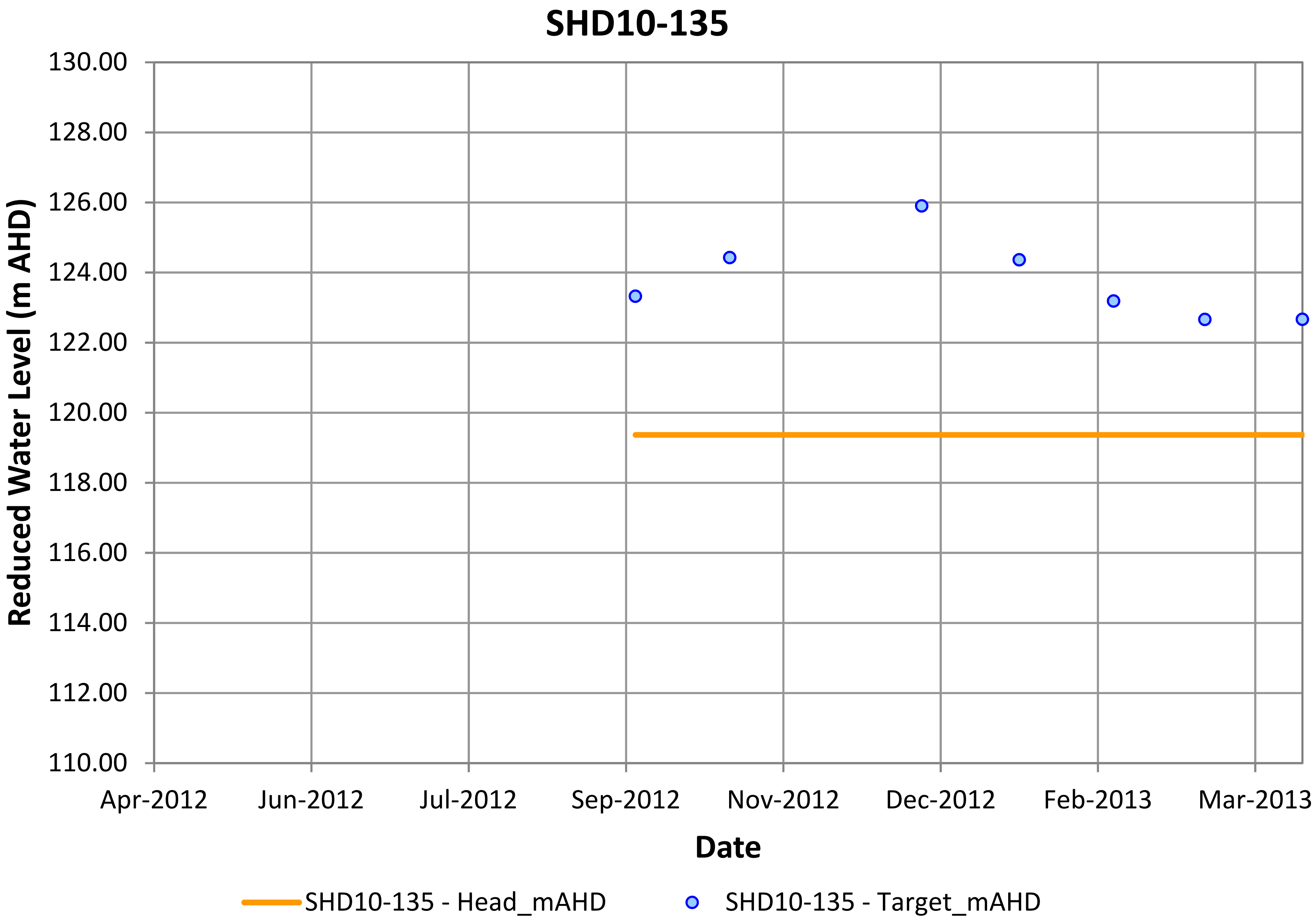

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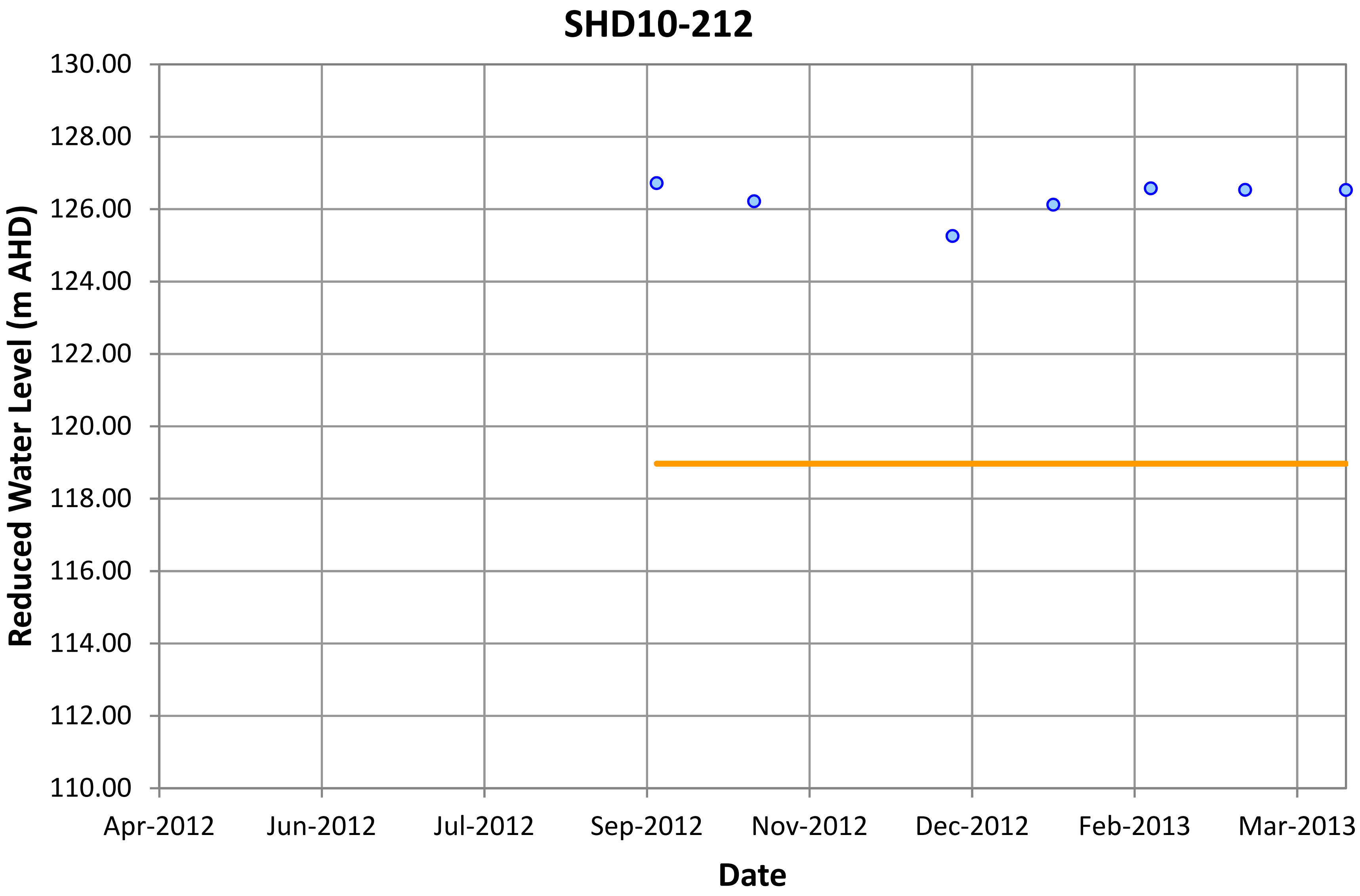

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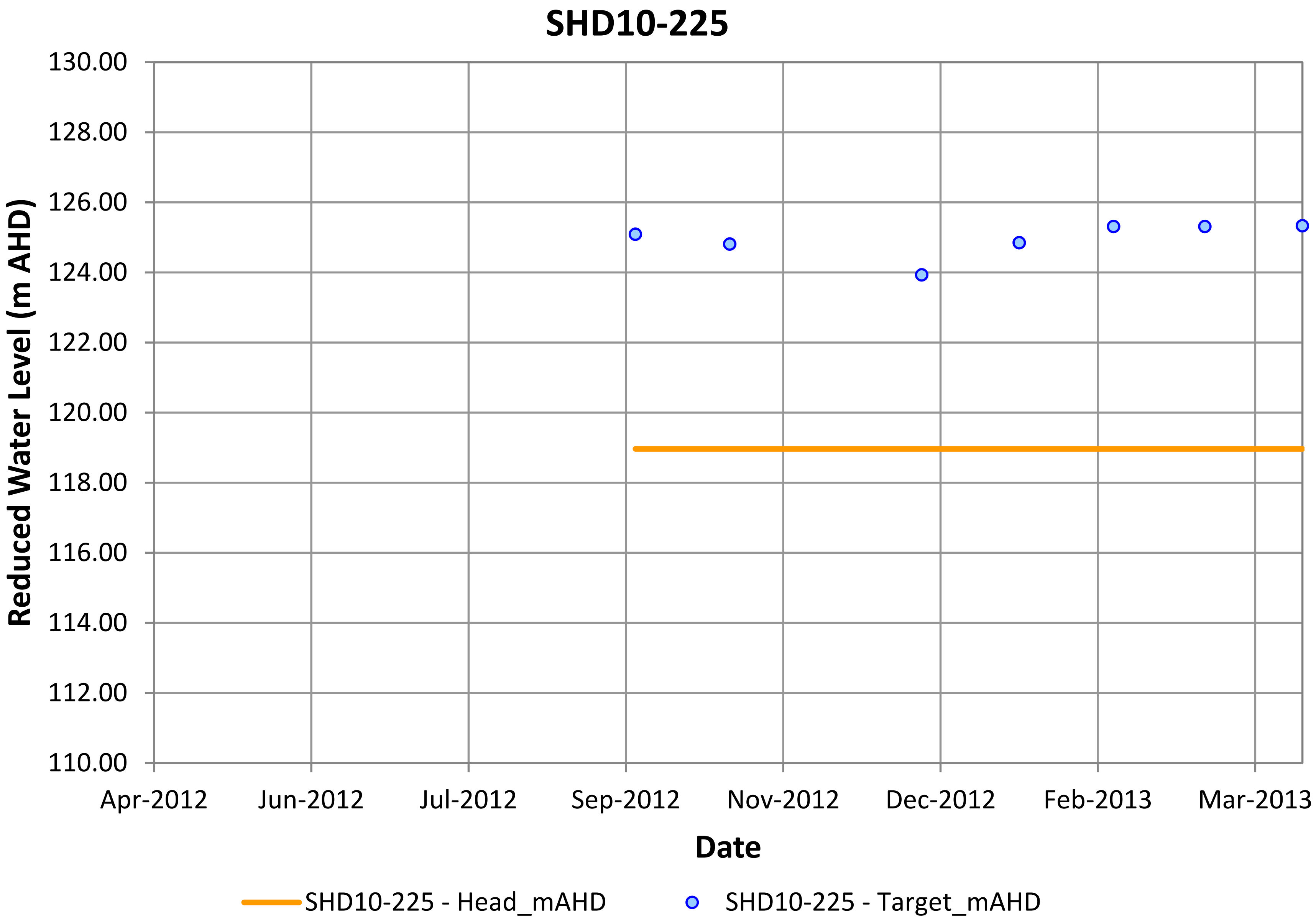

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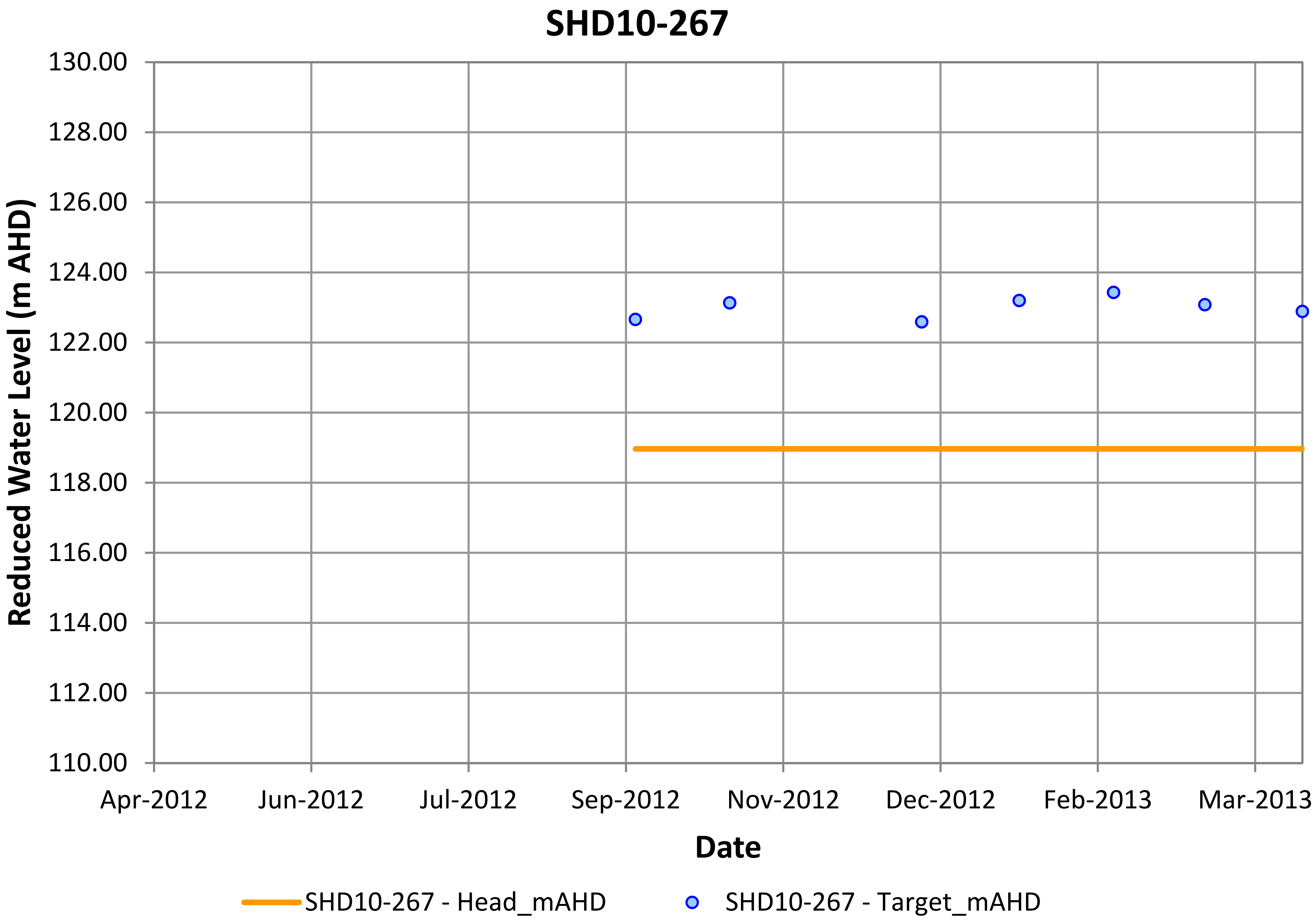

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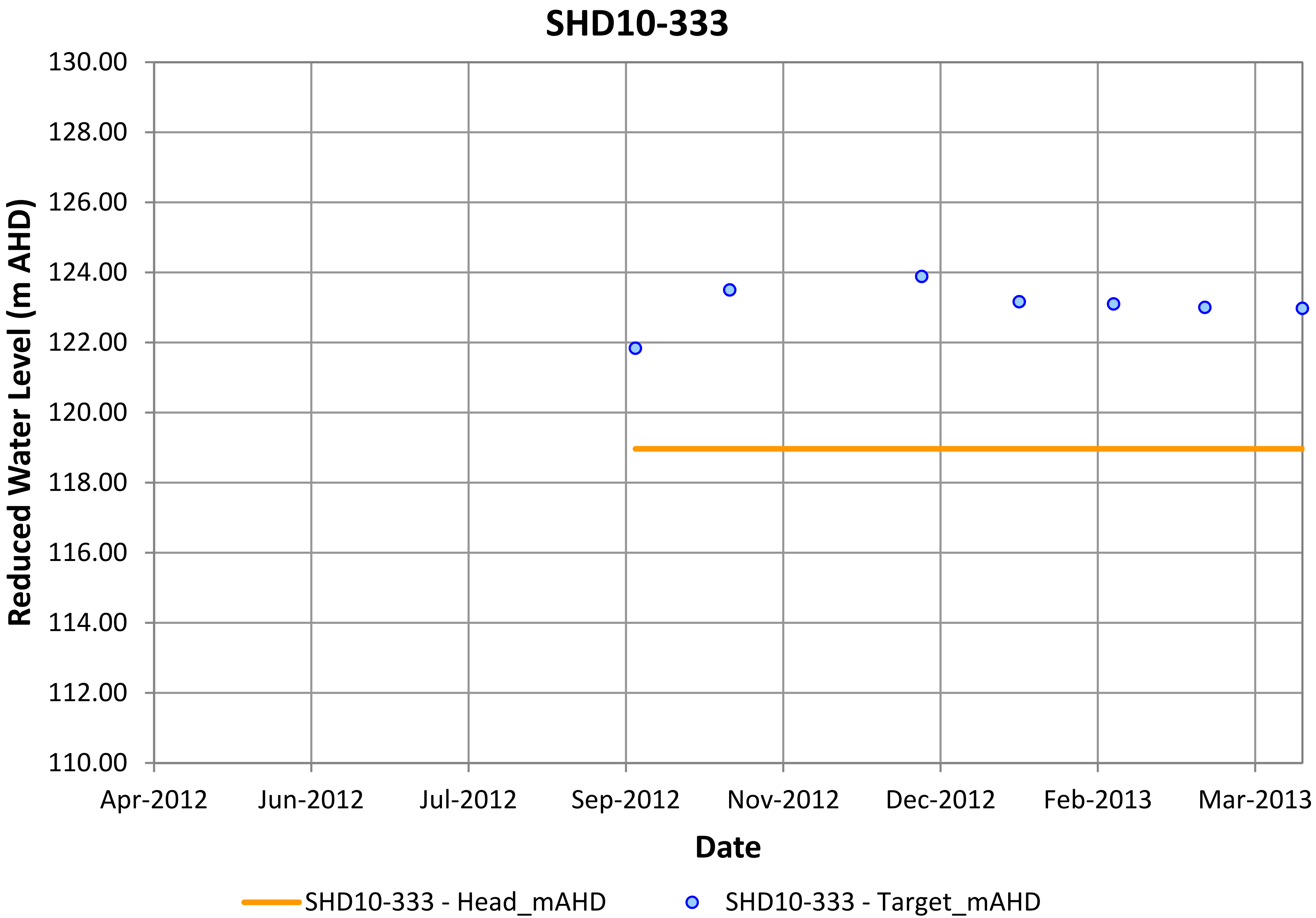

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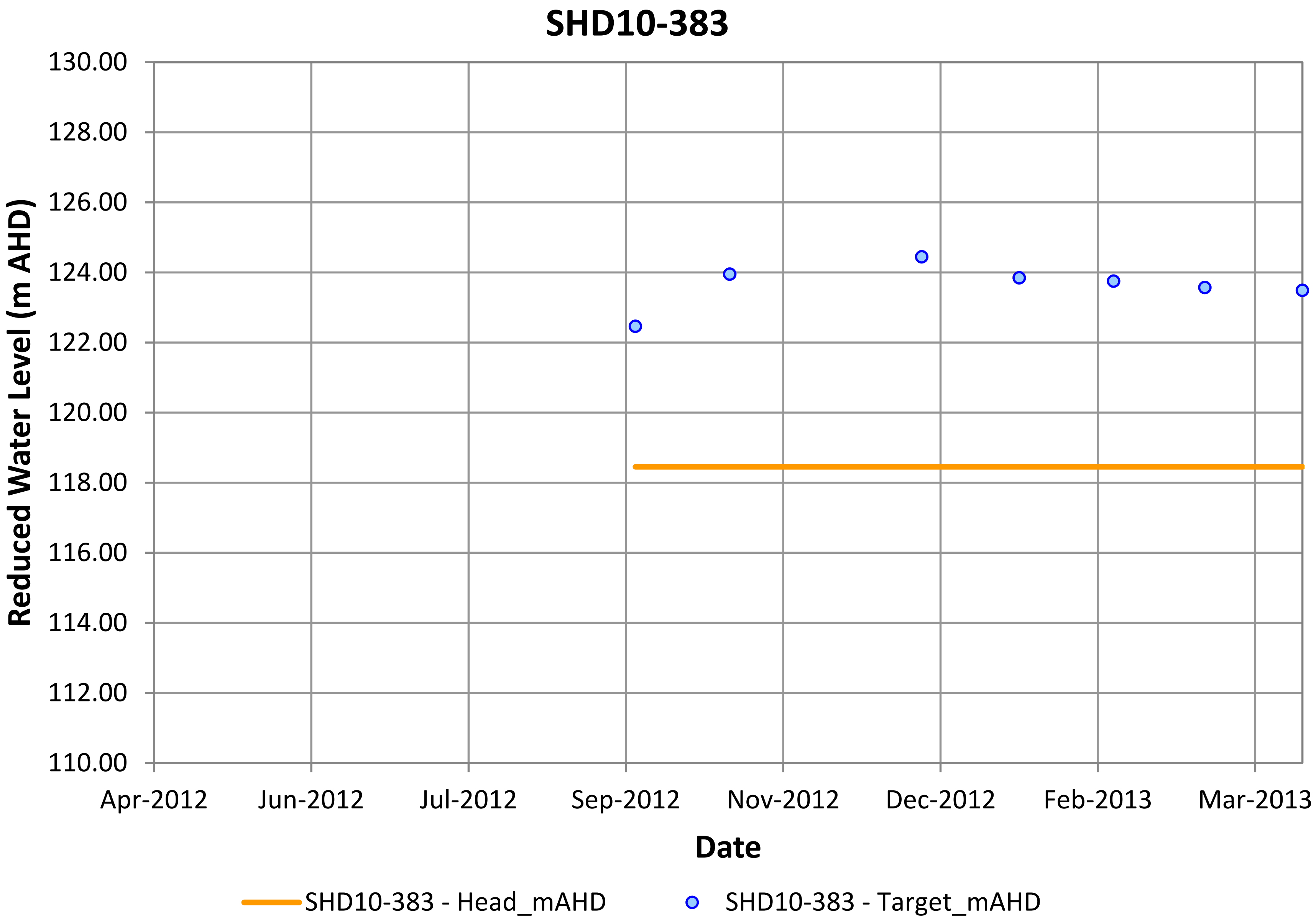

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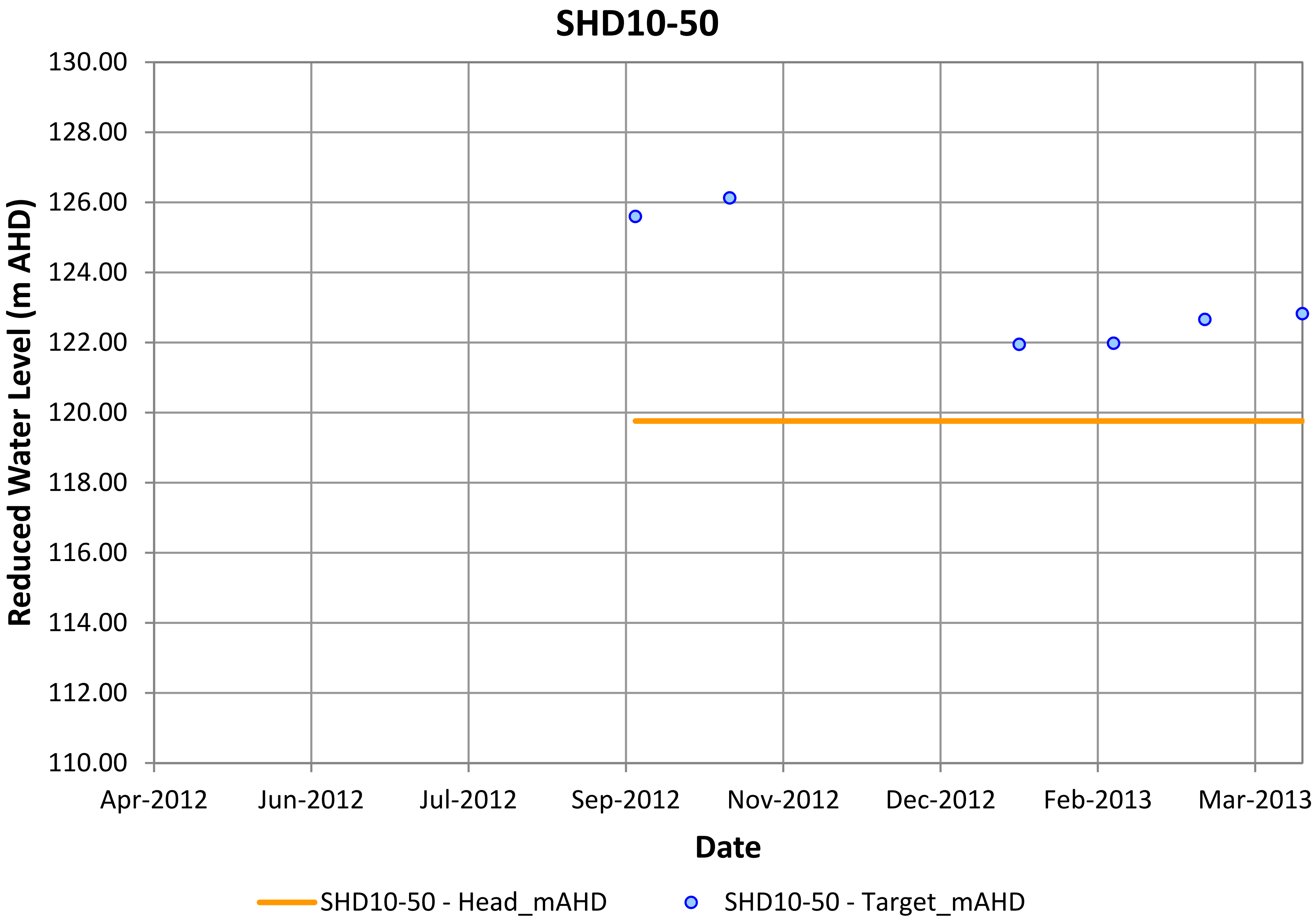

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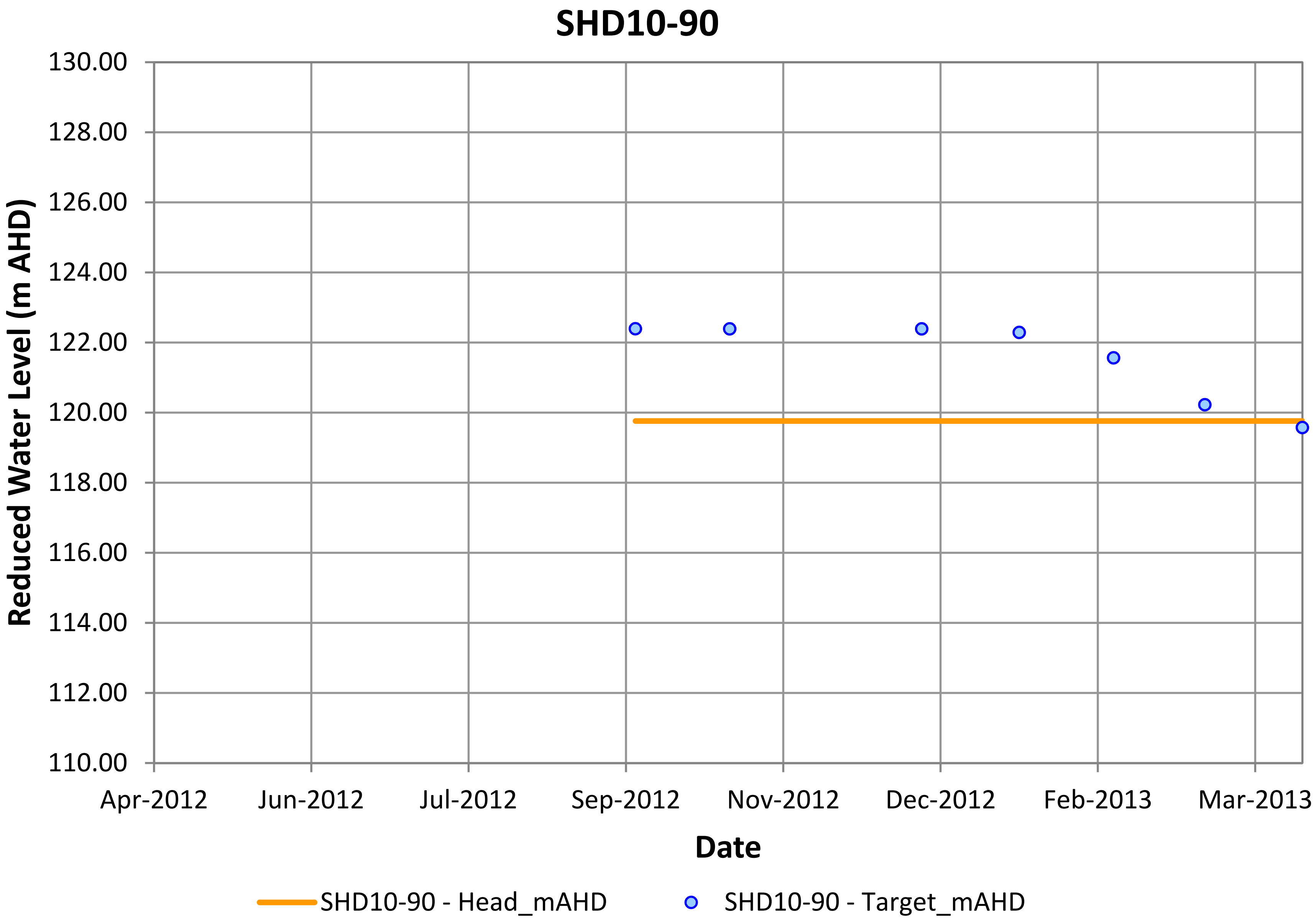

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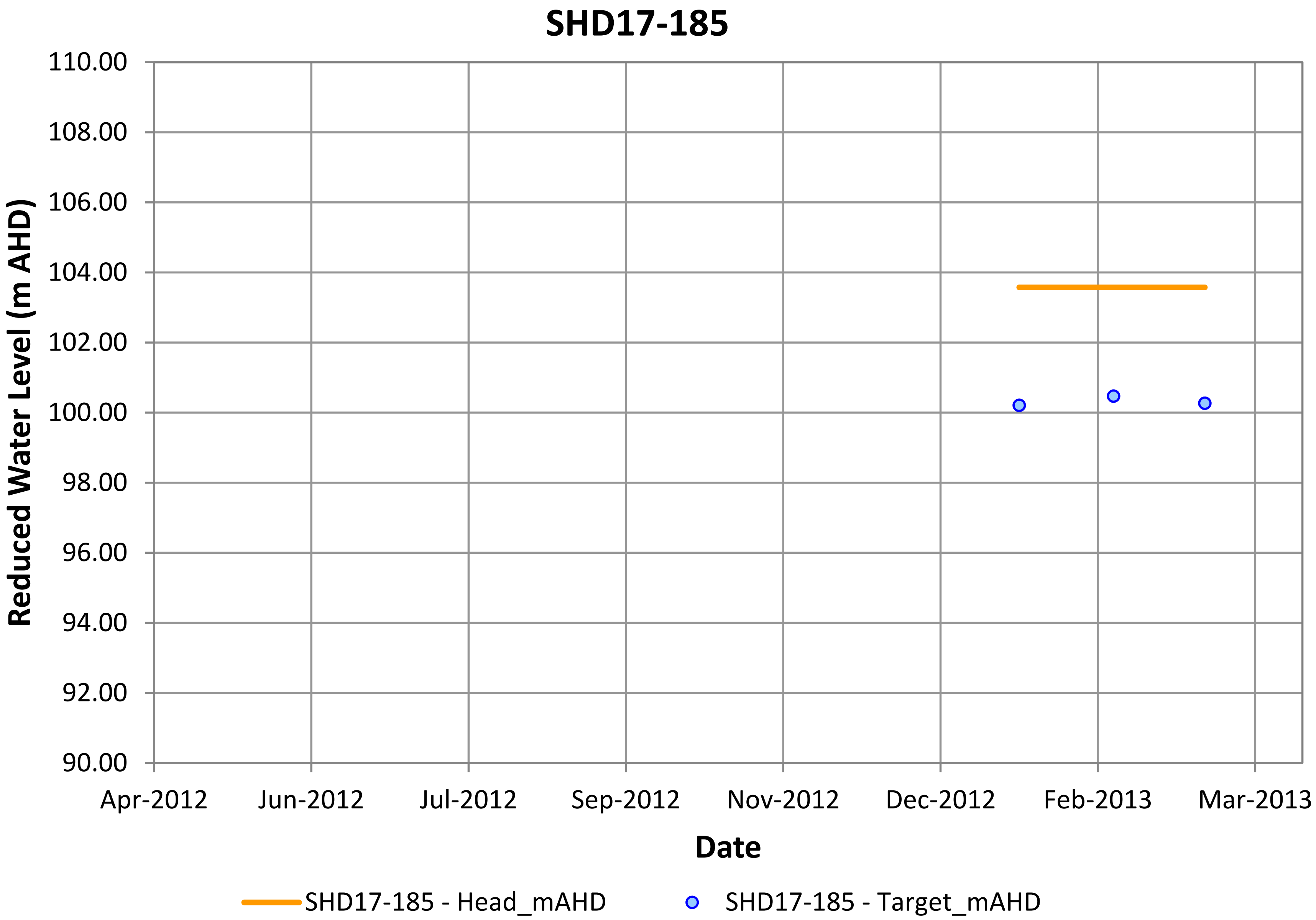

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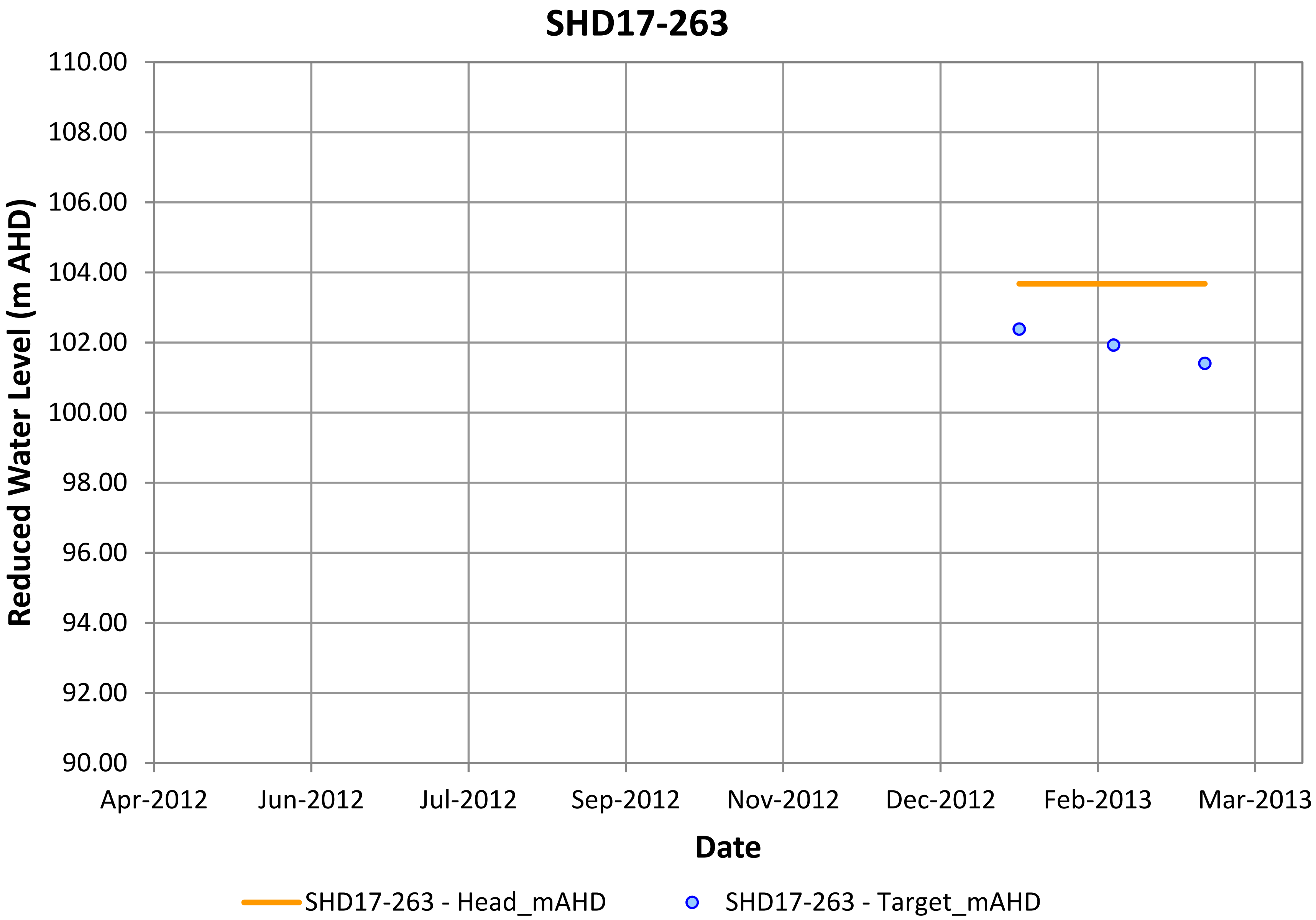

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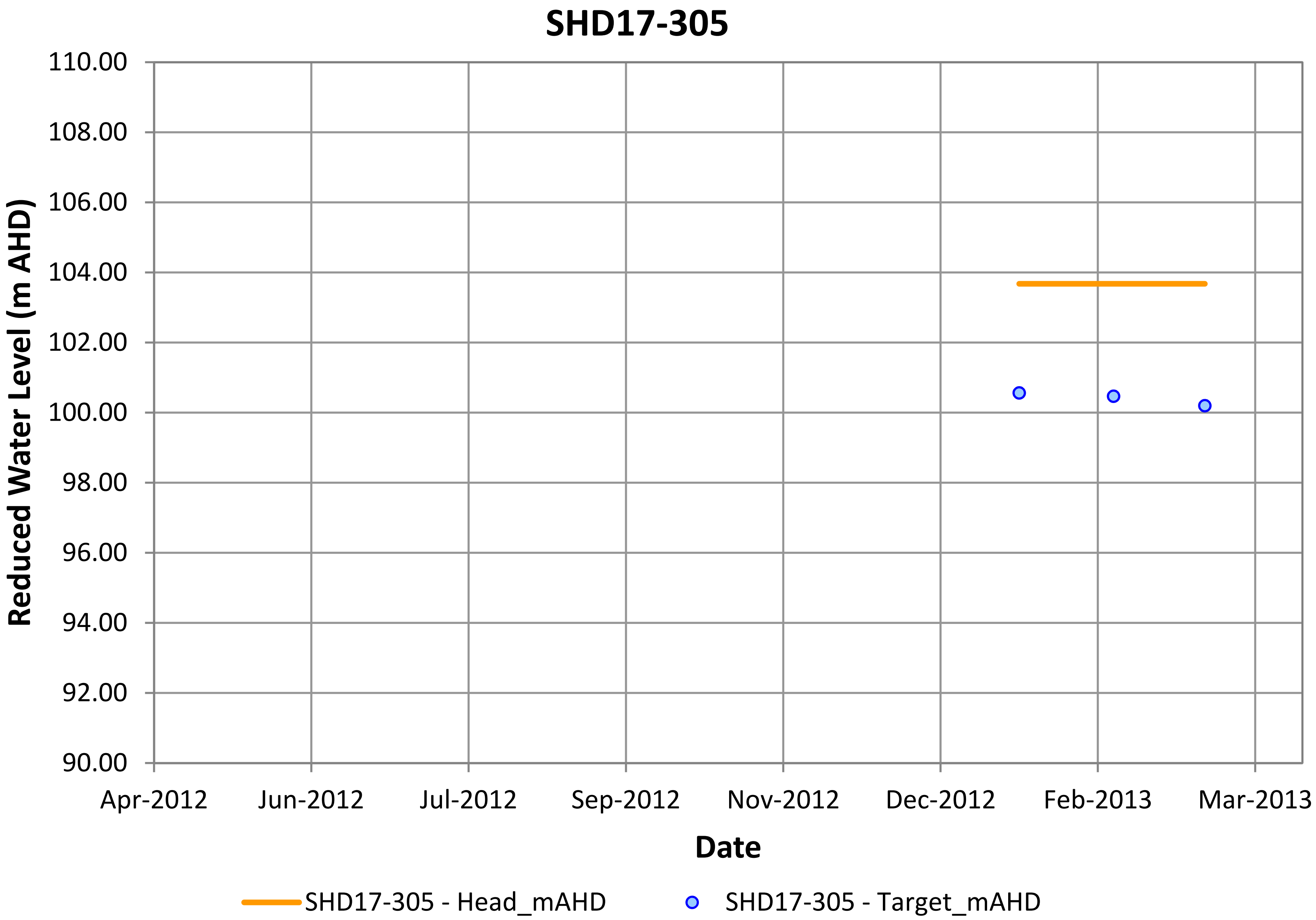

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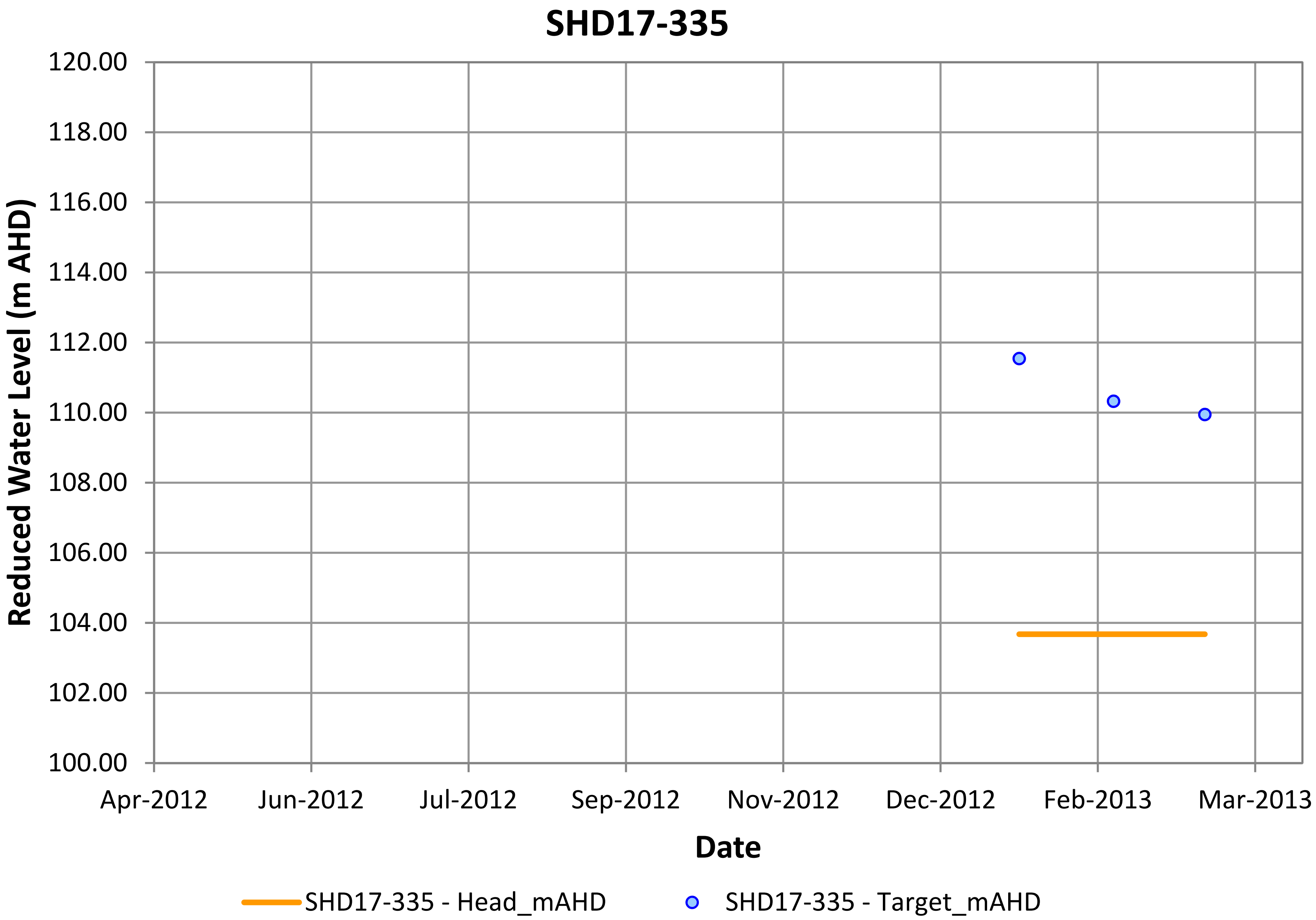

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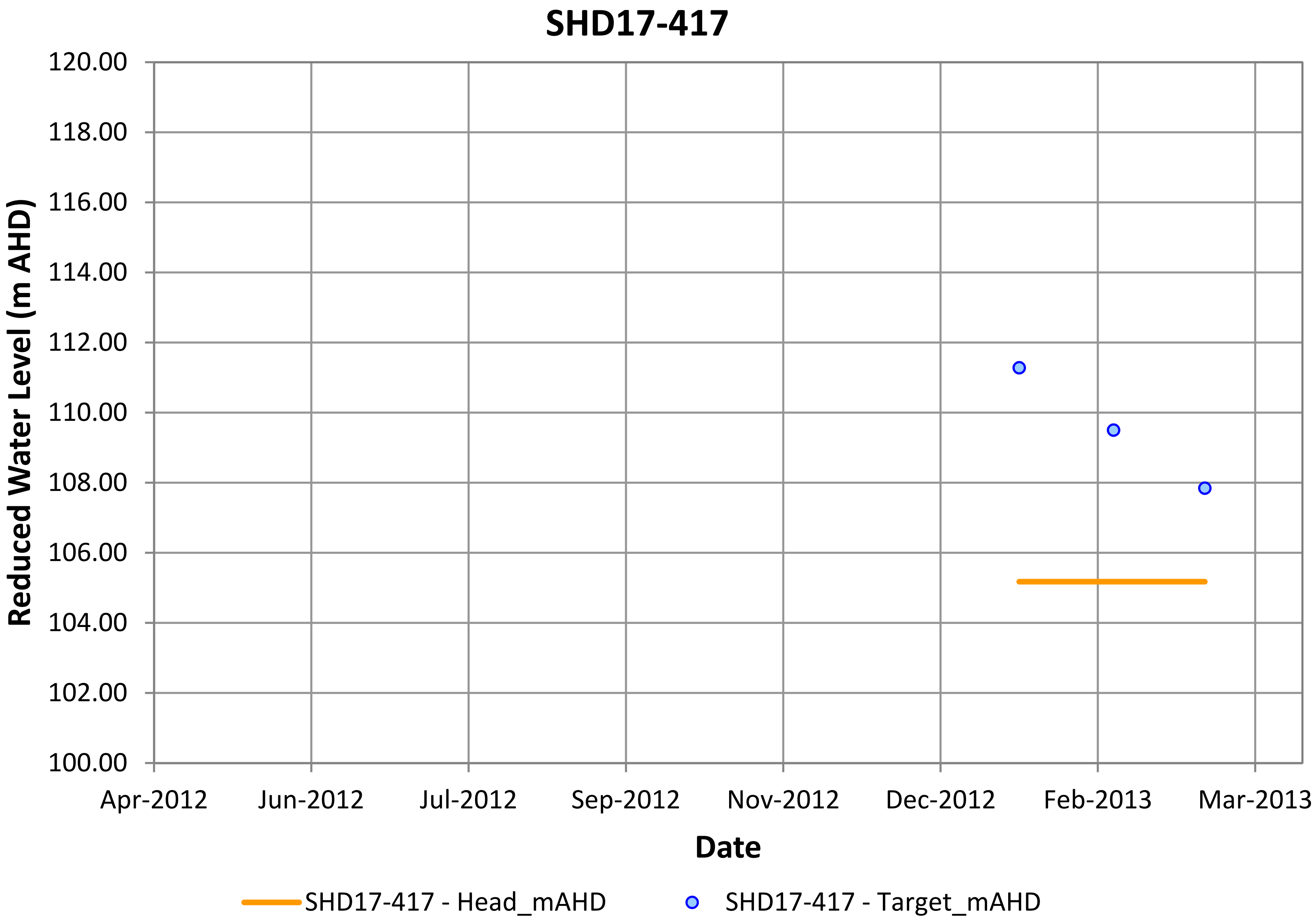

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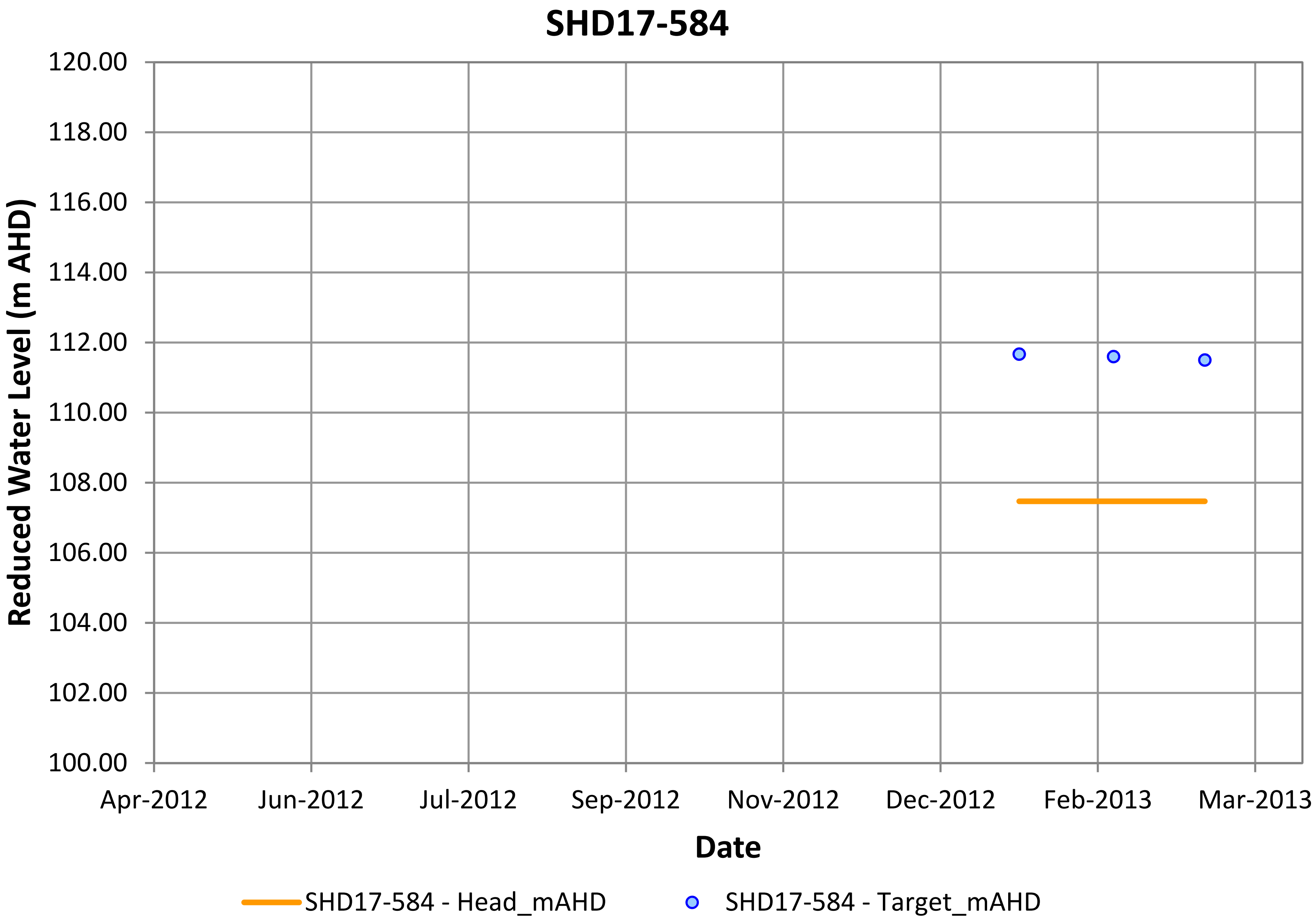

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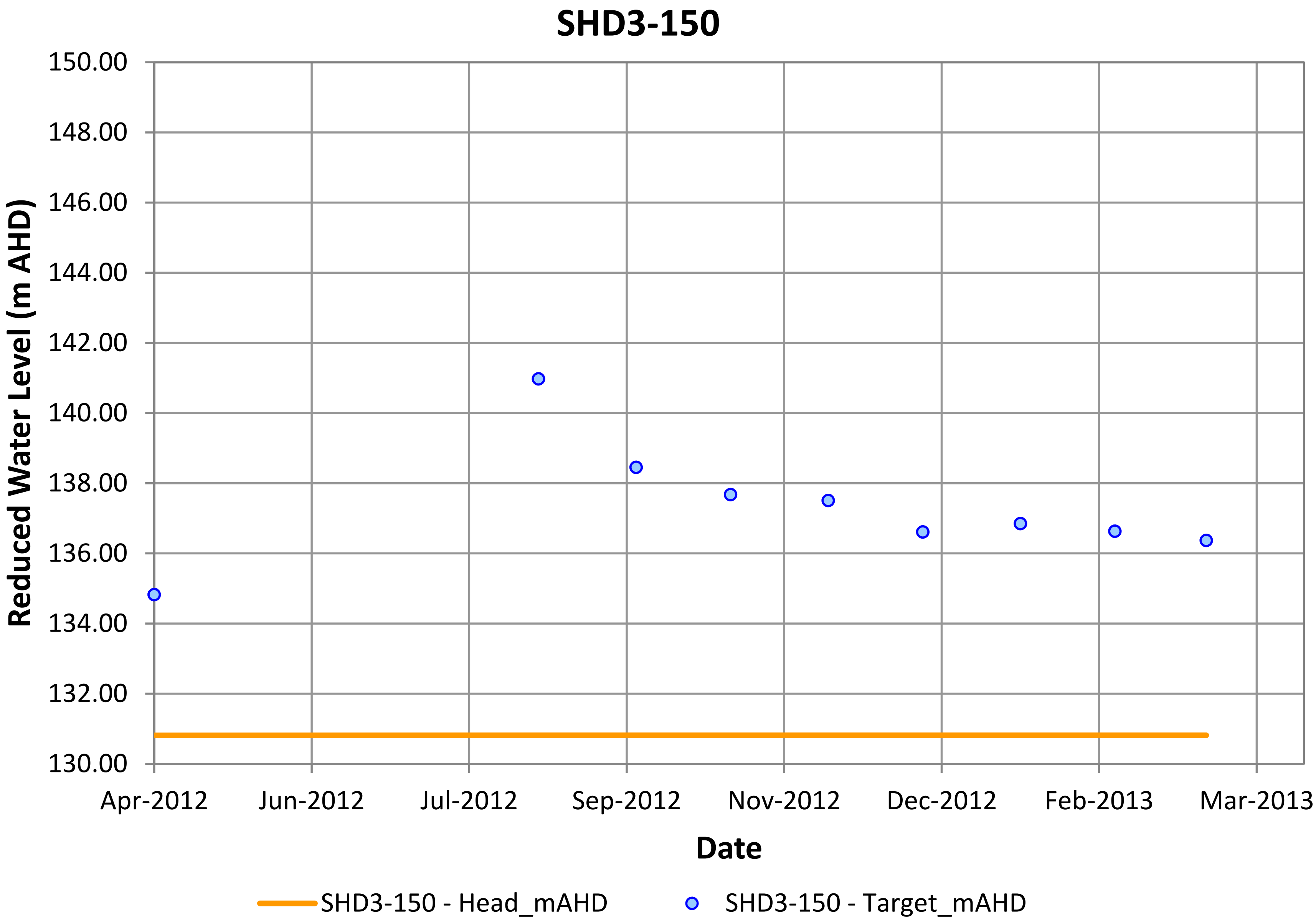

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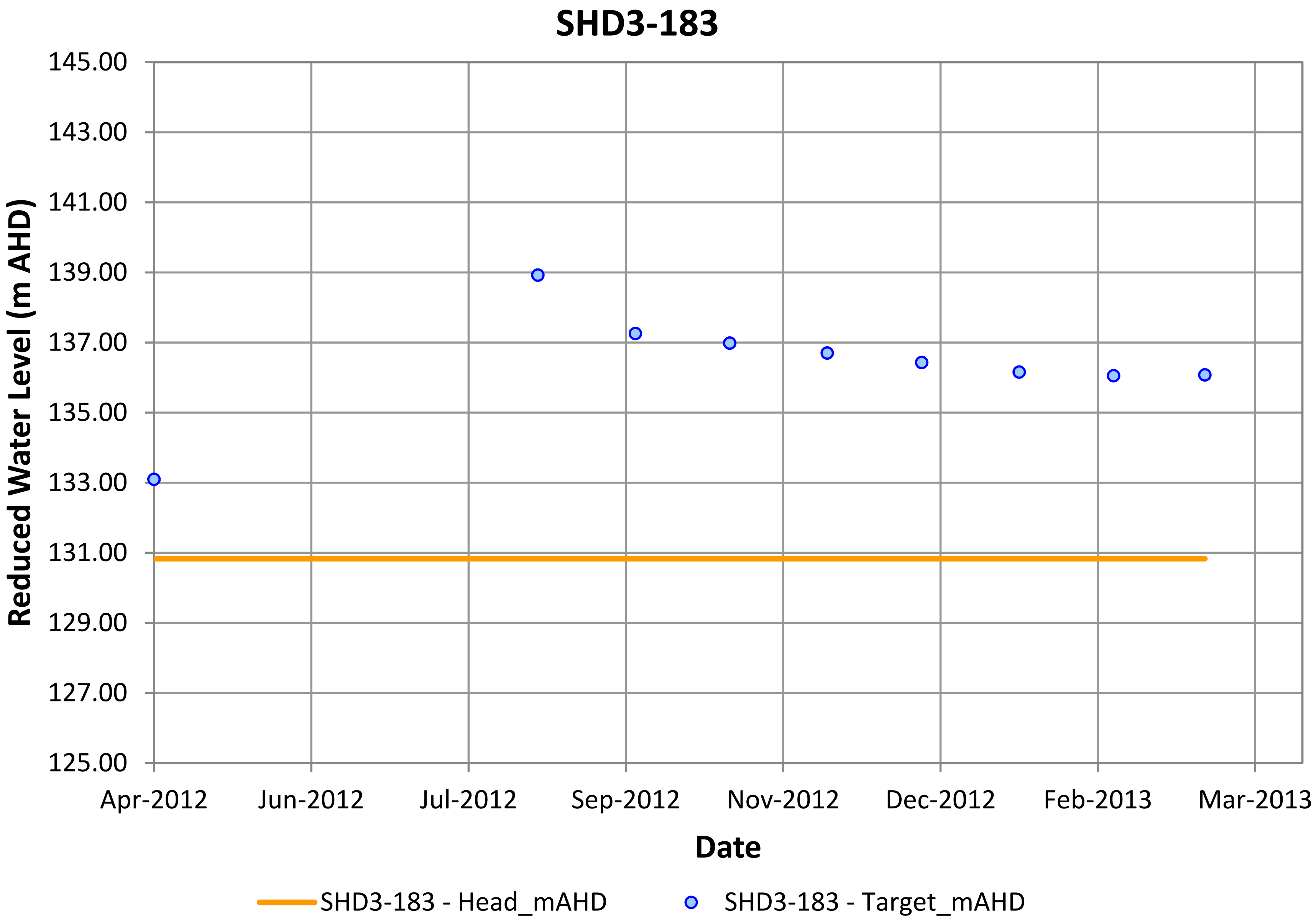

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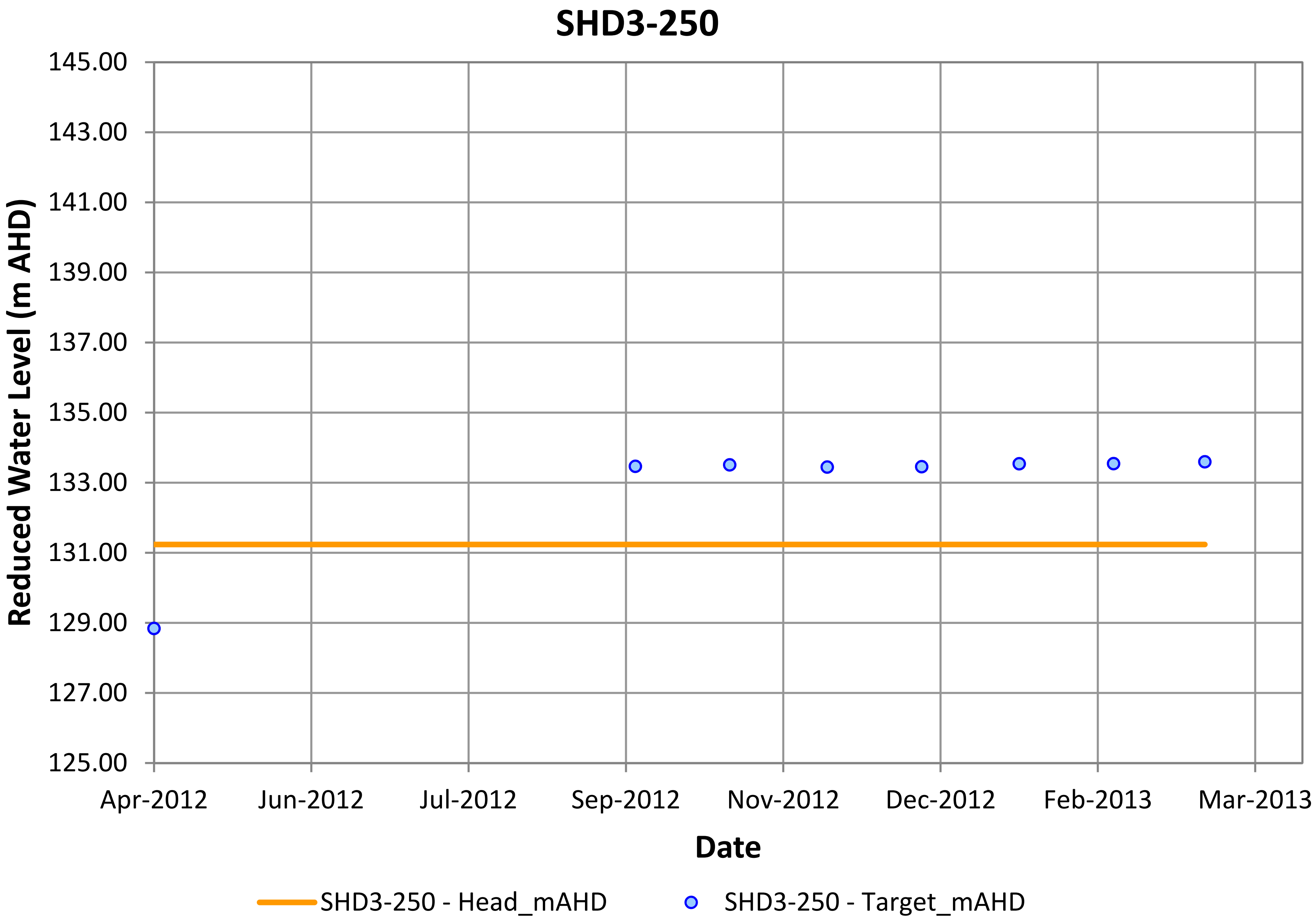

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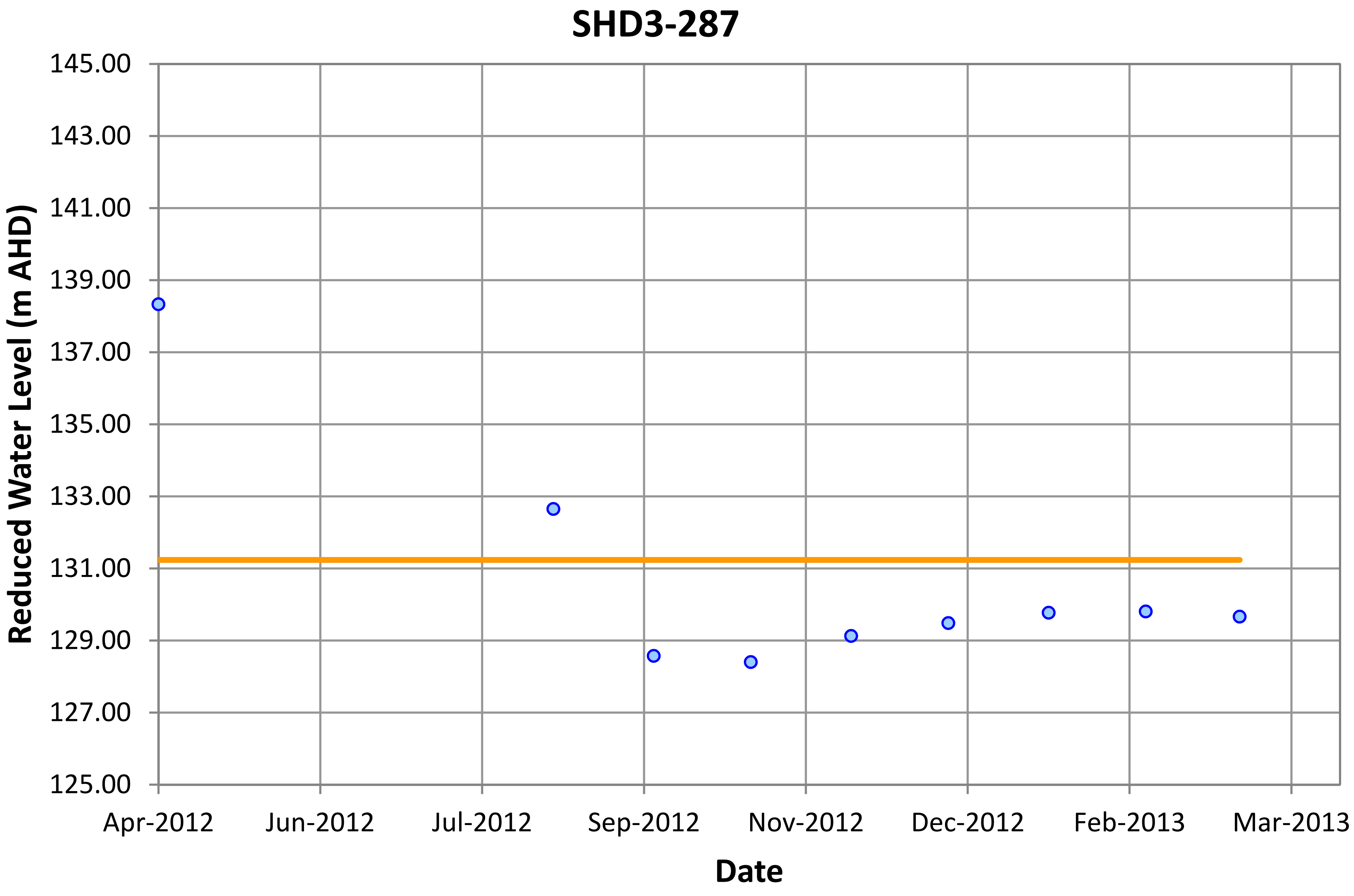

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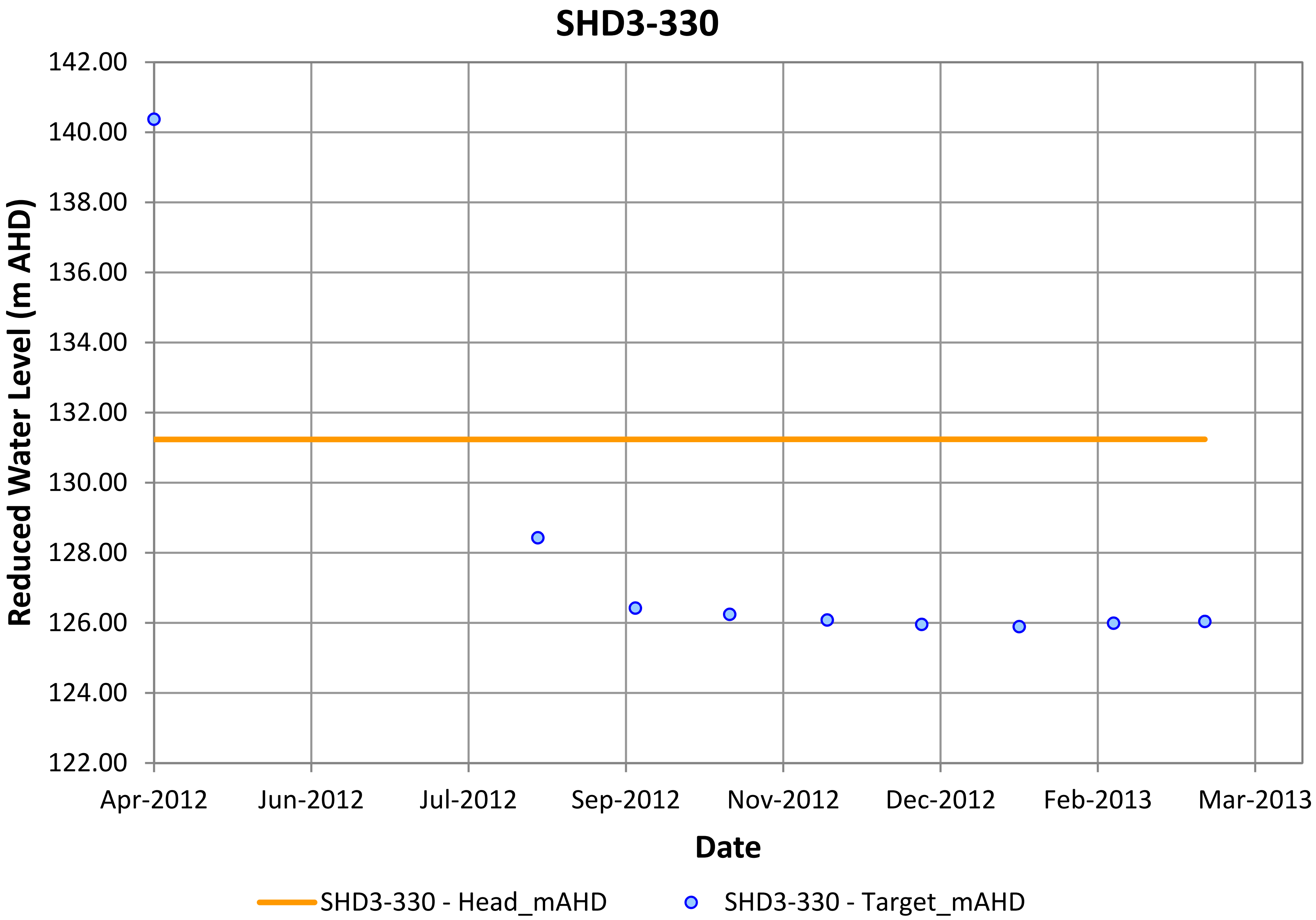

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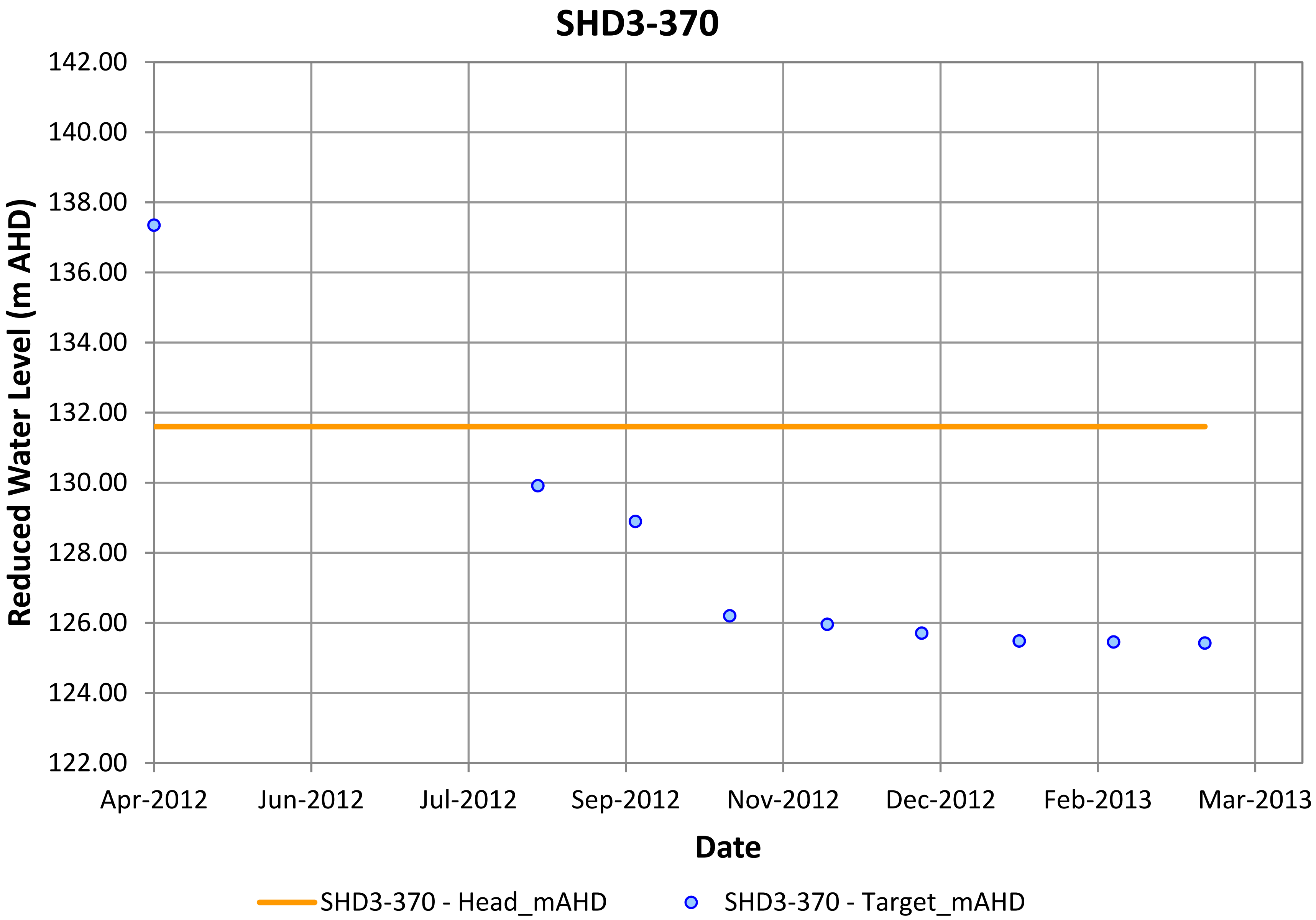

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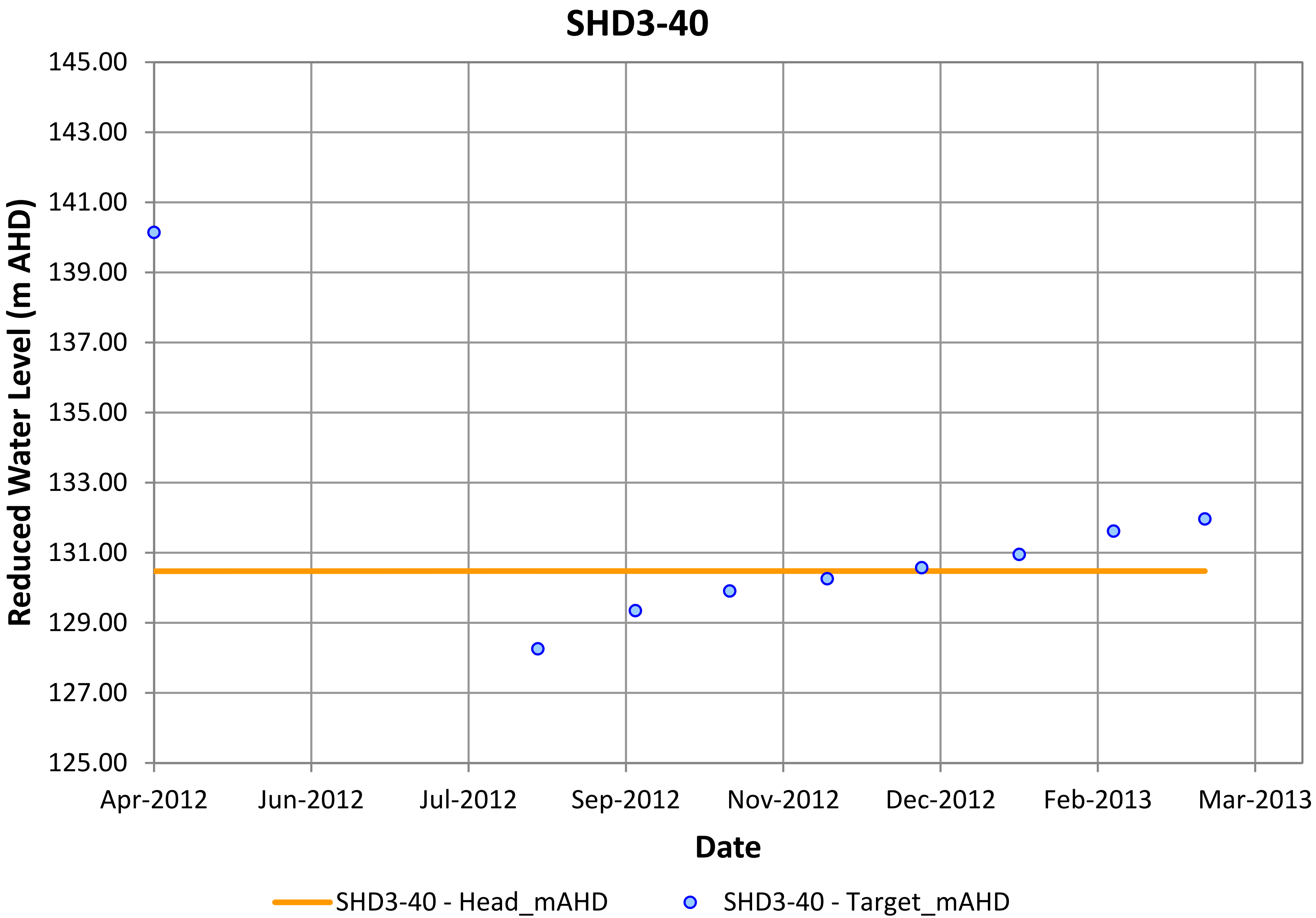

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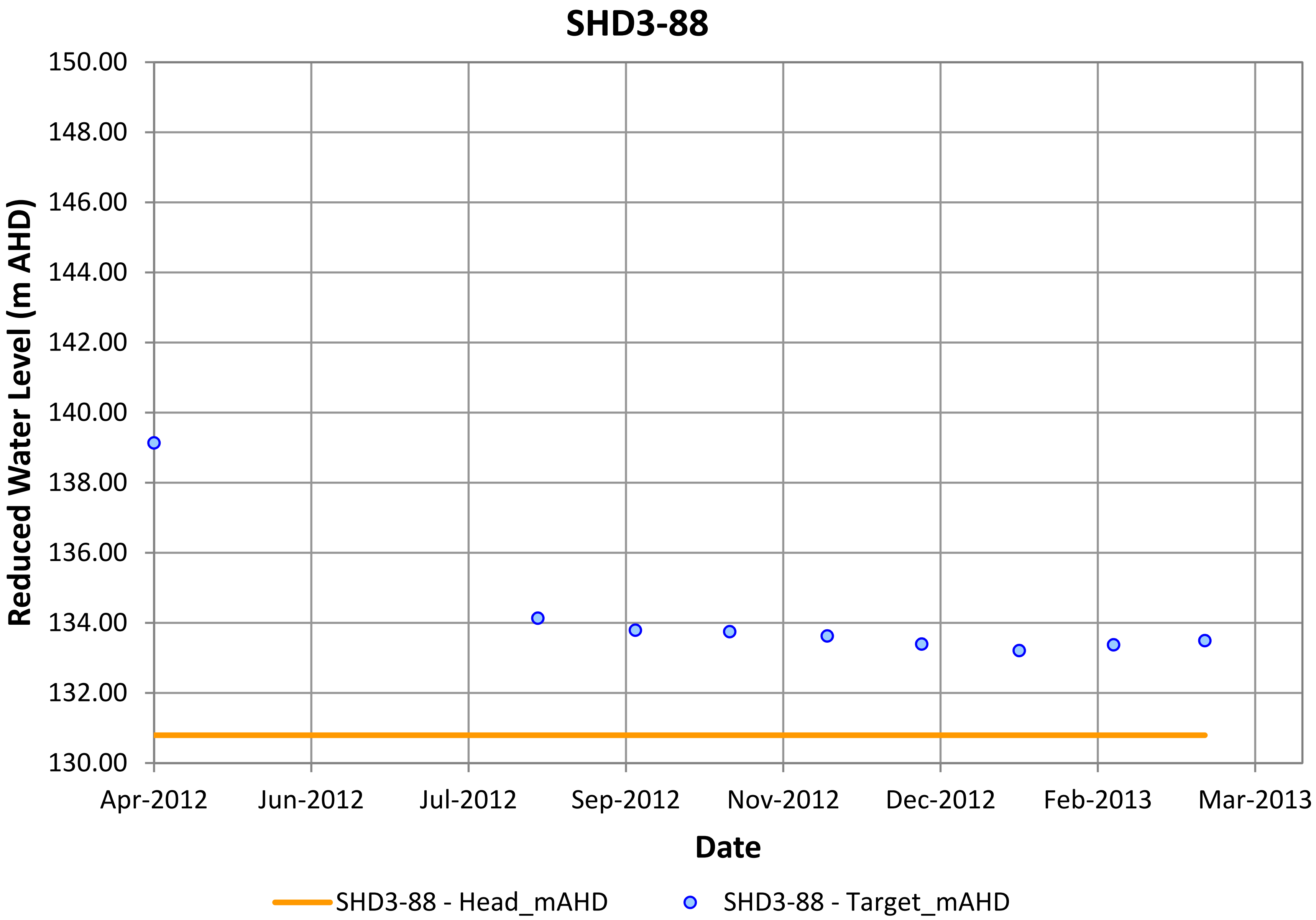

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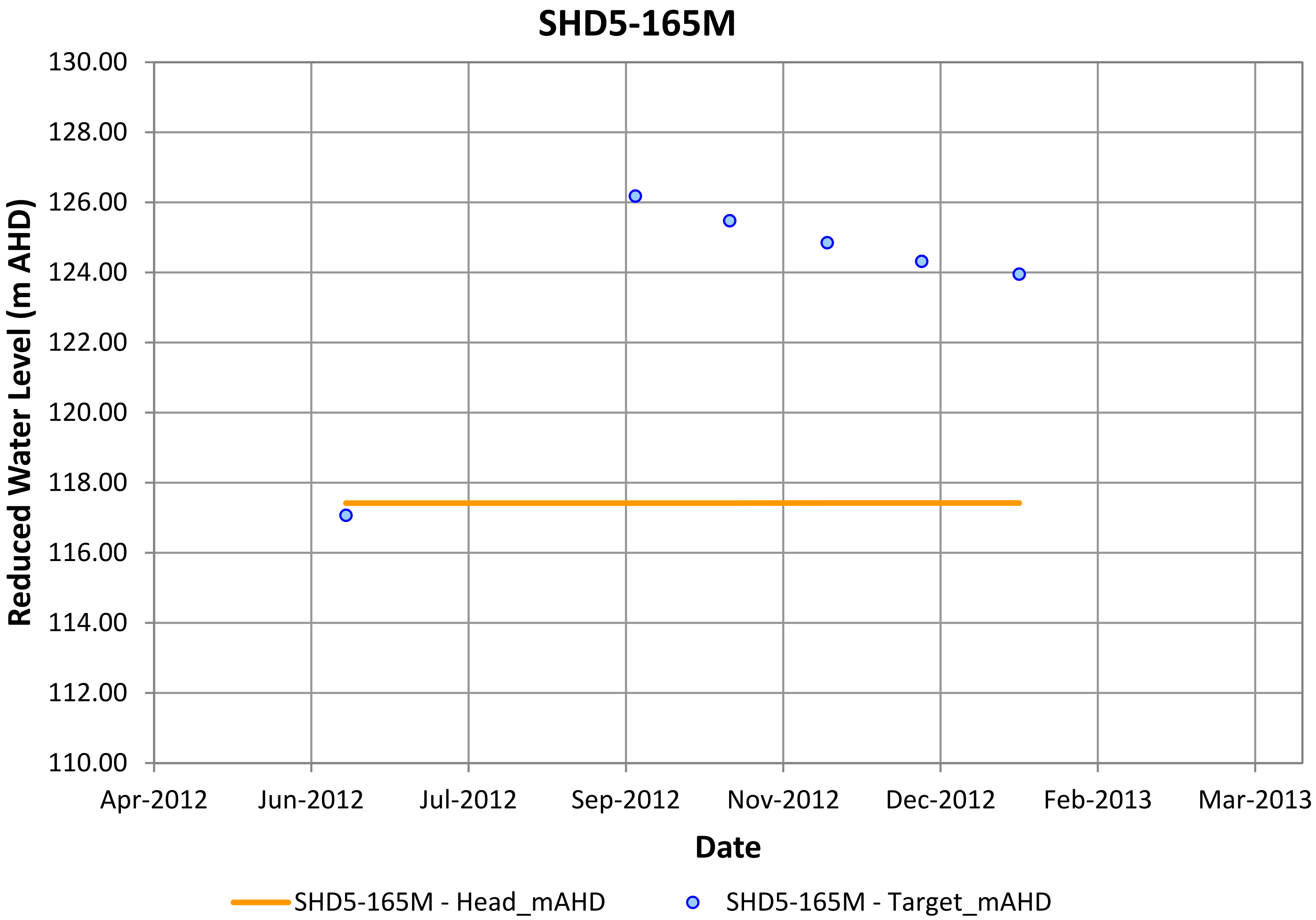

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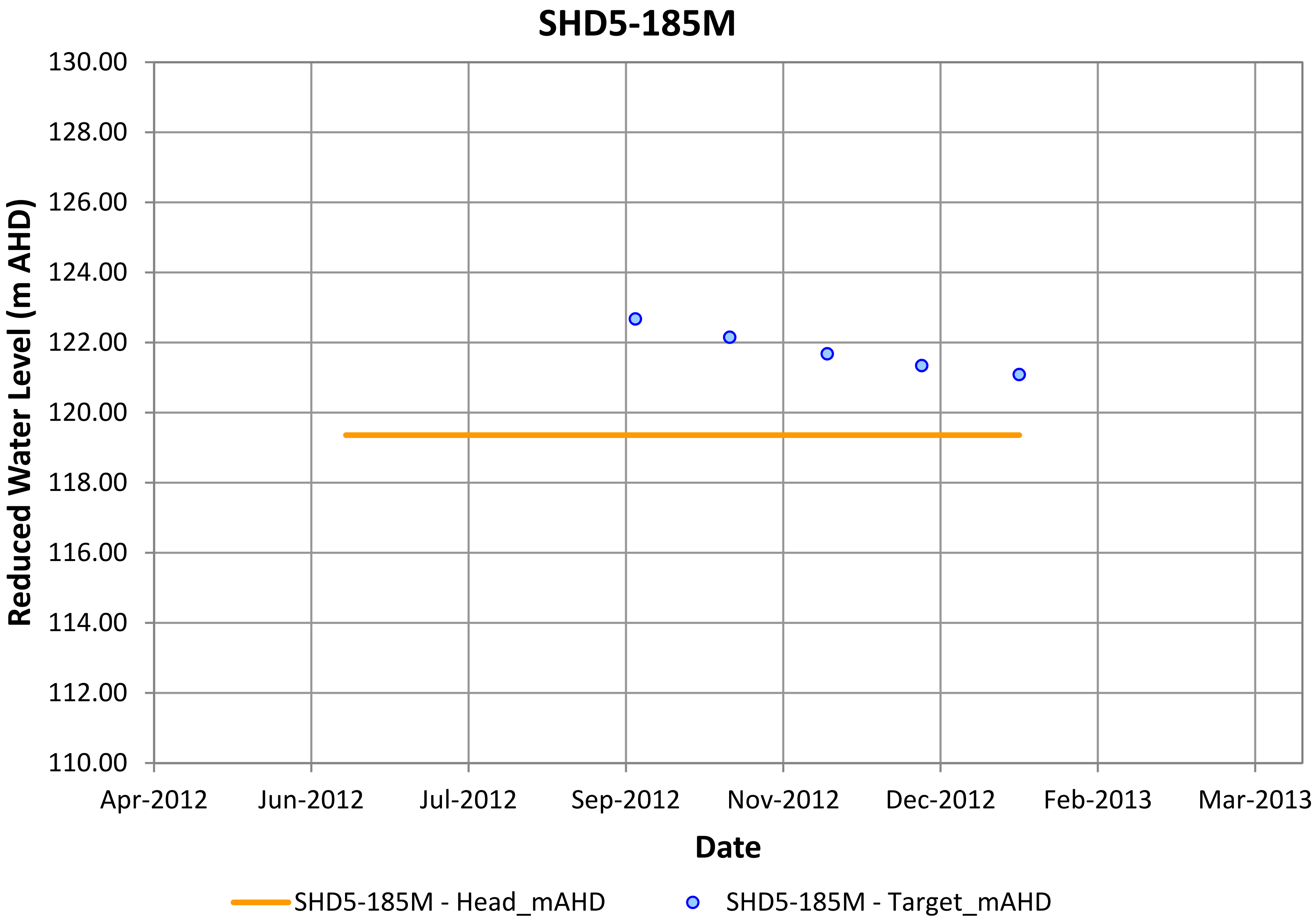

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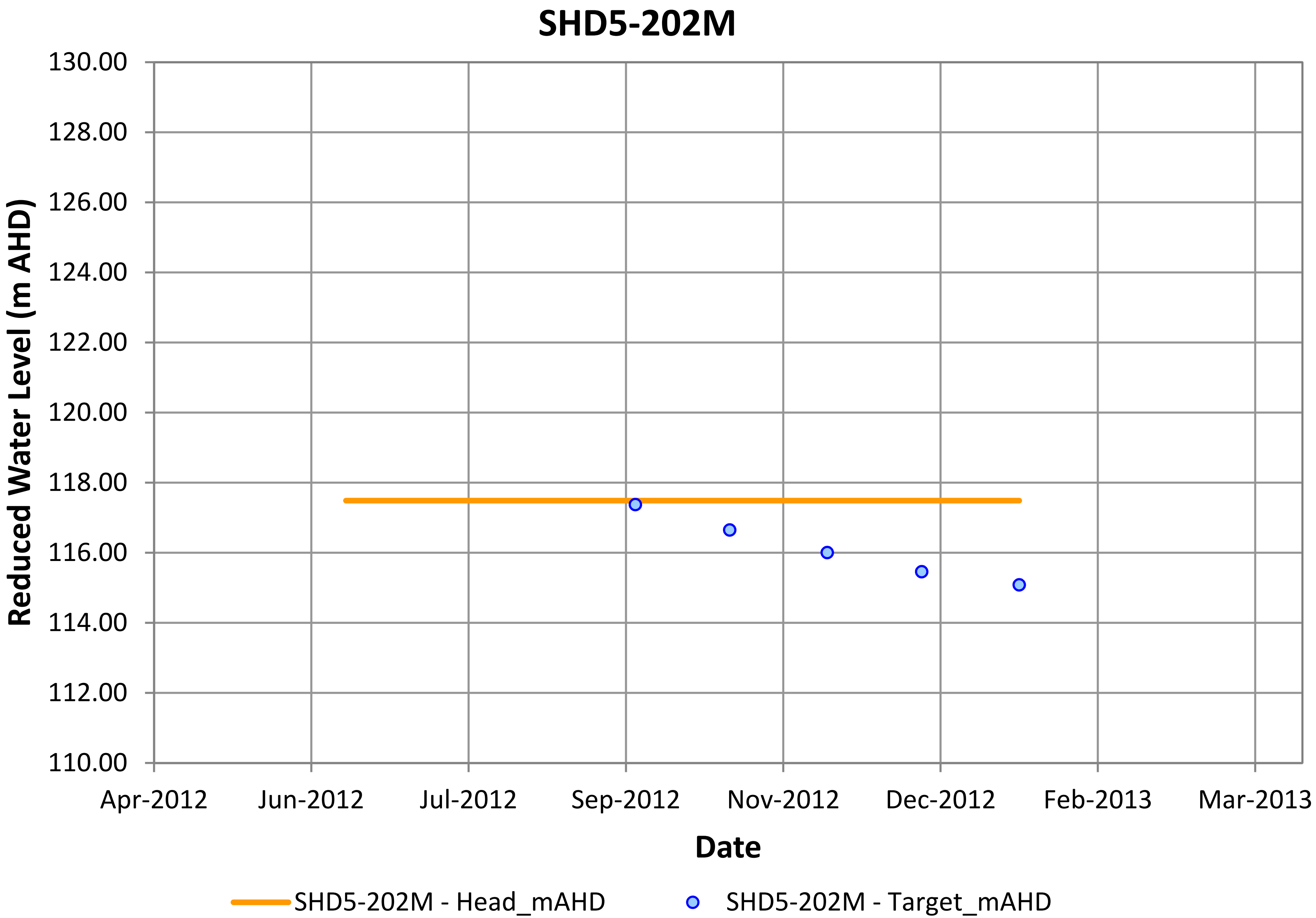

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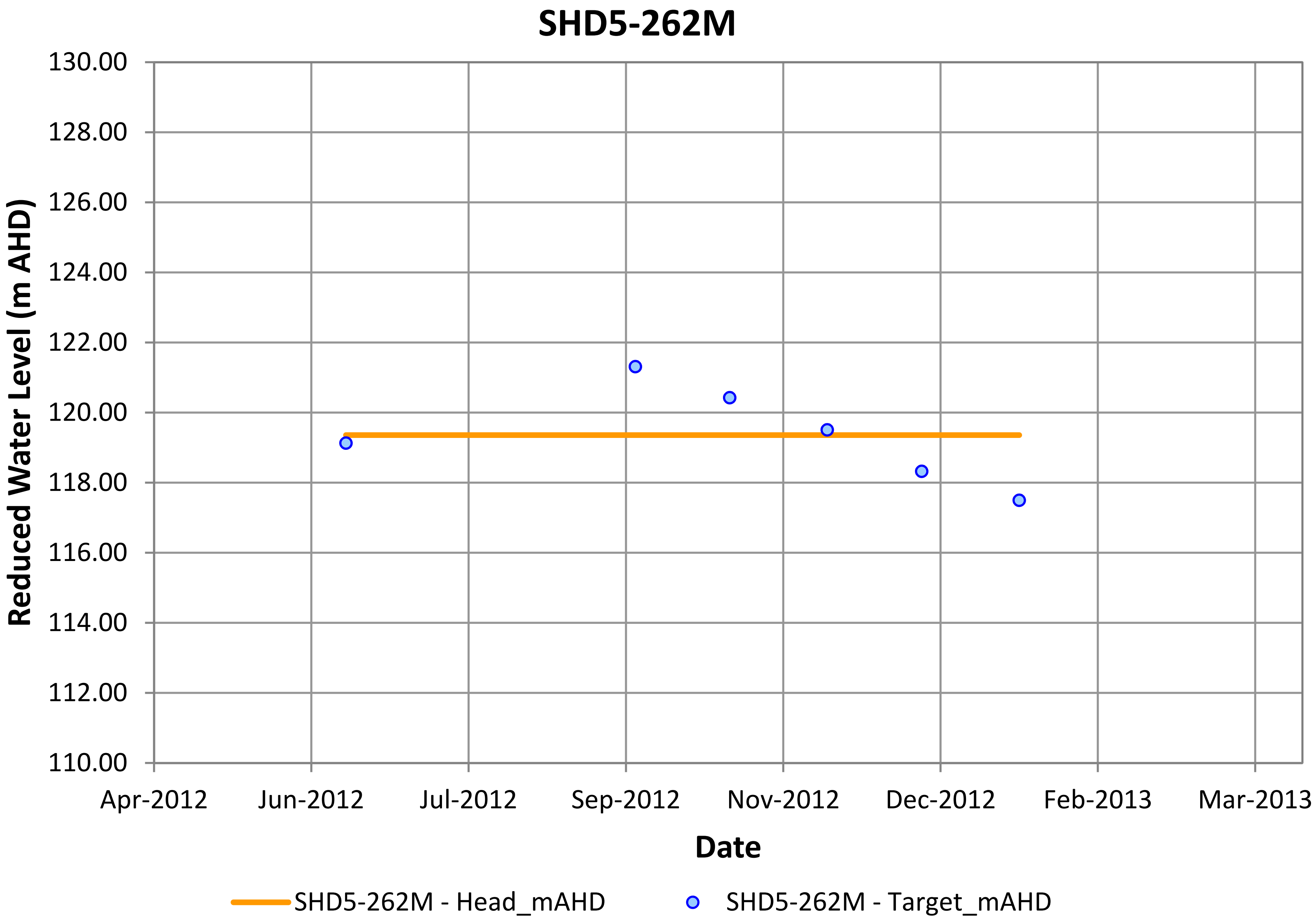

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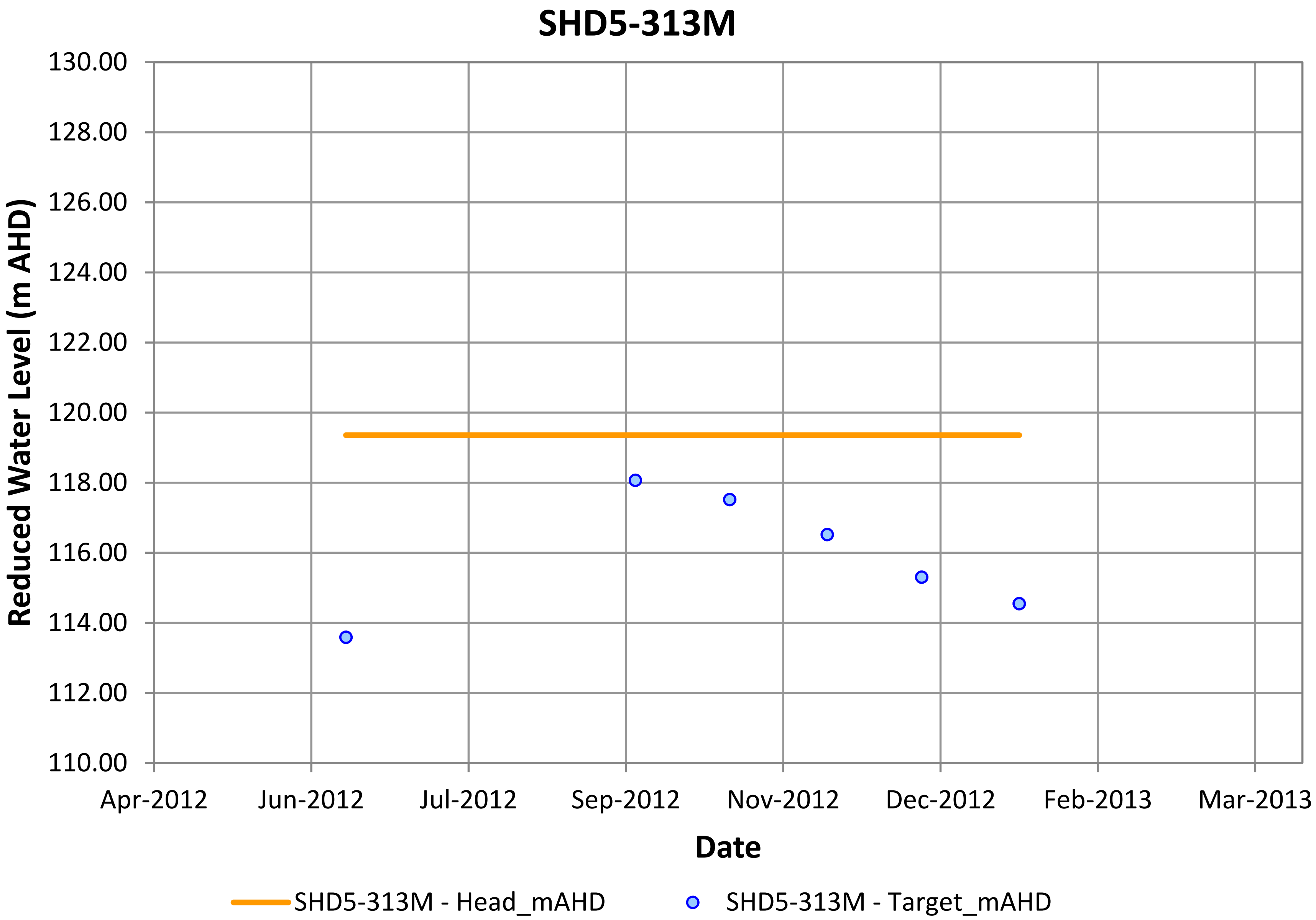

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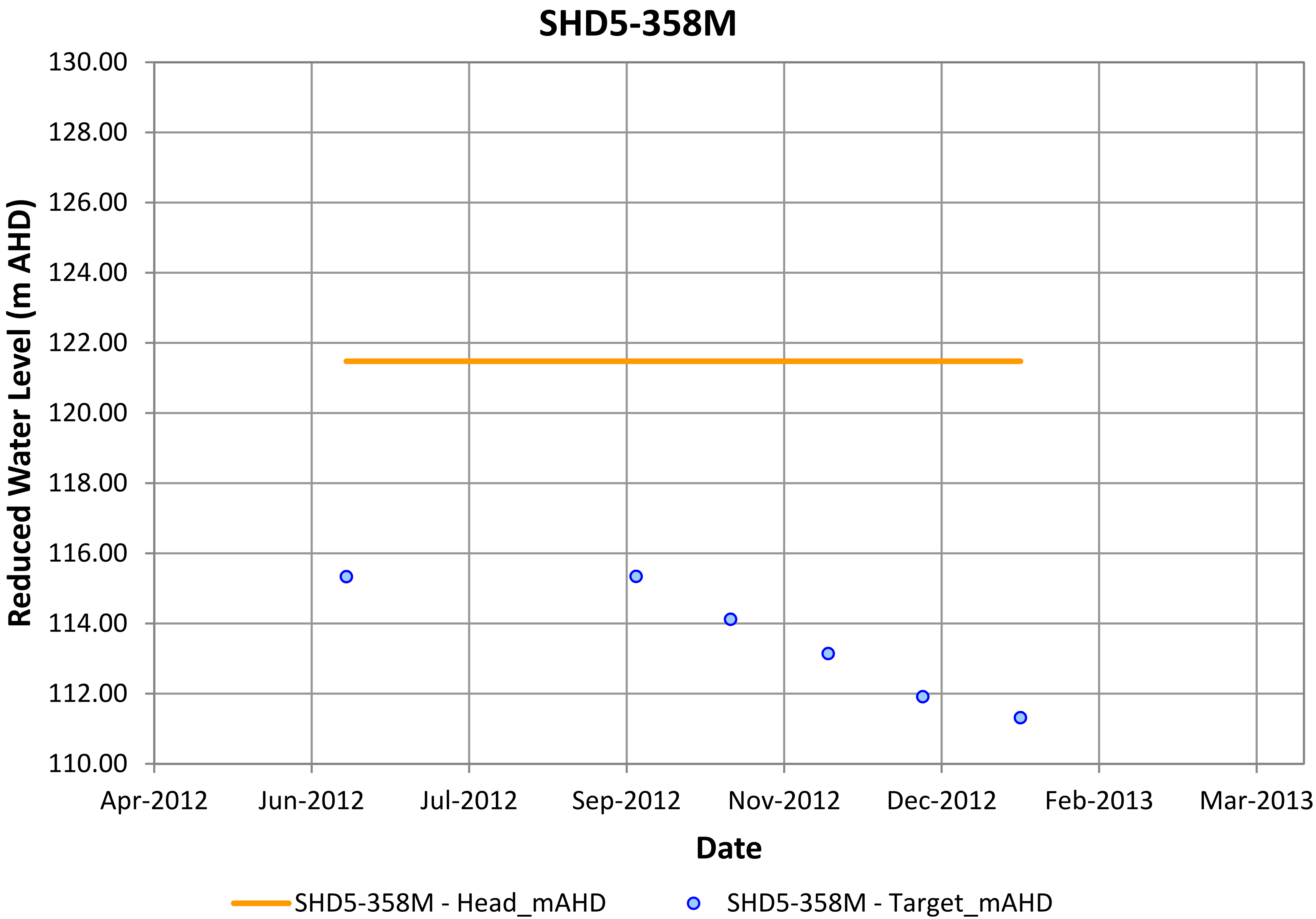

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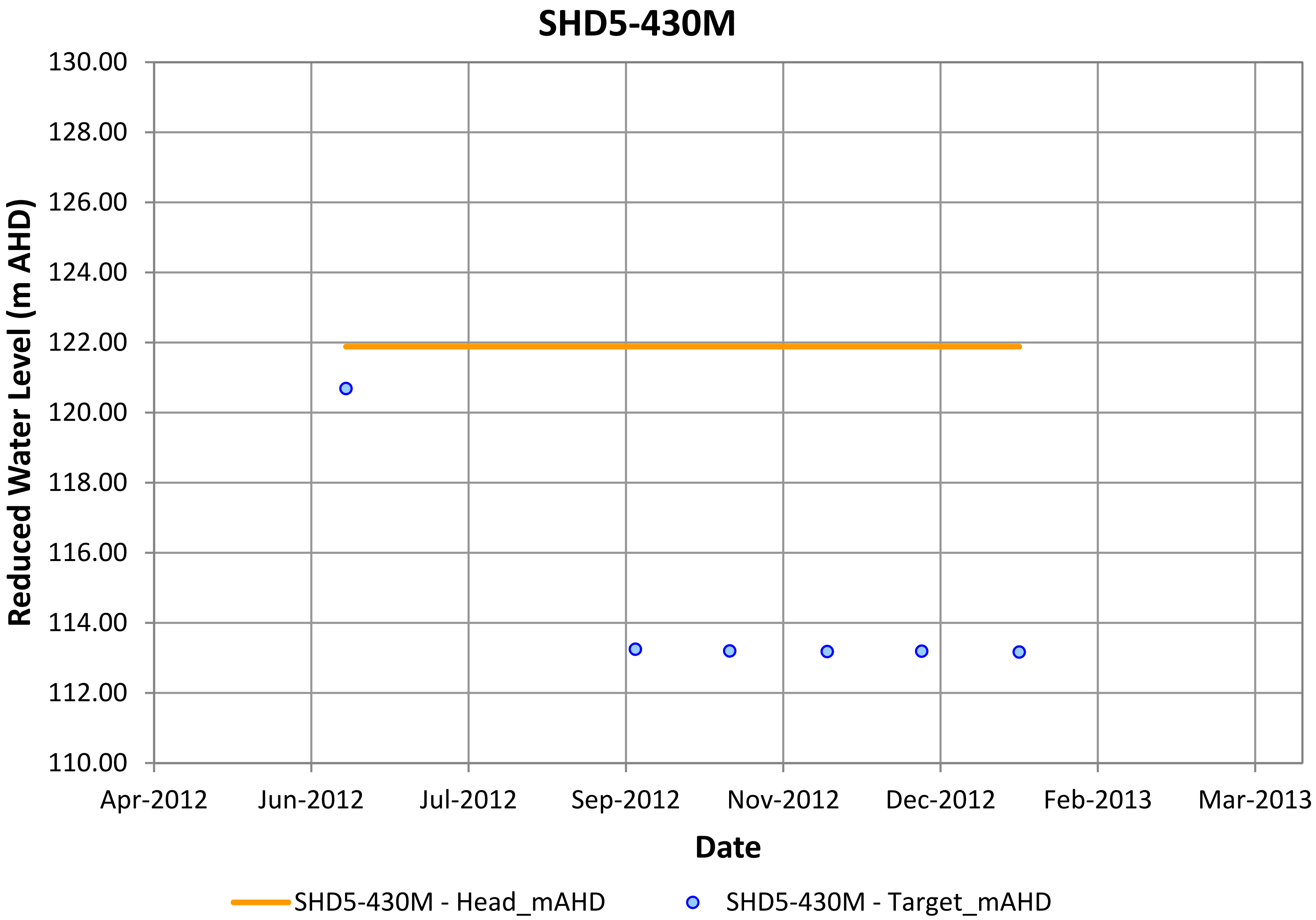

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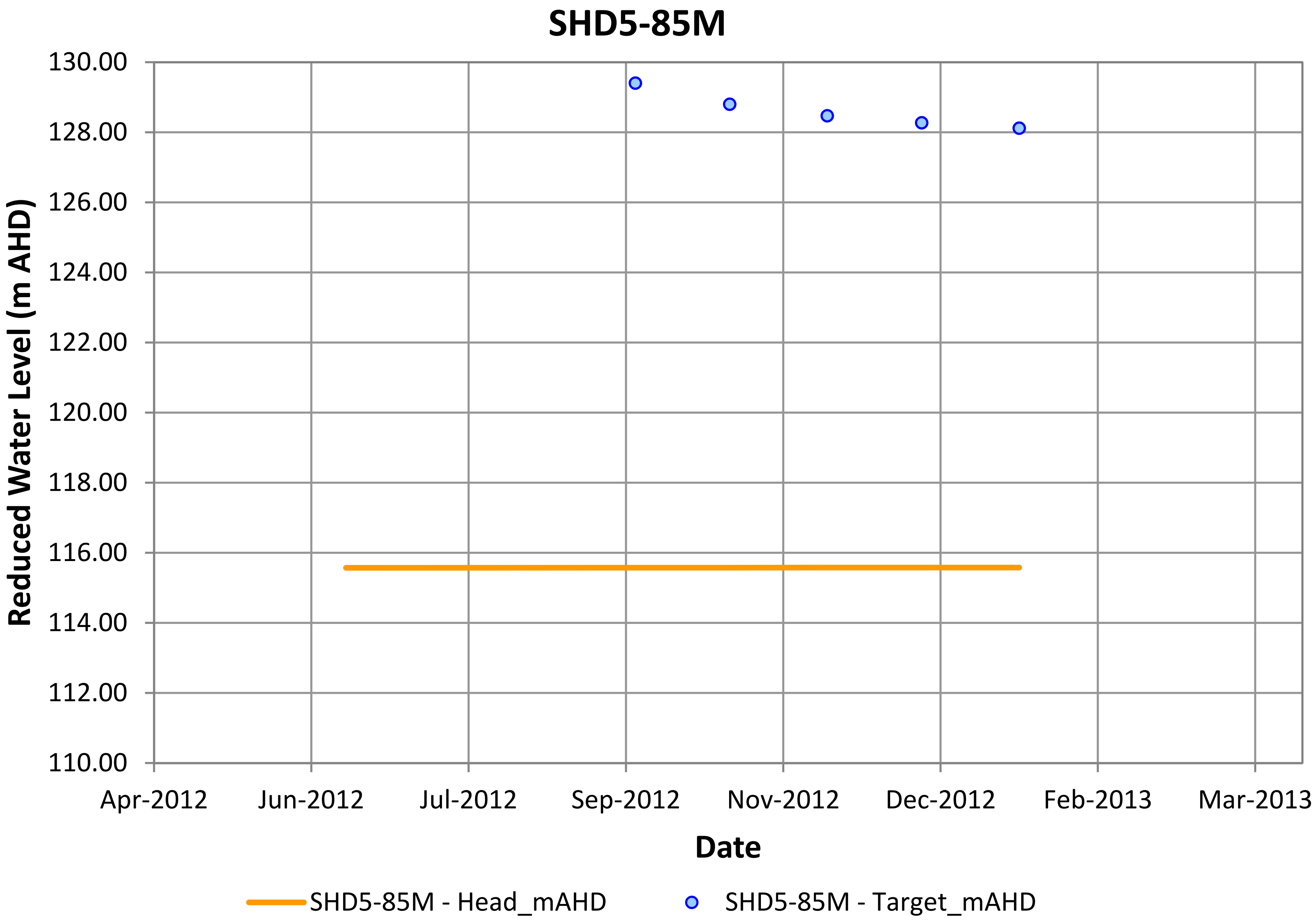

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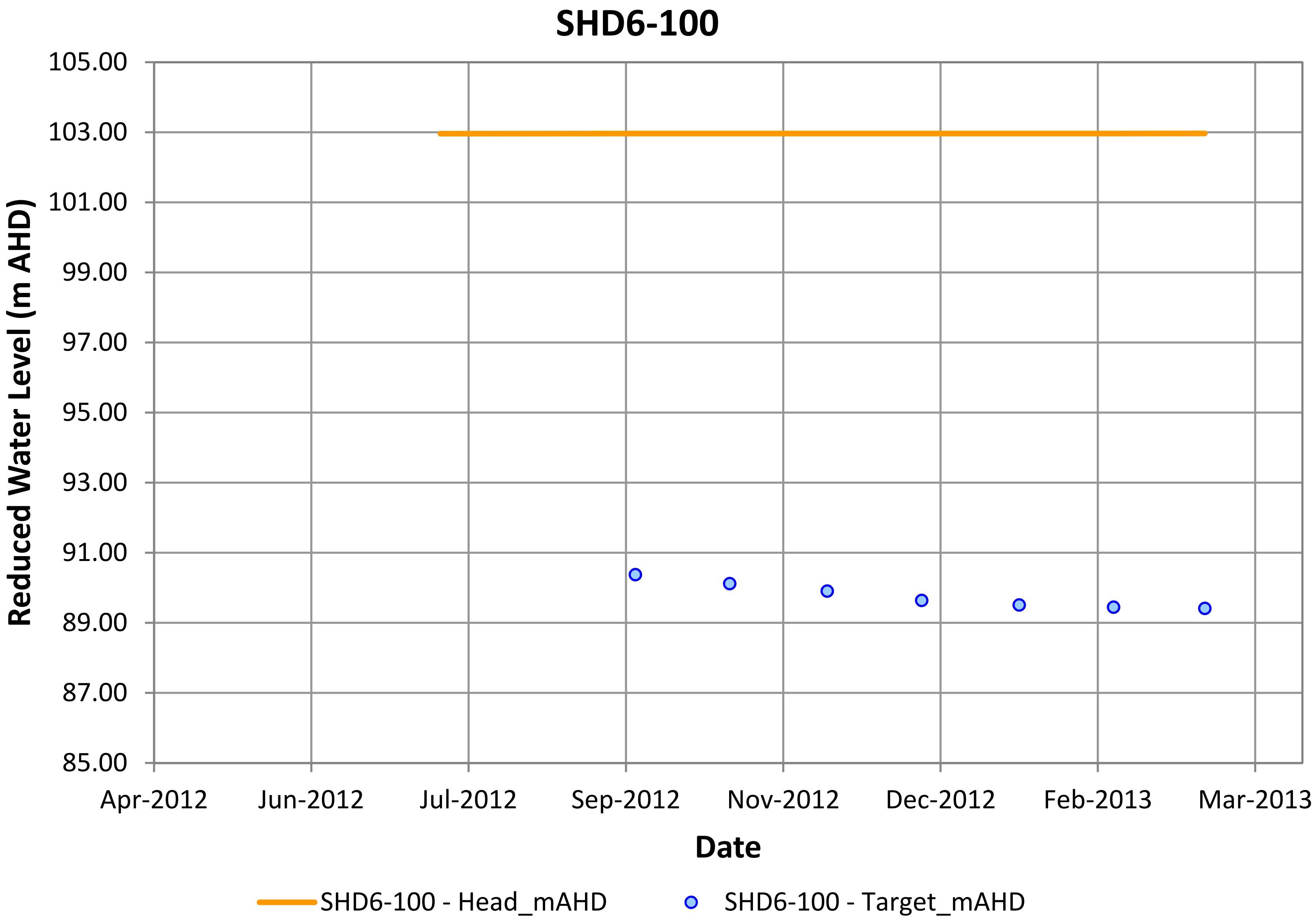

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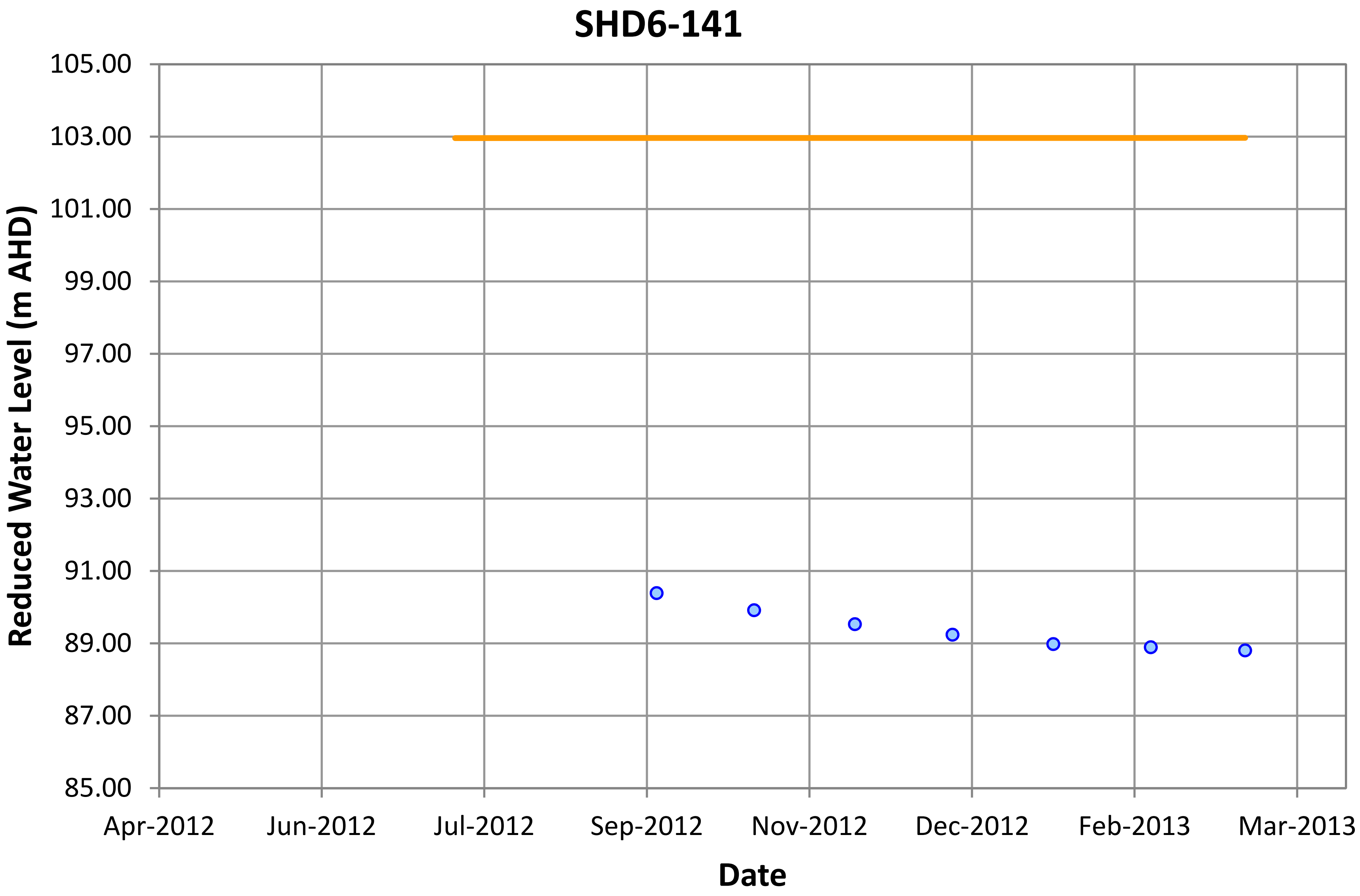

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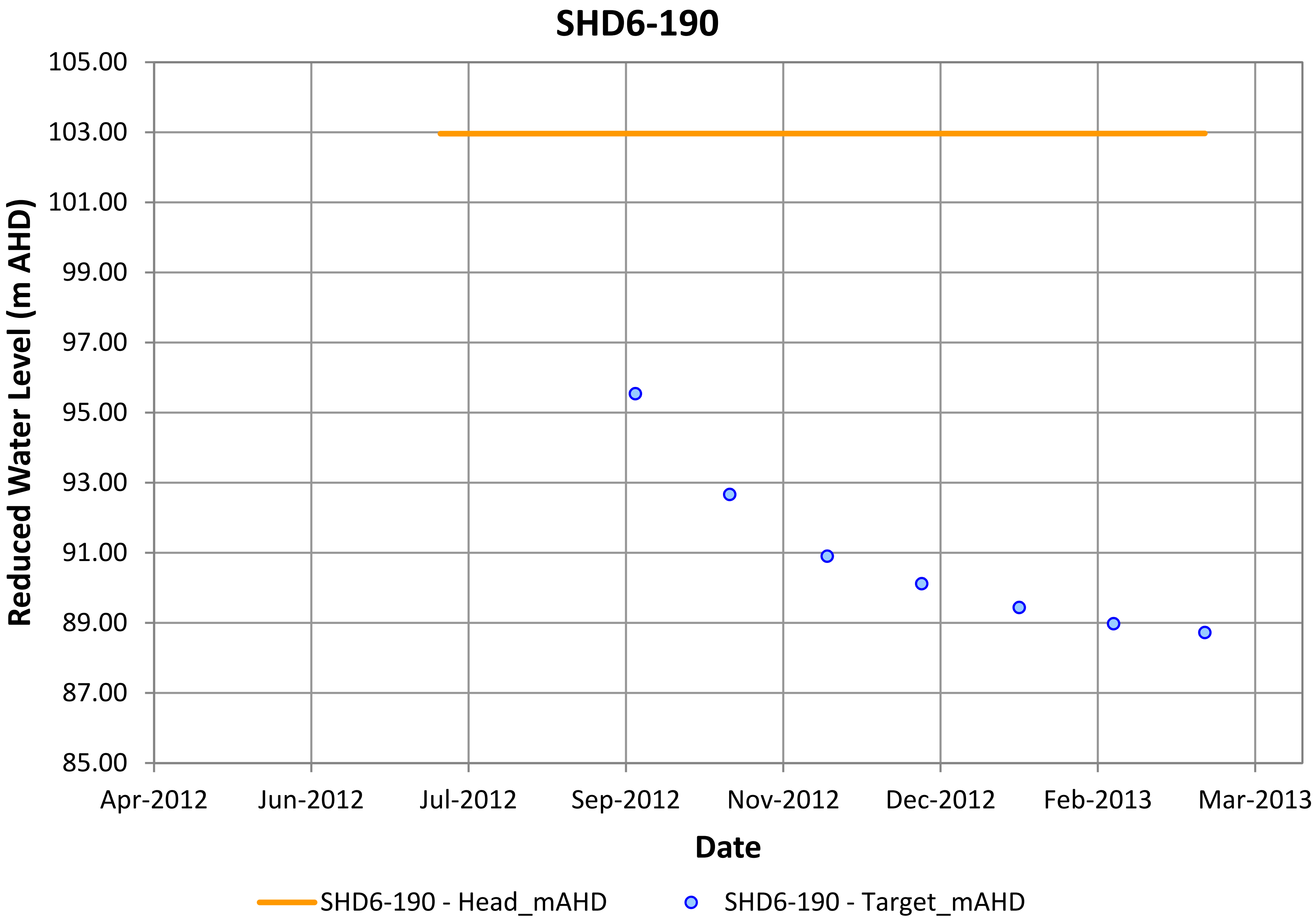

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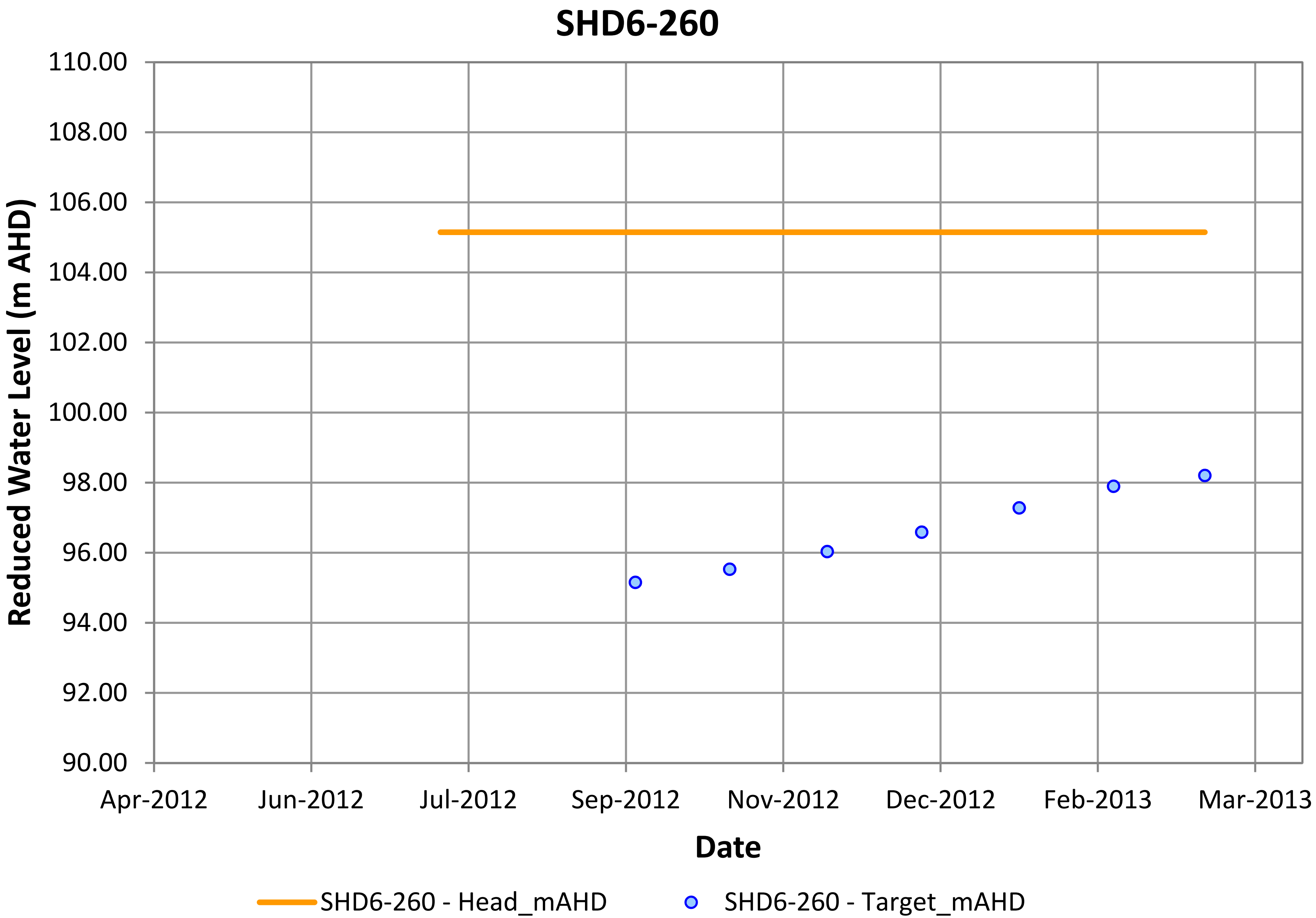

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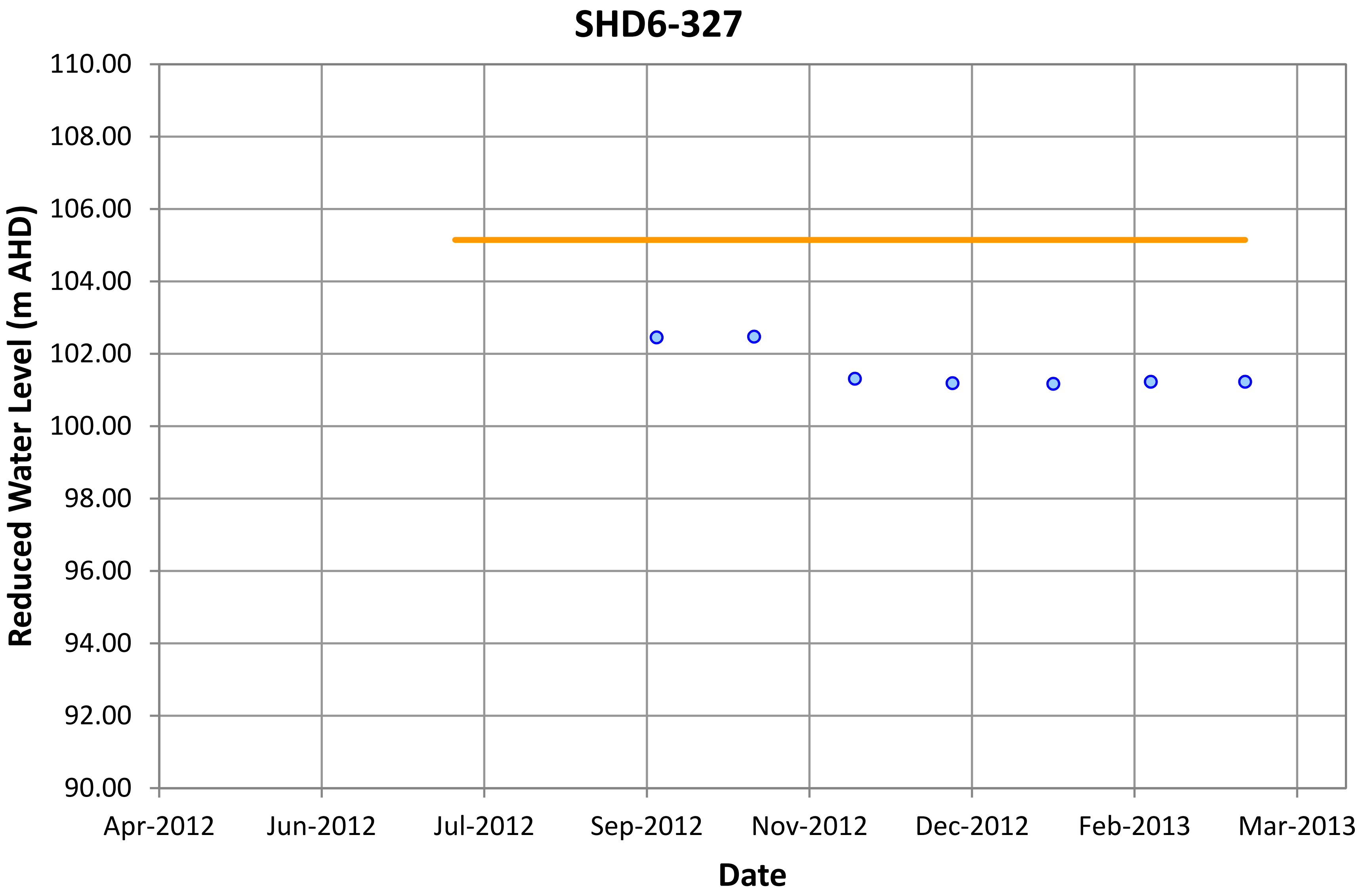

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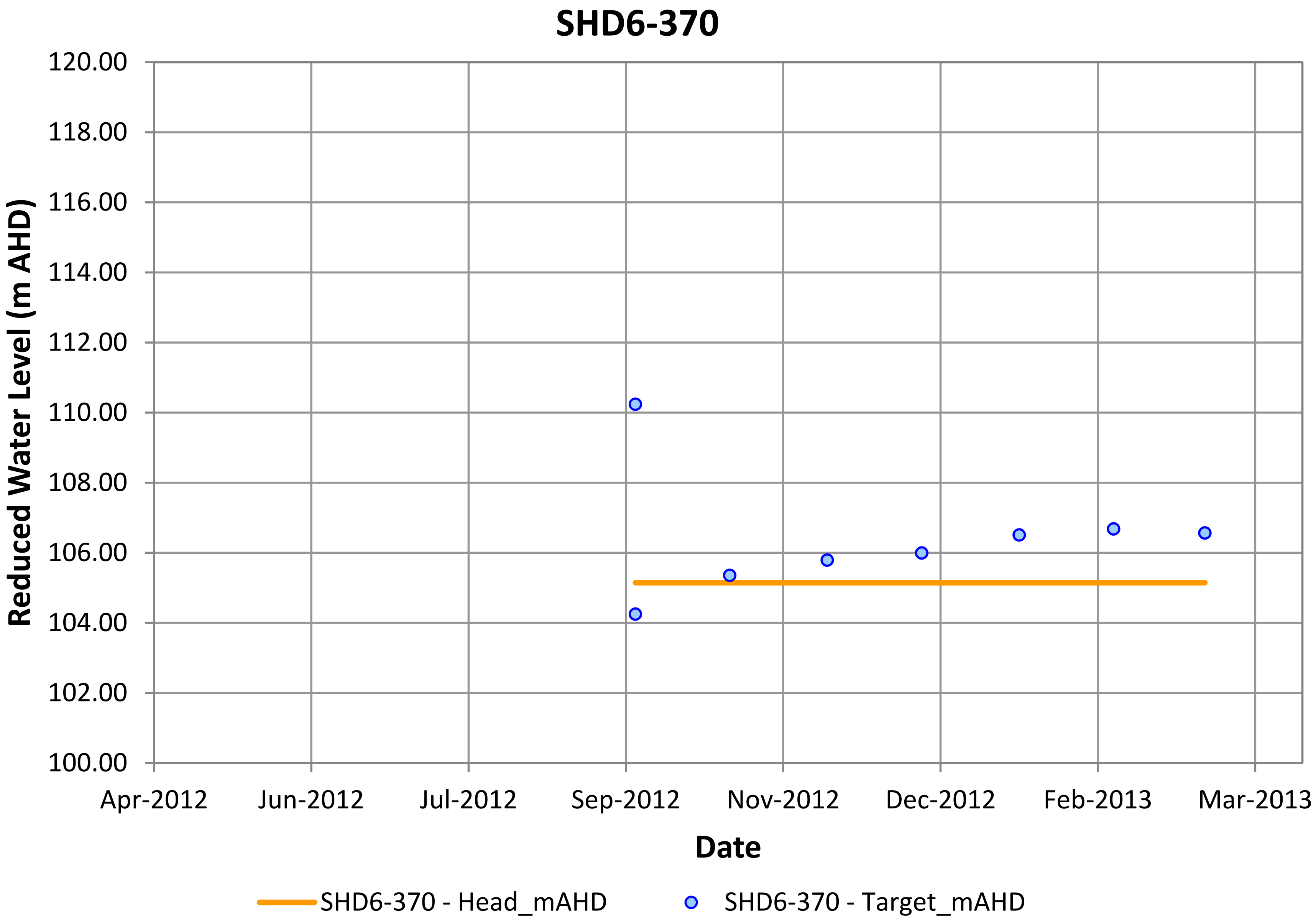

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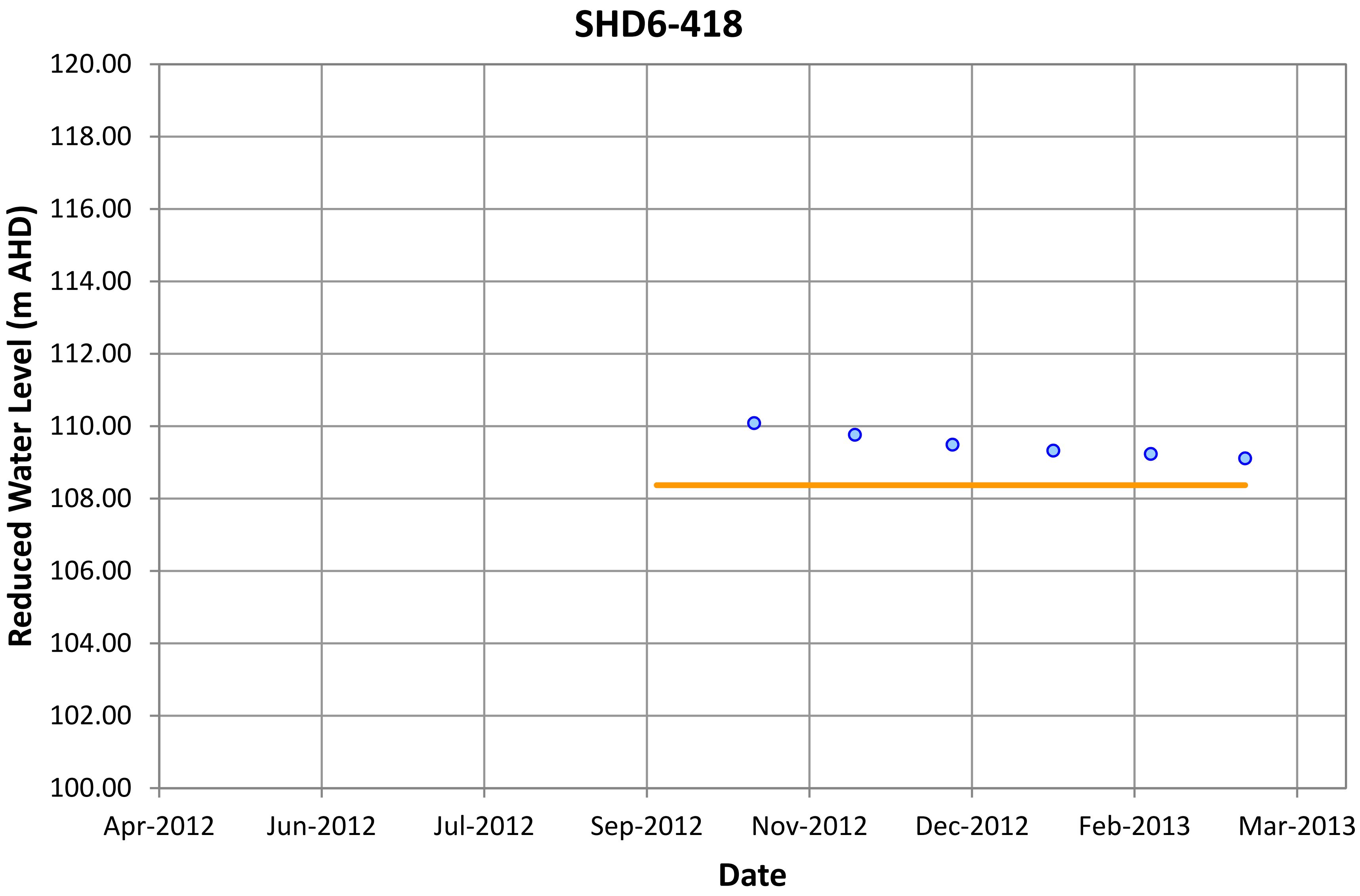

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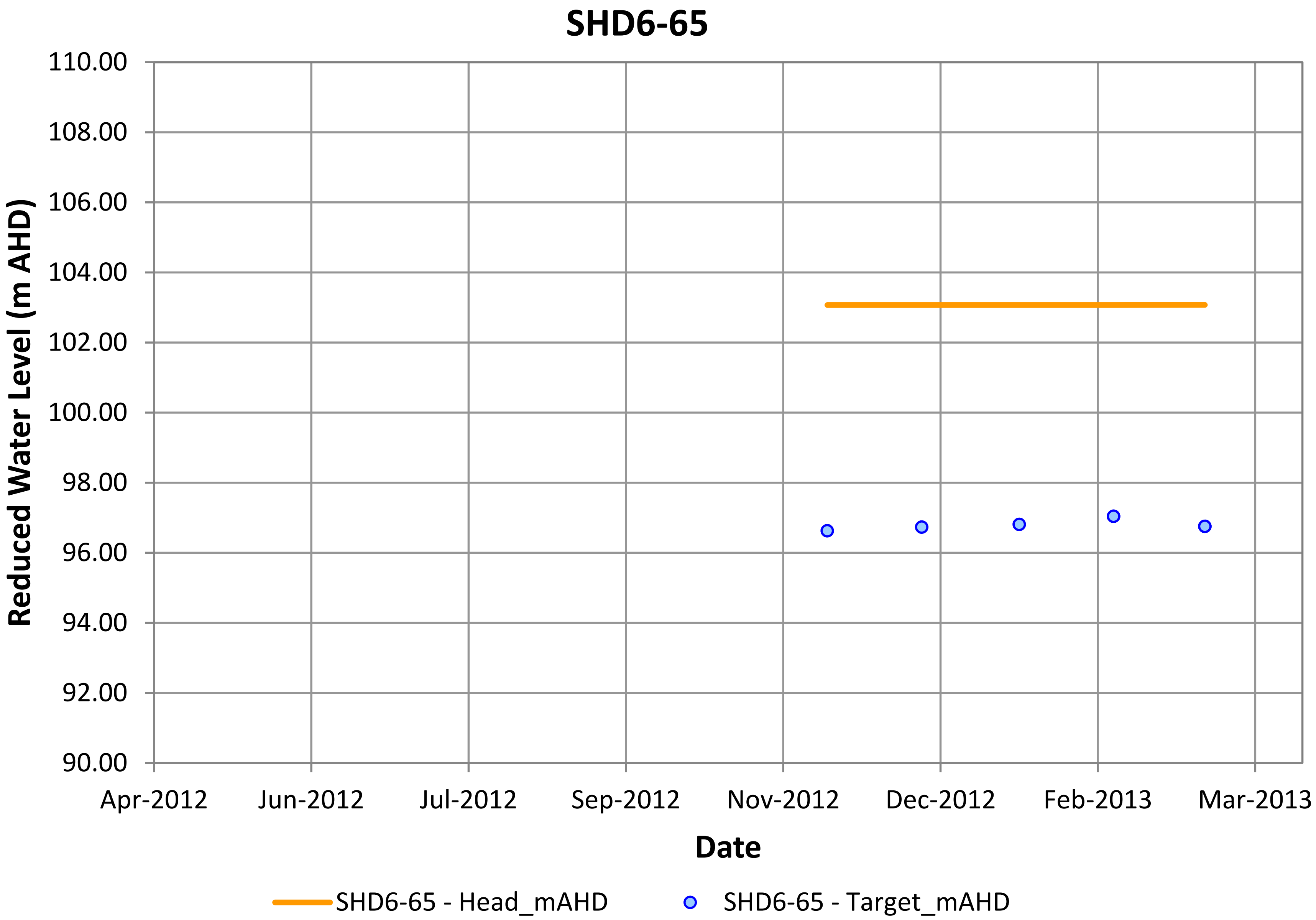

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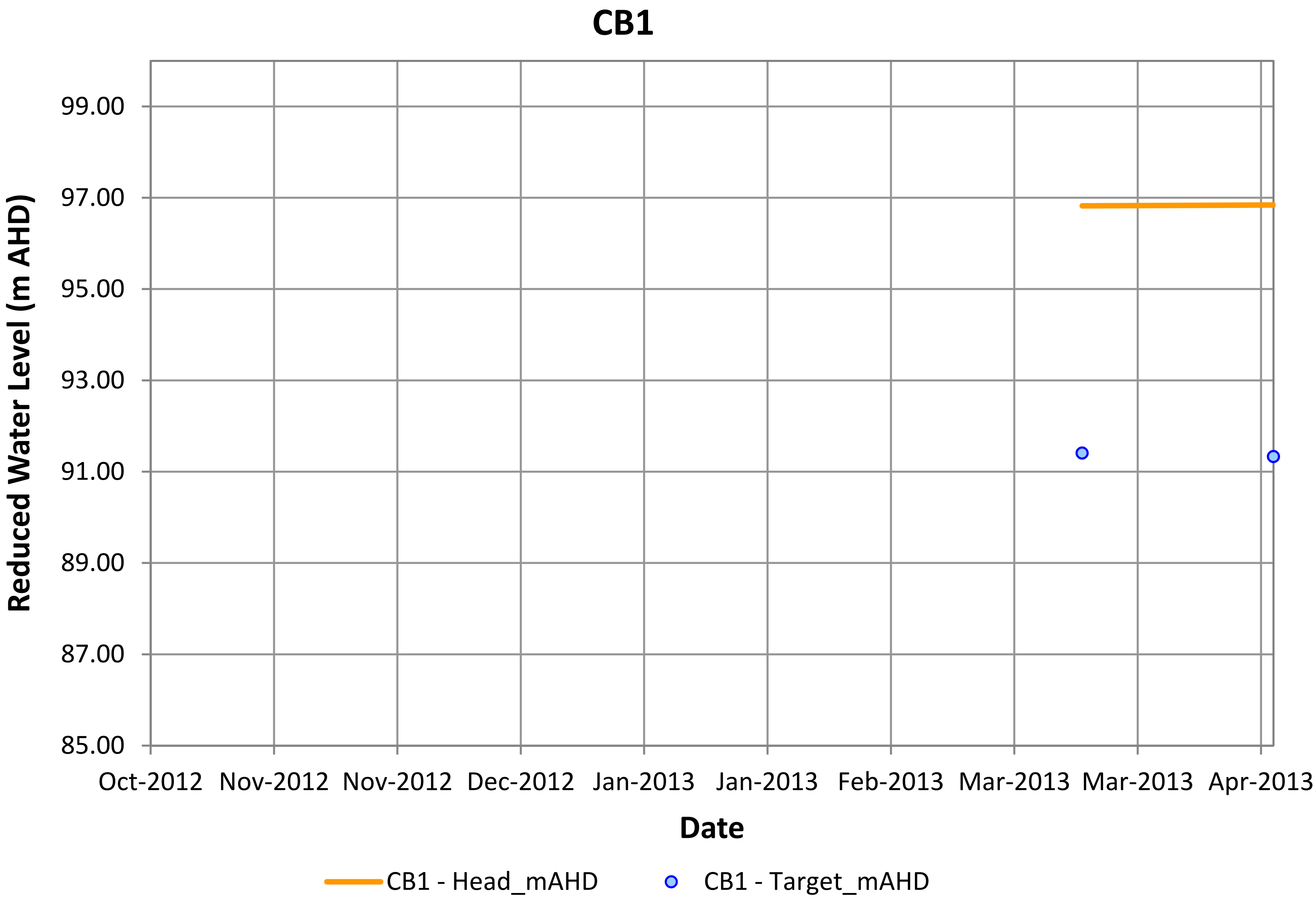

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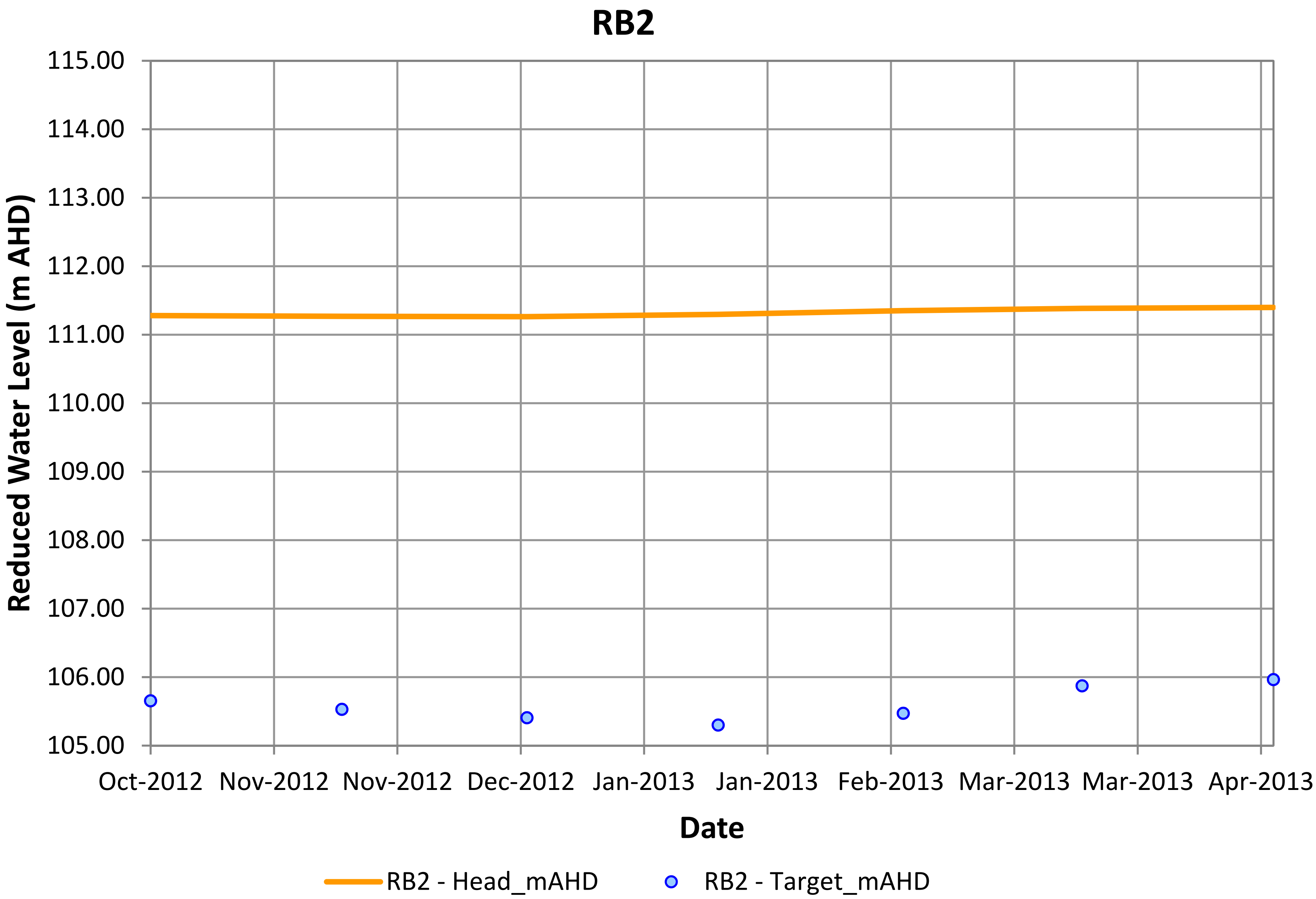

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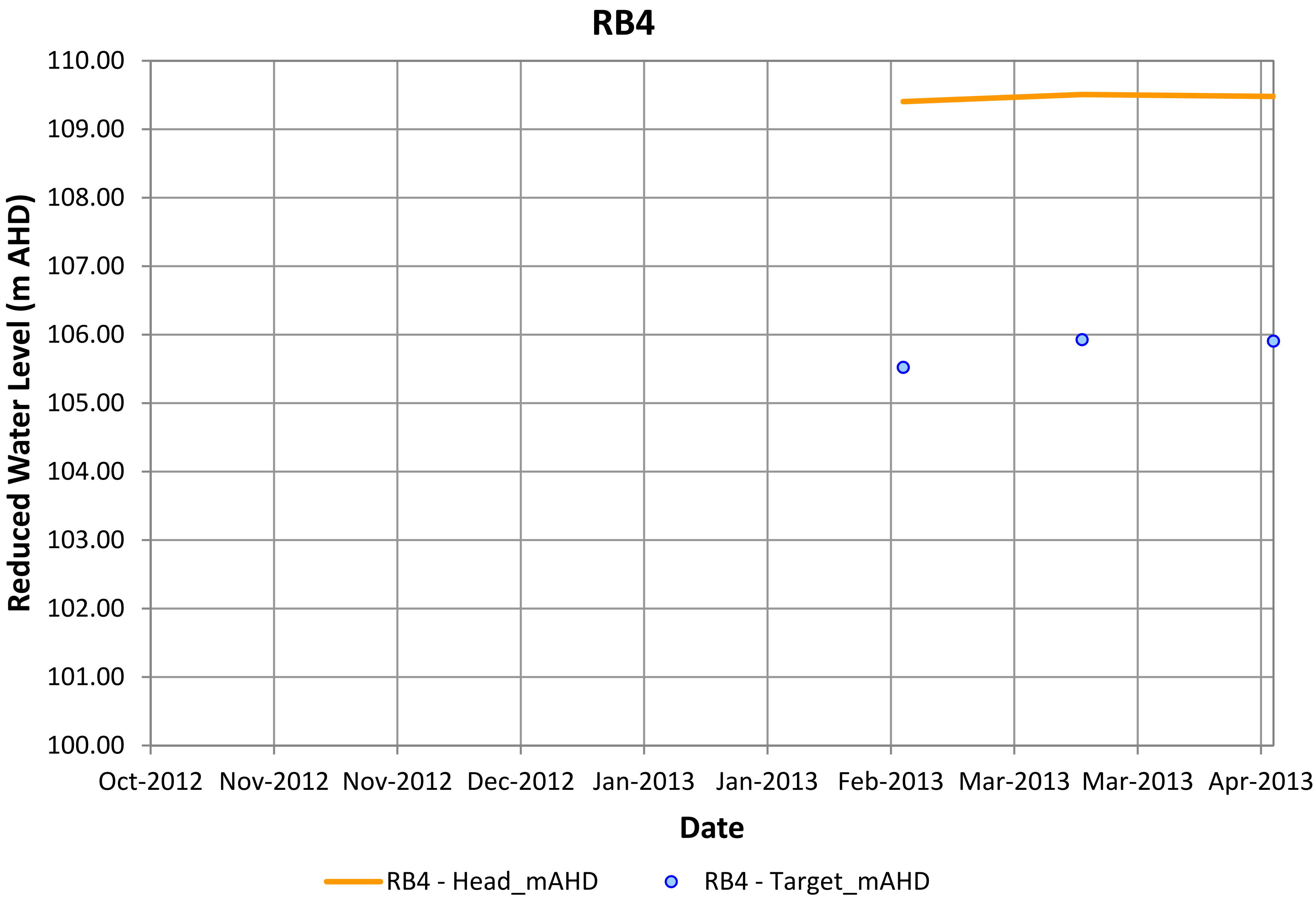

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