

Appendix G3
Geochemical Modeling Assessment



deposits from previous courses of Malibu Creek and to be hydraulically connected to the Pacific Ocean (evidence developed during our study corroborates this connection). The CCG in the project area is between approximately 90 to 110 feet thick and generally comprised of varying amounts of interbedded clay, silt, sand and gravel. The CCG is overlain by varying thicknesses of discontinuous low-permeability clayey aquitard materials, which provide varying degrees of confinement to the aquifer, and is underlain by Tertiary-age bedrock formations which form the base of the aquifer.

AS-BUILT WELL CONSTRUCTION

The three test wells utilized for the pilot injection testing were drilled, constructed and production tested in 2011 as part of the Phase 1 investigation² to assess the distribution, thickness, and hydraulic properties of the CCG aquifer. The locations of the test wells are shown on **Figure 1 – Test Well Location Map**. Summary lithologic logs and as-built construction diagrams are shown on **Figure 2 – Well Construction Diagrams and Generalized Lithologic Logs**. A summary of the as-built construction features of each of the test wells is presented below in **Table 1**:

Table 1. Summary of Test Well As-Built Construction

Well Feature (ft bgs)	MW01	MW02	MW03	Comments
Total Well Depth	155	153	140	Fully penetrating the CCG
Static Water Level	10 - 12	11 - 12	7 - 10	Range - varies with tidal conditions
Seal Depth	45	42	42	
Blank Casing Intervals	0 – 48	0 – 45	0 – 44	6-in-dia Sch. 80 PVC
Screen Intervals	48 – 148	45 – 145	44 – 134	6-in-dia SS WR Screen, 0.060-in slots
Total Screen Length	100	100	90	

As shown, the test wells are all similarly constructed, with 8-inch-diameter PVC upper blank casing sections to depths of approximately 45 feet and 90 to 100 feet of stainless steel wire-wrapped screen, and with total depths of approximately 140 to 155 feet.

WELL REDEVELOPMENT

As part of the pilot injection testing project, redevelopment of each of the three pilot test wells was performed in an effort to achieve optimal well efficiencies prior to injection testing. The details of the redevelopment effort were presented in a separate TM³ and will not be repeated here. In general, redevelopment consisted of dual-swab air-lift zone pumping of the well screens while simultaneously swabbing. Pre- and post-redevelopment well performance

² PWR was not involved in the Phase 1 investigation.

³ *Malibu Groundwater Injection Feasibility Project – Phase 3; Summary of Test Well Redevelopment Operations Technical Memorandum*, prepared by Pueblo Water Resources, Inc., for RMC Water and Environment, dated October 14, 2013.



testing, consisting of 100-minute constant rate pumping tests, was performed on each well to measure the efficacy of redevelopment in improving well performance. A summary of the pre- and post-redevelopment pumping tests is presented in **Table 2** below:

Table 2. Redevelopment Pumping Test Results

Well	Pre-Redevelopment			Post-Redevelopment			% Change
	Date	Rate (gpm)	Q/s (gpm/ft)	Date	Rate (gpm)	Q/s (gpm/ft)	
MCWP-MW01	6/16/13	206	10.1	8/6/13	134	112	+1009
MCWP-MW02	6/7/13	160	9.5	8/29/12	135	27.0	+184
MCWP-MW03	7/1/1	206	14.4	7/8/13	204	11.0	-24

As shown in **Table 2**, the pre-redevelopment specific capacities ranged between 9.5 and 14.4 gpm/ft and the post-redevelopment specific capacities ranged between 11.0 and 112 gpm/ft. For comparison, during the Phase 1 investigation in 2011, MCWP-MW01, -MW02 and -MW03 displayed 100-min specific capacities of 16.9, 12.3, and 23.3 gpm/ft, respectively, at pumping rates of approximately 100 gpm. These 2011 values are slightly greater than the pre-redevelopment values shown in **Table 2**; however, it is important to note that, according to well hydraulic theory, specific capacity generally decreases with increasing discharge rate; therefore, it is important to consider the test pumping rate when comparing specific capacity values.

In summary, MCWP-MW01 and -MW02 displayed significant improvements of approximately 10 and 2 times greater, respectively, than their pre-redevelopment performance, indicating that redevelopment was very effective at improving the hydraulic performance of these wells. MCWP-MW03 appeared to decline in performance by approximately 24 percent following redevelopment; however, following initial injection hydraulic testing, this well displayed a specific capacity of approximately 70 gpm/ft, which is approximately 5 times greater than the pre-injection specific capacity. These observations suggest that the near-bore and/or gravel pack matrices at MCWP-MW03 were sand locked and/or mechanically jammed prior to injection, which the flow reversal created by injection served to dislodge and significantly improve this well's hydraulic performance as well.

Well Efficiency

Well efficiency is defined as the ratio of the actual to the theoretical specific capacity, expressed as a percentage. The theoretical specific capacity is the specific capacity that would be observed if no additional hydraulic losses occur as water moves through the aquifer / well interface (i.e., well losses). Hydraulic efficiency is an important consideration for injection wells, as inefficient wells create excessive drawdown and drawup, which can limit backflushing and/or injection capacities.

There are always some hydraulic well losses associated with water moving through the near-bore, invaded zone of the aquifer, gravel pack, and well screen openings. Therefore, in practice, a 100-percent efficient, gravel-envelope well does not exist. These hydraulic losses



can be minimized through proper well design (e.g., gravel pack and screen selection), construction techniques (e.g., control of drilling-fluid properties, rapid completion of drilling and well construction activities, and adequate well development). Typical well efficiencies for properly-designed, constructed, and developed high-capacity wells are in the range of 60 to 80 percent.

Utilizing the aquifer parameters derived from the testing of MCWP-MW01, -MW02, and – MW03 (discussed in later sections), the theoretical specific capacity can be determined from equations presented by Walton (1991). Well efficiencies were calculated for each of the test wells during pre-redevelopment and post-redevelopment/pre-injection testing. The results of the well-efficiency estimates are presented in **Table 3** below:

Table 3. Well-Efficiency Estimates

Well	Pre-Redevelopment			Post-Redevelopment/Pre-Injection		
	Specific Capacity (gpm/ft)		Efficiency (%)	Specific Capacity (gpm/ft)		Efficiency (%)
	Actual	Theoretical		Actual	Theoretical	
MW01	10.1	110	9	103	110	94
MW02	9.5	59.3	16	27.0	59.3	46
MW03	14.4	62.2	23	11.0	62.2	18

As shown, the estimated efficiencies of MCWP-MW01, -MW02 and MW03 prior to redevelopment were very low at 9, 16 and 23 percent, respectively. Following redevelopment, the efficiency increased at MCWP-MW01 and –MW02 to approximately 94 and 46 percent, respectively, which indicate highly to moderately efficient wells. These results suggest that the test wells were not properly developed following their construction in 2011. Following redevelopment of MCWP-MW03, the efficiency declined slightly to approximately 18 percent, which indicates a relatively inefficient well; however, as will be discussed later, the act of injection and subsequent backflushing created flow reversals which served to dislodge and improve this well's efficiency.

PILOT INJECTION TESTING

The primary purpose of the pilot injection testing program was to empirically establish well injection capacities for the CCG. The testing program was intended to demonstrate injection well hydraulics and observe the local aquifer response to injection. These data are used as the basis for establishing per-well injection capacities and the development of the final design for the initial phase of construction of the permanent project injection well system. Primary issues investigated include:

- Determination of injection well efficiency and specific capacity / injectivity.
- Evaluation of injection well plugging rates (both active and residual).



- Determination of optimal rates, frequency, and duration of backflushing in order to maintain long-term injection capacity.
- Determination of long-term sustainable injection rates.
- Determination of local aquifer response to injection at the test well sites.

It should be noted that due to regulatory constraints and a physical lack of an available surrogate for treated wastewater effluent, potable water was used for pilot injection testing. As such, the results and conclusions developed from the subject testing program will need to be verified through injection trials utilizing treated wastewater effluent from the CCWTF (when available) and/or a suitable proxy.

Procedures and Monitoring Program

The pilot injection testing program was performed between July 8 and September 20, 2013. Based on the results of the Phase 1 and 2 analyses, a maximum per-well injection rate of approximately 100 gpm was preliminarily estimated for the test injection wells. The pilot injection testing program was designed around this injection rate, and consisted of the following sequential tests at each of the three test wells:

1. 100-minute pre-injection production performance test
2. 8-hr variable rate injection test
3. Backflushing
4. 24-hr constant rate injection test
5. Backflushing
6. 7-day constant rate injection test
7. Backflushing
8. 7-day water-level recovery period
9. 100-minute post-injection production performance test (72-hour test at MCWP-MW03)

Injection testing was conducted under the State Water Resources Control Board General Waste Discharge Requirements for ASR Projects that Inject Drinking Water into Groundwater (Order No. 2012-0010-DWQ). Injection feed water was potable water provided from the Los Angeles County Waterworks District 29 distribution system via temporary connections at fire hydrants near each test injection well site. Injection operations were performed through four 1-inch diameter Schedule 40 PVC drop tubes fitted with fixed orifice caps at the bottom of each tube. Positive pressures were maintained within the piping system and drop tubes during injection testing to prevent water cascading and cavitation in the wells. Injection rates were controlled by several valves on the wellhead piping system. Injection flow rates and total injected volumes were measured with a totalizing meter and were periodically verified with an ultrasonic flow meter throughout the program.



Each of the test wells, as well as proximate deep and shallow monitoring well pairs at each test well site, were instrumented with pressure transducers/data loggers to monitor and record well and aquifer water-level response to injection at the various rates and durations, and were manually verified with an electric sounder throughout the testing program. Barometric pressure was logged with a pressure transducer placed above the water table within a monitoring well at the MCWP-MW01 site (MCWP-MW04D). The observed water level data were corrected to remove barometric and tidal variation influences, as well as the influences of stage variations in Malibu Lagoon, and then used for analysis of well performance and aquifer response.⁴

A summary of the construction details of the injection test program wells is presented in **Table 4** below and the locations of the test injection wells and their proximate monitoring well pairs for the MCWP-MW01, -MW02, and MW03 test wells are shown on **Figures 3 through 5**, respectively:

Table 4. Injection Testing Wells Construction Details Summary

Well Name	Type	Distance from Test Well (ft)	Well Depth (ft)	Screened Intervals (ft bgs)	Aquifer Zone Monitored
MCWP-MW01	Test Well	--	155	48 – 148	CCG
MCWP-MW04D	Monitoring Well	20	148	50 – 145	CCG
MCWP-MW04S	Monitoring Well	40	20	10 – 20	Shallow
MCWP-MW02	Test Well	--	153	45 – 145	CCG
MCWP-MW06	Monitoring Well	20	140	55 – 135	CCG
LY-MW04	Monitoring Well	35	30	13 – 23	Shallow
MCWP-MW03	Test Well	--	140	44 – 134	CCG
MCWP-MW07D	Monitoring Well	20	134	55 – 125	CCG
MCWP-MW7S	Monitoring Well	40	17	7 – 17	Shallow

The above-described injection testing program was implemented at each of the three test wells during the following periods:

- MCWP-MW03: July 8 through August 1, 2013
- MCWP-MW01: August 6 through 26, 2013
- MCWP-MW02: August 29 through September 20, 2013

⁴ Water-level data correction was performed by McDonald Morrissey Associates, Inc. (MMA) utilizing the same methodologies developed for the Phase 2 analysis (RMC, et al, June 29, 2012), and are documented in their report regarding the Phase 3 groundwater modeling effort.



Observed water-level data collected at the on-site wells during each of the above testing periods are shown on **Figures 6 through 8**, respectively. Field data sheets are provided in **Appendix A**. The results of each testing phase are discussed in further detail in the following sections.

Pre-Injection Performance Tests

Pre-injection performance tests were performed to establish baseline well performance for comparison to post-injection performance testing (discussed in a later section) and determination of residual plugging due to injection. The tests were conducted on July 8, August 6, and August 29, 2013 at MCWP-MW03, -MW01, and -MW02, respectively. The performance tests were limited to approximate 100-minute constant rate discharge tests because the long-term response of a well is a logarithmic function, and a pumping test of this duration is sufficient to document well performance (i.e., specific capacity). The testing results are summarized in **Table 5** below:

Table 5. Pre-Injection Pumping Test Results

Well	Date	Rate (gpm)	SWL (ft bgs)	PWL (ft bgs)	DDN (ft)	Q/s (gpm/ft)
MCWP-MW01	8/6/13	134	10.7	12.0	1.3	103
MCWP-MW02	8/29/12	135	11.8	16.8	5.0	27.0
MCWP-MW03	7/8/13	204	8.9	27.4	18.5	11.0

Notes:

SWL = Static Water Level

PWL = Pumping Water Level (corrected for barometric, tidal, and lagoon stage variations)

DDN = Drawdown (corrected for barometric, tidal, and lagoon stage variations)

Q/s = Specific Capacity at 100 minutes.

Variable-Rate Injection Tests

The primary purpose of the variable-rate injection tests was to assess variations in well specific injectivity (the converse of specific capacity for pumping) at differing injection rates and to confirm suitable rates for long-term injection testing. The tests consisted of four steps, each at a successively higher rate. The duration of each step was approximately 100-minutes. The four test rates were approximately 50, 75, 100, and 125 gpm (i.e., $\frac{1}{2}$, $\frac{3}{4}$, 1 and $1\frac{1}{4}$ times the design injection rate of 100 gpm). The resulting water-level drawup and specific injectivities associated with each of these steps at MCWP-MW01, -MW02 and -MW03 are shown on **Figures 9 through 11**, respectively, and are summarized below in **Table 6**.



Table 6. Variable-Rate Injection Test Results

Well / Step	Date	SWL (ft. bgs)	Rate (gpm)	IWL (ft. bgs)	DUP (ft)	Q/s (gpm/ft)
MCWP-MW01	8/7/13	10.64				
		Step 1	52	10.22	0.31	167
		Step 2	77	9.99	0.65	119
		Step 3	104	9.81	0.83	125
		Step 4	129	9.65	0.99	130
MCWP-MW02	9/3/13	11.69				
		Step 1	51	10.08	1.41	36.2
		Step 2	76	9.39	2.30	33.0
		Step 3	100	8.41	3.28	30.5
		Step 4	125	7.22	4.47	28.0
MCWP-MW03	7/10/13	8.98				
		Step 1	51	8.46	0.52	100
		Step 2	77	8.17	0.81	95.1
		Step 3	101	7.90	1.08	93.5
		Step 4	127	7.56	1.42	87.3

Notes:

SWL = Static Water Level

IWL = Injection Water Level (corrected for barometric, tidal, and lagoon stage variations)

DUP = Drawup (corrected for barometric, tidal, and lagoon stage variations)

Q/s = Specific Injectivity

As shown, MCWP-MW01 displayed the highest specific injectivities, ranging between approximately 120 and 170 gpm/ft, with –MW02 displaying the lowest, ranging between approximately 28 and 36 gpm/ft. MCWP-MW03 displayed specific injectivities between those of –MW01 and –MW02, ranging between approximately 90 and 100 gpm/ft. It is important to note that according to well hydraulic theory, specific injectivity is expected to generally decrease with increasing injection rate and duration of injection; therefore, it is important to consider the test duration and injection rate when comparing specific injectivity values.

24-hour Constant Rate Injection Tests

Following the initial variable rate injection tests, backflushing (discussed below), and periods of water-level recovery, 24-hour constant rate injection tests were performed at each of the three test wells. This phase of testing consisted of continuous rate injection tests performed at injection rates of approximately 100 gpm. Water-level data for the 24-hour constant rate



injection tests at MCWP-MW01, -MW02, and -MW03 are graphically presented on **Figures 12 through 14**, respectively, and the results are summarized in **Table 7** below:

Table 7. 24-hour Constant Rate Injection Test Results

Well	Date	SWL (ft bgs)	Rate (gpm)	IWL (ft bgs)	DUP (ft)	Q/s (gpm/ft)
MCWP-MW01	8/8/13 thru 8/9/13	10.78	107	9.73	1.05	102
MCWP-MW02	9/4/13 thru 9/5/13	11.64	101	7.22	4.42	22.8
MCWP-MW03	7/11/13 thru 7/12/13	8.96	101	7.72	1.24	81.5

Notes:

SWL = Static Water Level

IWL = Injection Water Level (corrected for barometric, tidal, and lagoon stage variations)

DUP = Drawup (corrected for barometric, tidal, and lagoon stage variations)

Q/s = Specific Injectivity at 24 hours

As shown, 24-hour specific injectivities for MCWP-MW01, -MW02, and -MW03 were approximately 102, 23, and 82 gpm/ft, respectively. These values are comparable to those observed during the variable rate injection tests. **Figures 12 through 14** also clearly show the influence of diurnal tidal fluctuations on the observed water levels at each well site, with diurnal fluctuations ranging between approximately 0.8 to 1.5 feet depending on proximity to the Pacific Ocean. Given the magnitude of tidally-influenced fluctuations relative to the amount of water-level drawup due to injection (i.e., they are of similar magnitude, particularly at MCWP-MW01 and -MW03), the importance of correcting water-level data for tidal influence in analyzing well and aquifer response to injection is apparent. In addition, the tidal fluctuation data are indicative of a hydraulic connection between the CCG aquifer and the Pacific Ocean (further evidence of the connection with Pacific Ocean is provided by observed variations in electrical conductivity of the water at MCWP-MW03⁵)

7-day Constant Rate Injection Tests

Following the 24-hour injection tests, backflushing (discussed below) and periods of water level recovery, 7-day constant rate injection test were performed at each test well. This phase of testing consisted of continuous rate injection tests performed at average injection rates of approximately 100 gpm, with total volumes of approximately 1.0 million gallons (3.1 acre-feet) injected at each well. Water-level data for the 7-day constant-rate injection tests at MCWP-MW01, -MW02, and -MW03 are graphically presented on **Figures 15 through 17**, respectively, and the results are summarized in **Table 8** below:

⁵ Discussed in a separate PWR TM entitled *Malibu Groundwater Injection Feasibility Project – Phase 3; Geochemical Modeling Assessment*, dated February 4, 2014 (draft).



Table 8. 7-day Constant Rate Injection Test Results

Well	Dates	SWL (ft bgs)	Rate (gpm)	IWL (ft bgs)	DUP (ft)	Q/s (gpm/ft)
MCWP-MW01	8/12/13 thru 8/19/13	10.87	105	9.81	1.06	99.1
MCWP-MW02	9/6/13 thru 9/13/13	11.69	101	3.36	8.33	12.1
MCWP-MW03	7/15/13 thru 7/22/13	9.06	102	8.15	1.33	76.7

Notes:

SWL = Static Water Level

IWL = Injection Water Level (corrected for barometric, tidal, and lagoon stage variations)

DUP = Drawup (corrected for barometric, tidal, and lagoon stage variations)

Q/s = Specific Injectivity at 7 days

As shown, 7-day specific injectivities for MCWP-MW01 and -MW03 were approximately 99 and 77 gpm/ft, respectively. These values are generally comparable to those observed during the 24-hour constant rate injection tests, suggesting that very little (if any) plugging occurred during the 7-day tests at these two wells. MCWP-MW02, on the other hand, displayed a 7-day specific injectivity of approximately 12 gpm/ft, which is approximately one-half of the 24-hour specific injectivity. As shown on **Figure 16**, MCWP-MW02 experienced a non-linear rise in water level (as plotted on a semi-log plot) after approximately 1000 minutes of injection due to the effects of plugging. Well plugging is discussed in further detail in a later section.

Aquifer Response / Well Interference

Response to injection operations during the 7-day injection tests was observed at both the on-site and off-site monitoring wells completed in the CCG (refer to **Figures 15 through 17**), whereas no discernable response to injection into the CCG was observed at any of the monitoring wells completed in the shallow aquifer (refer to **Figures 6 through 8**), indicating a lack of hydraulic connection between the shallow aquifer and the CCG. The aquifer responses at the various CCG monitoring wells associated with each of the 7-day injection tests are summarized below in **Table 9**:

Table 9. 7-Day Injection Test CCG Aquifer Response Summary

MCWP-MW01 Test			MCWP-MW02 Test			MCWP-MW03 Test		
MW	Distance (ft)	DUP Response (ft)	MW	Distance (ft)	DUP Response (ft)	MW	Distance (ft)	DUP Response (ft)
MW04D	20	0.70	MW06	20	1.30	MW07D	20	1.15
MW07D	1250	0.50	MW04D	1360	0.30	MW04D	1250	0.50
MW06	1360	0.30	MW07D	2450	0.20	MW06	2450	0.20

Notes:

Drawup (DUP) response at monitoring wells rounded to the nearest 0.05 ft. due to inherent difficulty in discerning a more precise response through tidal fluctuations. These values are used by MMA as calibration targets in calibration of the groundwater model.



As shown, the response of the CCG aquifer to the 7-day injection tests was similar for all three tests, generally ranging between approximately 0.2 to 1.3 feet at the farthest and nearest monitoring wells, respectively. Given static water levels in the CCG range between approximately 8 to 12 feet below ground surface, depending on location and tidal conditions, these relatively low amounts of interference should not significantly affect sustainable injection rates for the permanent project; however, the issue of long-term well interference (as well as aquifer boundary conditions that can affect aquifer response to injection such as the Pacific Ocean and basin bedrock boundaries) is best assessed through the planned groundwater modeling effort by McDonald Morrissey Associates, Inc. (MMA).

Backflushing

Following each of the above-described injection tests, backflushing was performed on the wells. Backflushing operations generally consisted of pumping the wells to waste at a rate of approximately 135 gpm for periods of approximately 20 to 30 minutes. During each backflushing pumping event, well discharge turbidity was measured and tracked. Following initial pumping, if the final turbidity exceeded 5 NTU, further backflushing was performed until discharge water during these subsequent pumping/surging cycles was essentially clear. Backflushing operations are summarized in **Table 10** below:

Table 10. Well Backflushing Summary

Well	Date	Time	Description	Turbidity (NTU) vs. Time (minutes)						
				2	5	10	15	20	25	30
MW01	8/7/13	17:35	After Variable Rate Injection Test	0	0	0	0	0	--	--
	8/9/13	10:30	After 24-hr Injection Test	0	0	0	0	0	--	--
	8/19/13	18:20	After 7-day Injection Test	0	0	0	0	0	--	--
MW02	9/3/13	16:30	After Variable Rate Injection Test	125	42	8	5	6	--	--
	9/5/13	11:00	After 24-hr Injection Test	68	53	16	7	0	--	--
	9/13/13	13:00	After 7-day Injection Test	145	129	45	29	20	24	9
	9/19/13	11:20	After 7-day Injection Test Recovery	60	48	23	19	21	12	13
				54	34	23	19	22	14	16
				75	59	23	12	13	14	11
				66	31	19	9	11	6	3
MW03	7/10/13	17:10	After Variable Rate Injection Test	0	0	0	0	0	--	--
	7/12/13	11:00	After 24-hr Injection Test	0	0	0	0	0	--	--
	7/22/13	15:15	After 7-day Injection Test	0	0	0	0	0	--	--

As shown, backflushing of MCWP-MW01 and -MW03 resulted in no measureable turbidity produced, even upon initial startup of the pump. Backflushing of MCWP-MW02, on the



other hand, resulted in the production of very turbid water after each injection test. In particular, following the 7-day injection test at MCWP–MW02, a significant amount of repeated backflushing cycles was required in order to achieve relatively clear discharge. These observations are consistent with the observed plugging at each well, with MCPW-MW01 and –MW03 displaying no measurable plugging, whereas –MW02 experienced a relatively significant amount of plugging (discussed in further detail in later section). The lack of observed plugging and the production of measurable turbidity at MCWP-MW01 and –MW03 indicates that longer duration and/or greater injection rates would be required to observe measurable plugging at these two wells.

Post-Injection Performance Tests

100-minute post-injection performance tests were performed at each of the three test wells. The purpose of the tests was to document the performance of the wells following injection operations, to assess the effectiveness of backflush pumping, and to determine if any residual plugging of the wells had occurred. The results are summarized in **Table 11** below:

Table 11. Post-Injection Pumping Test Results

Well	Date	Rate (gpm)	SWL (ft. bgs)	PWL (ft. bgs)	DDN (ft)	Q/s (gpm/ft)	Pre-Injection Q/s (gpm/ft) ¹	% Change
MCWP-MW01	8/26/13	133	11.24	12.28	1.04	128	103	+24
MCWP-MW02	9/20/13	135	11.68	17.27	5.59	24.1	27.0	-11
MCWP-MW03	7/29/13	126	8.99	10.18	1.19	106	11.0	+864

Notes:

SWL = Static Water Level

PWL = Pumping Water Level (corrected for barometric, tidal, and lagoon stage variations)

DDN = Drawdown (corrected for barometric, tidal, and lagoon stage variations)

Q/s = Specific Capacity at 100 minutes

¹ = From **Table 5**

As shown, the performance of MCWP-MW01 and –MW03 actually improved as a result of injection operations. In particular, MCWP-MW03 observed an over 8-fold increase in improvement. As discussed previously, these observations suggest that the near-bore and/or gravel pack matrices were sand locked and/or mechanically jammed prior to injection, which the flow reversals created by injection and pumping served to dislodge and improve the hydraulic performance of these two wells. The performance of MCPW-MW02 declined slightly, indicative of residual plugging having occurred at this well. As discussed in the backflushing section, this well was still producing turbid water after over an hour of active backflushing following the 7-day injection test. These observations suggest that additional backflushing would provide further removal of residual plugging materials and improved performance at this well.

Aquifer Parameter Analysis

Time vs. Drawdown, Drawup and Recovery data from all of the various pumping and injection tests performed at each of the three test wells were analyzed to derive aquifer



parameters of transmissivity and storativity for the CCG aquifer. These parameters are then utilized in analyses of injection well capacity constraints at each site. Jacob's approximation (Cooper and Jacob, 1946) to the Theis non-equilibrium well equation (Theis, 1935) was used to derive aquifer parameters. The analyses of well drawdown, drawup, and recovery data are presented on **Figures B1 through B48** and are contained in **Appendix B**. The results of the analyses are summarized below in **Table 12**:

**Table 12. Summary of CCG Aquifer Parameter Estimates
 Time vs. Drawdown / Drawup / Recovery Data**

Well Tested / Test	Aquifer Parameters						
	Data Set	TW		MW			
		T (gpd/ft)	K (ft/d)	T (gpd/ft)	K (ft/d)	S (unitless)	Ss (unitless)
MCWP-MW01							
Pre-Injection Pumping Test	Drawdown	121,986	163	136,062	182	8.47E-02	8.47E-04
	Recovery	160,800	215	221,100	296	4.64E-02	4.64E-04
24-hr Injection Test	Drawup	97,406	130	134,514	180	1.41E-01	1.41E-03
	Recovery	166,165	222	176,550	236	1.19E-01	1.19E-03
7-day Injection Test	Drawup	126,000	168	132,000	176	1.29E-01	1.29E-03
	Recovery	154,000	206	126,000	168	7.84E-02	7.84E-04
Post-Injection Pumping Test	Drawdown	159,600	213	125,119	167	8.44E-02	8.44E-04
	Recovery	206,541	276	220,281	294	4.63E-02	4.63E-04
	<i>Average</i>	<i>149,062</i>	<i>199</i>	<i>158,953</i>	<i>213</i>	<i>9.12E-02</i>	<i>9.12E-04</i>
MCWP-MW02							
Pre-Injection Pumping Test	Drawdown	122,897	164	148,500	199	1.56E-05	1.56E-07
	Recovery	198,000	265	178,200	238	1.86E-06	1.86E-08
24-hr Injection Test	Drawup	62,009	83	121,200	162	1.26E-04	1.26E-06
	Recovery	177,760	238	156,847	210	1.65E-05	1.65E-07
7-day Injection Test	Drawup	72,065	96	148,133	198	1.56E-05	1.56E-07
	Recovery	166,650	223	156,847	210	1.65E-05	1.65E-07
Post-Injection Pumping Test	Drawdown	99,000	132	198,000	265	4.16E-05	4.16E-07
	Recovery	170,357	228	154,956	207	2.44E-05	2.44E-07
	<i>Average</i>	<i>133,592</i>	<i>179</i>	<i>157,835</i>	<i>211</i>	<i>3.23E-05</i>	<i>3.23E-07</i>
MCWP-MW03							
Pre-Injection Pumping Test	Drawdown	77,287	115	83,325	124	6.06E-02	6.73E-04
	Recovery	104,565	155	126,971	189	1.05E-02	1.17E-04
24-hr Injection Test	Drawup	76,471	114	91,945	137	2.41E-02	2.68E-04
	Recovery	95,229	141	91,945	137	4.76E-02	5.29E-04
7-day Injection Test	Drawup	99,733	148	107,712	160	3.39E-02	3.77E-04
	Recovery	--	--	--	--	--	--
Post-Injection Pumping Test	Drawdown	70,775	105	67,866	101	9.16E-02	1.02E-03
	Recovery	73,920	110	97,835	145	4.04E-02	4.49E-04
	<i>Average</i>	<i>85,426</i>	<i>127</i>	<i>95,371</i>	<i>142</i>	<i>4.41E-02</i>	<i>4.90E-04</i>

Notes:

- TW - Test Well (MCWP-MW01, -MW02, and -MW03)
- MW - Proximate (20 ft) CCG Monitoring Well to each Test Well (refer to **Table 4**)
- T - Transmissivity
- K - Hydraulic Conductivity
- S - Storativity
- Ss - Specific Storage



As shown in **Table 12**, aquifer testing at MCWP-MW01 yielded transmissivity values ranging between approximately 97,400 and 221,100 gpd/ft, averaging approximately 154,000 gpd/ft. The average transmissivity value corresponds to a hydraulic conductivity value of approximately 206 feet per day (ft/d)⁶. The storage coefficient derived from the MCWP-MW04D data was estimated to be approximately 9.12×10^{-2} (dimensionless), corresponding to specific storage value of 9.12×10^{-4} (dimensionless)⁶. The observed value of the storage coefficient is indicative that groundwater conditions are semi-confined at this location.

Aquifer testing at MCWP-MW02 yielded transmissivity values ranging between approximately 62,000 and 198,000 gpd/ft, averaging approximately 145,700 gpd/ft. The average transmissivity value corresponds to a hydraulic conductivity value of approximately 195 ft/d⁷. The storage coefficient derived from the MCWP-MW06 data was estimated to be approximately 3.23×10^{-5} (dimensionless), corresponding to specific storage value of 3.23×10^{-7} (dimensionless)⁷, indicative of confined groundwater conditions at this location.

Aquifer testing at MCWP-MW03 yielded transmissivity values ranging between approximately 67,900 and 127,000 gpd/ft, averaging approximately 90,400 gpd/ft. The average transmissivity value corresponds to a hydraulic conductivity value of approximately 134 ft/d⁸. The storage coefficient derived from the MCWP-MW067D data was estimated to be approximately 4.41×10^{-2} (dimensionless), corresponding to specific storage value of 4.41×10^{-4} (dimensionless)⁸, indicative that groundwater conditions are semi-confined at this location.

Distance vs. Drawup data from the 7-day injection tests performed at each of the three test wells, and Distance vs. Drawdown data from the 72-hour pumping test performed at MCWP-MW03, were also analyzed to derive aquifer parameters of transmissivity and storativity for the CCG aquifer. The analyses are presented on **Figures B49 through B52** and are contained in **Appendix B** and are summarized below in **Table 13**.

As shown in **Table 13**, analysis of the Distance vs. Drawup and Drawdown data yielded transmissivity values ranging between approximately 100,620 and 326,120 gpd/ft, averaging approximately 177,850 gpd/ft. The average transmissivity value corresponds to a hydraulic conductivity value of approximately 238 ft/d⁹. These values are slightly greater than those derived from analyses of the Time vs. Drawdown / Drawup / Recovery data. It is noted that the values derived from the Distance vs. Drawdown / Drawup data are based on the aquifer response to pumping / injection over a much larger area because the more distant monitoring well data are utilized, whereas the values derived from the Time vs. Drawdown / Drawup data are based on site-specific and localized response of the pumping / injection wells themselves and the proximate monitoring wells only.

The storage coefficients derived ranged between approximately 2.6×10^{-3} and 1.7×10^{-5} , averaging approximately 2.8×10^{-3} (dimensionless), corresponding to an average specific

⁶ Based on an aquifer thickness (b) of 100 ft at MCWP-MW01.

⁷ Based on an aquifer thickness (b) of 100 ft at MCWP-MW02.

⁸ Based on an aquifer thickness (b) of 90 ft at MCWP-MW03.



storage value of 2.8×10^{-5} (dimensionless)⁹. These storativity values are within the range derived from Time vs. Drawdown / Drawup data and are indicative that groundwater conditions in the CCG aquifer are generally semi-confined to confined.

**Table 13. Summary of CCG Aquifer Parameter Estimates
 Distance vs. Drawdown / Drawup Data**

Well Tested / Test	Aquifer Parameters				
	Data Set	MW			
		T (gpd/ft)	K (ft/d)	S (unitless)	Ss (unitless)
MCWP-MW01					
7-day Injection Test	Drawup	326,118	436	1.71E-05	1.71E-05
MCWP-MW02					
7-day Injection Test	Drawup	100,619	135	8.45E-03	8.45E-03
MCWP-MW03					
7-day Injection Test	Drawup	122,400	164	2.57E-03	2.57E-03
72-hr Pumping Test	Drawdown	162,263	217	1.62E-04	1.62E-04
	<i>Average</i>	<i>177,850</i>	<i>238</i>	<i>2.80E-03</i>	<i>2.80E-03</i>

Notes:

MW - Monitoring Well data (refer to **Table 4**)

T - Transmissivity

K - Hydraulic Conductivity (based on 100 ft. thickness for CCG aquifer)

S - Storativity

Ss - Specific Storage

It is noted that the transmissivity values derived from this testing program are significantly greater than those derived from the Phase 1 pumping tests¹⁰. For example, the Time vs. Drawdown transmissivity value derived from the MCWP-MW01 pumping test during Phase 1 was approximately 42,200 gpd/ft compared to an average value of approximately 154,000 gpd/ft from the subject testing program. These results are consistent with the results of the redevelopment performance testing (as well as the post-injection performance testing), which suggested that the test wells were relatively inefficient during the Phase 1 investigation.

Storage coefficient values could not be derived from the Phase 1 testing program due to a lack of suitable monitoring wells in the CCG at the time. The values derived from the subject program, however, indicate that groundwater conditions in the central and western areas of the CCG aquifer (i.e., in the vicinity of MCWP-MW01 and –MW03) are unconfined to semi-confined, whereas in the eastern area in the vicinity of MCWP-MW02 confined conditions exist. These observations are consistent with the presence of relatively higher percentages of fine-grained materials (i.e., silt and clay) at MCWP-MW02 as compared to –MW01 and –MW03 (refer to

⁹ Based on an average aquifer thickness (b) of 100 ft for the CCG aquifer.

¹⁰ *Malibu GW Injection Feasibility Phase 1 Results Technical Memorandum*, prepared by Groundwater Dynamics, et al, for RMC Water and Environment, dated February 7, 2012.



Figure 2). The relatively unconfined conditions at MCWP-MW01 and –MW03 indicate that it will be important to avoid pressurizing the CCG aquifer (i.e., raising water levels/piezometric heads above ground surface) during injection in order to prevent upward vertical leakage and the potential for “daylighting” of water from the CCG aquifer during project operation.

Plugging Rate Analysis

Experience at injection sites around the world shows that all injection wells are subject to some amount of plugging, because no water source is completely free of particulates. During injection, trace amounts of suspended solids are continually being deposited in the gravel pack and aquifer pore spaces, much as a media filter captures particulates in the filter bed. The effect of plugging is to impede the flow of water from the injection well into the aquifer, causing increased injection heads in the well to maintain a given injection rate, or reduced injection rates at a given head level. Well plugging reduces injection capacity, and consequently, well life.

Plugging can occur due to poor water quality, improper system operation, or poor design practices. In general, plugging issues fall into four general categories: physical plugging (by particulate matter), chemical reaction (between the injectate and native waters or aquifer minerals), biofouling (the proliferation of bacteria in the gravel pack and/or aquifer), and gas binding (the vapor locking of the aquifer by entrained or evolved gasses in the injectate). It is important to note that potable water was used during the pilot injection testing program instead of treated wastewater effluent. As a result, only physical plugging by particulates could be evaluated as part of the subject testing program. The potential for plugging by other mechanisms (e.g., chemical reactions and biofouling) was, however, evaluated as part of this project through analytic modeling and is documented in a separate TM¹¹.

Relative measurements of the particulate matter in the injectate were made through silt density index (SDI) testing during injection. The SDI was originally developed to quantitatively assess particulate concentrations in reverse osmosis feed waters. The SDI involves pressure filtration of source water through a 0.45 micron membrane, and observation of the decrease in flow over time; the resulting value of SDI is dimensionless, and used as a comparative value for tracking relative well plugging rates versus water quality or other parameters. SDI test results are summarized in **Table 14** below.

As shown in **Table 14**, SDI values during injection testing were generally consistent at all three test wells, ranging between approximately 1.9 and 4.4, and averaging 2.1, 2.4, and 2.5 for the 7-day Constant Rate Injection Tests at MCWP-MW01, -MW02, and –MW03 respectively. Values within this range are generally representative of source waters with a relatively low amount of particulates. It is noted that SDI testing performed on the Lumber Yard Wastewater Treatment Plant effluent¹² ranged between 1.8 and 2.3, averaging 2.1, values that are very

¹¹ *Malibu Groundwater Injection Feasibility Project – Phase 3; Geochemical Modeling Assessment*, prepared by PWR for RMC Water and Environment, dated February 4, 2014 (draft).

¹² Based on our discussions at the Phase 3 project kickoff meeting on 2/8/13, it is our understanding that the Lumber Yard Wastewater Treatment Plant effluent is considered by RMC to be a representative proxy for the effluent anticipated from the planned CCWWTP.



comparable to those of the potable water used for injection testing. As such, the rates of physical plugging due to particulates observed during the pilot injection testing program can be considered representative for the permanent project.

Table 14. Summary of Silt Density Index (SDI) Test Results

Well / Testing Phase	Number of Tests	Low Value	High Value	Average Value
MCWP-MW01				
Variable Rate	4	2.1	2.4	2.3
24-hr Constant Rate	2	2.0	2.2	2.1
7-day Constant Rate	8	1.9	2.5	2.1
MCWP-MW02				
Variable Rate	4	2.9	4.4	3.4
24-hr Constant Rate	2	2.4	2.9	2.7
7-day Constant Rate	8	2.1	2.9	2.4
MCWP-MW03				
Variable Rate	4	2.8	3.1	3.0
24-hr Constant Rate	3	2.7	2.9	2.8
7-day Constant Rate	8	2.4	3.2	2.5

Plugging rates during injection testing of the three test wells were calculated utilizing the Graphical Observed vs. Theoretical Drawup Method (Pyne, 1995). Water level rise in an injection well is a combination of both aquifer response and well losses. Theoretically, at any given constant injection rate, well losses should remain constant; therefore, in the absence of plugging, any water level rise in the well would be due only to aquifer response. The difference between the theoretical and the observed water levels can be presumed to be caused by plugging.

It is important to note that the theoretical water level rise corresponds to the water level that would occur if well losses were negligible and well efficiency was 100 percent. In order to account for well efficiency losses, the graphical method involves drawing a straight line through early to moderate elapsed time data points (e.g., 10 to 100 minutes). Assuming no plugging is occurring, the theoretical water level rise during injection would plot on along a straight line on a semi-log plot. The variance from the straight line is assumed to be indicative of the amount of plugging.

The amount of plugging, in feet of water level rise, was calculated for the 7-day Constant Rate Injection Tests and the plugging rate analyses are presented graphically on **Figures 18 through 20**. As shown on **Figures 18 and 20**, no measurable plugging occurred during the 7-day injection tests at MCWP-MW01 and -MW03. As shown on **Figure 19**, MCWP-MW02



observed a relatively high rate of plugging, with approximately 3.8 feet of water-level rise due to plugging after 7 days of injection (equivalent to a plugging rate of approximately 0.5 feet per day).

Filtration is the mechanism by which suspended solids in the injectate accumulate within the pore spaces of the aquifer matrix. All other factors being equal, aquifer materials with smaller pore spaces will tend to experience greater rates of plugging than those with large pore spaces. As noted previously, the SDI of the injectate during the MCWP-MW02 test was comparable to that observed at MCWP-MW01 and –MW03; therefore, the higher rate of plugging at MCWP-MW02 is likely attributable to the higher percentage of fine-grained materials (silt and clay) in the CCG aquifer matrix at MCWP-MW02 compared to –MW01 and –MW03 (refer to **Figure 2** and the Phase 1 TM for lithologic descriptions at each test well). These fine-grained materials have much smaller interstitial pore spaces in the aquifer matrix that are more readily blocked by particulates compared to those of coarse-grained materials (sand and gravel). The lack of observed plugging (active or residual) at MCWP-MW01 and –MW03 during the pilot injection testing suggests that longer duration injection periods and/or greater injection rates would be required for the pore spaces to become blocked and for measurable plugging to occur at these wells.

INJECTION WELL CAPACITY CONSTRAINTS ANALYSIS

The capacity of any given injection well is dependent on a variety of site-specific factors, which can be generally categorized into issues associated with; 1) well response to injection, and 2) aquifer response to injection. Examples of issues associated with the well response include allowable drawup within the well casing before some head limitation is reached, and the available drawdown for well backflushing. Issues associated with aquifer response to injection involve the available "freeboard" in the aquifer for water levels (piezometric head) to be increased without inducing undesirable results. To the extent possible, injection wells should be designed to maximize injection rates while operating within the constraints of these site-specific factors. A discussion of each of these factors and their influence on the theoretical injection capacity of permanent injection wells at each test well site is presented below.

Well Response to Injection

One method of estimating the injection capacity limits of an injection well is to determine the amount of drawup available within the well casing for injection, and calculate the maximum injection rate based on the theoretical water level response to injection utilizing the Theis Equation (Theis, 1935).

Available Drawup. During injection, the water level (head) in the well and aquifer will increase due to mounding in the aquifer. The available drawup in the well casing for injection is determined based on the depth to water prior to injection (static water level) plus the amount of wellhead pressurization considered reasonable (if any). For this project, non-pressurized injection is conservatively assumed (i.e., water levels within the well casing are not allowed exceed the ground surface). A summary of the available drawup constraints for each of the test well sites based on the above limiting criteria is presented below in **Table 15**:



Table 15. Available Drawup Summary

Well	Available Drawup (ft.) ¹
MCWP-MW01	9
MCWP-MW02	10
MCWP-MW03	7

Notes:

1 - Based on minimum Depth to Water (DTW) at high tides.

As shown in **Table 15**, the available drawup within the well casings (under current conditions and at high tides) ranges between approximately 7 and 10 feet, depending on location.

Well Response to Injection. The theoretical drawup response of a well to injection can be calculated utilizing the Theis Equation and aquifer parameters of transmissivity and storativity. For purposes of this analysis, the aquifer parameters derived from the 7-day Constant Rate Injection Tests are utilized (refer to **Table 12** and **Appendix B**). For purposes of this analysis, it was assumed that continuous injection operations would occur for 10 years. It is noted that this is considered a conservative assumption, because in practice injection will be periodically interrupted for both routine backflushing (daily to weekly) and formal well rehabilitation activities (yearly to every 5 years), which will result in a cessation of the hydraulic stress created by injection, some degree of water level recovery, and a “resetting” of the drawup curve each time. The cumulative practical effect of these cessations in injection is to lessen the amount of total drawup over the long-term as compared to the conservatively assumed continuous injection operation.

The theoretical calculations based on the Theis Equation assume a perfectly efficient well without hydraulic losses in the well casing, well screen, gravel pack or well bore. In practice, however, properly constructed new municipal production and injection wells typically have efficiencies of approximately 60 to 80 percent¹³. For purposes of this analysis, it is conservatively assumed that new injection wells will have baseline well efficiencies (i.e., prior to any plugging) of approximately 70 percent.

Based on these relationships and assumptions, the resulting injection rate that would raise water levels within the well casing to ground surface after 10 years of continuous injection are presented in **Table 16** below:

¹³ Well efficiency is defined as the ratio of the actual to the theoretical specific capacity (or the ratio of total hydraulic head loss to formation losses).



Table 16. Theoretical Well Response Constraint Summary

Well	Aquifer Parameters		Theoretical Injection Rate (gpm)	Injection Rate w/ Efficiency Losses ¹ (gpm)
	T (gpd/ft) ²	S (unitless)		
MCWP-MW01	132,000	1.29E-01	405	284
MCWP-MW02	148,133	1.56E-05	375	263
MCWP-MW03	107,712	3.39E-02	245	172

Notes:

1 - 70% well efficiency assumed for new injection wells.

As shown in **Table 16**, it is estimated that theoretical injection rates (accounting for efficiency losses) of approximately 170 to 280 gpm, depending on location, would create drawup within the injection well casings that would raise water levels up to the ground surface after 10 years of continuous injection (with routine backflushing to limit plugging).

Backflushing Capacity. This constraint considers the amount of drawdown available above the well screens for backflushing. No source of injection water is completely free of particulates; therefore, backflushing of injection wells is routinely performed to create flow reversals in the well, which removes particles introduced into the well during injection (this is analogous to backwashing of media filters to affect particulate removal). Periodic, vigorous backflushing is absolutely necessary to maintain injection capacity. The ability to adequately backflush injection wells while maintaining a flooded screen section is a critically important consideration when designing and operating injection well facilities.

Based on experience at other injection wells, it has been shown that it is desirable to backflush injection wells at rates of at least twice the rate of injection in order to maximize backflushing effectiveness over the long term. This is done to create pore throat velocities that are sufficient to remove particulates introduced during injection that have filled pore spaces and cling to grains of sand. This criterion is considered to be the most conservative and important for maintaining long-term injection performance, and is, therefore, adopted as the backflushing criteria. A summary of the factors related to backflushing is presented in **Table 17** below:

Table 17. Backflushing Capacity Constraint Summary

Well	SWL ¹ (ft bgs)	Top of Screen (ft bgs)	Available Drawdown (ft)	Q/s ² (gpm/ft)	Capacity (gpm)	
					Backflush	Injection
MCWP-MW01	12	48	36	46.7	1683	841
MCWP-MW02	12	45	33	34.3	1132	566
MCWP-MW03	10	44	34	35.8	1217	608

Notes:

1 - Static Water Level (SWL) at low tides.

2 - 70% well efficiency assumed for new injection wells.



As shown in **Table 17**, the theoretical injection rates as constrained by backflushing capacity range between approximately 570 and 840 gpm. These rates are significantly greater than the injection capacities based on the theoretical well response criterion; therefore, backflushing capacity is not a limiting factor for this project.

Aquifer Response to Injection

Utilizing the aquifer parameters presented previously, the theoretical water-level mounding response to injection within the aquifer system can also be calculated utilizing the Theis Equation. These aquifer parameters relate to other potential constraints in injection well operations, as described and analyzed below.

Hydrofracturing Limits. As discussed previously, the CCG aquifer displays varying degrees of confinement created by laterally discontinuous overlying low permeability layers. During injection, the injection heads must not exceed pressures that would create vertical cracks in the confining layers (hydraulic fracturing) through which injected water may flow upward into overlying sediments (i.e., the shallow aquifer) or to the ground surface (daylighting). The pressure in the confined aquifer must not exceed vertical grain pressures of the materials overlying the confining layer to avoid hydraulic fracturing. Based on soil mechanics, Huisman and Olsthoorn (1983) suggest that the maximum allowable drawup to avoid hydraulic fracturing can be calculated using the following equation:

$$s < 0.22 (A+B)$$

Where: s = total drawup (ft)

A = depth from ground surface to the top of confining layer (ft)

B = depth from ground surface to static water level (ft).

The depth to the top of the confining layer above the CCG aquifer at each test well site was established based on review of the lithologic logs. Utilizing the Theis Equation and the aquifer parameters presented previously, the estimated injection rate that would be within the hydrofracturing limits at the borehole wall (1.0 ft radius) for the subject wells is presented in **Table 18** below:

Table 18. Hydrofracturing Potential Constraint Summary

Well	Depth to Confining Layer (ft)	Static Water Level (ft bgs)	Total Available Drawup (ft)	Max. Injection Rate (gpm)
MCWP-MW01	35	9	10	450
MCWP-MW02	40	10	11	410
MCWP-MW03	33	7	9	315

As shown in **Table 18**, the injection rates as constrained by hydrofracturing potential limits range between approximately 315 and 450 gpm. Again, these rates are greater than the injection capacities based on the theoretical well response criterion; therefore, hydrofracturing potential is not a limiting factor for this project.



Offsite Impacts Limits. This constraint is based on estimates of the maximum injection rate that can be achieved without causing water levels in the aquifer system offsite to rise above some level that would cause undesirable results. Typically, this means raising water levels above the ground surface at an offsite well and causing it to become artesian and start flowing at the surface (daylighting). For this project, a much more conservative limiting factor of maintaining aquifer water levels at least 5 feet below ground surface at distances greater than 20 feet from each injection well is utilized. This constraint is based on avoiding raising offsite water levels that could impact shallow structures, existing septic systems, building foundations, etc. Utilizing the Theis Equation and the aquifer parameters presented above, the maximum injection rates that can be sustained for 10 years of continuous injection without raising water levels to less than 5 feet below ground surface at distances greater than 20 feet from the injection well is summarized in **Table 19** below.

Table 19. Offsite Impact Limits Constraint Summary

Well	Limiting Distance from Injection Well (ft)	Allowable Drawup ¹ (ft)	Max. Injection Rate (gpm)
MCWP-MW01	20	4	310
MCWP-MW02	20	5	270
MCWP-MW03	20	2	120

Notes:

1 - Based on maintaining aquifer water levels > 5 ft below ground surface.

As shown in **Table 19**, the injection rates as constrained by offsite impact limits range between approximately 120 and 310 gpm. At the MCWP-MW01 and -MW02 sites, these rates are slightly greater than the injection capacities based on the theoretical well response criterion; therefore, the offsite impacts criterion is not a limiting factor on injection at those locations. At MCWP-MW03, however, the rate constrained by offsite impacts is 120 gpm, which is less than the injection capacity based on the theoretical well response criterion of approximately 170 gpm; therefore, the offsite impact criterion is a limiting factor for injection at the MCWP-MW03 location. The principal reason for this is the relatively shallow depth to water and limited available drawup at MCWP-MW03. As shown, under this criterion there is only 2 feet of available drawup offsite at MCWP-MW03, compared to 4 to 5 feet at -MW01 and -MW02, respectively.

Summary of Injection Well Capacity Constraints

A summary of all the injection capacity constraints presented above for the three MCWP test wells is presented in **Table 20** below:



Table 20. Injection Capacity Constraints Summary

Well	Injection Capacity (gpm) vs. Constraint			
	Well Response	Backflushing Capacity	Hydro-Fracturing	Offsite Impacts
MCWP-MW01	284	841	450	310
MCWP-MW02	263	566	410	270
MCWP-MW03	172	608	315	120

Notes:

Primary limiting factor capacity shown in **bold** type.

In summary, a review of the various hydrogeologic and operational factors that limit the injection capacity of wells in the CCG aquifer reveals that the well response to injection criterion represents the primary constraint on the injection capacity at MCWP-MW01 and –MW02, with injection rates of approximately 260 to 280 gpm. The offsite impacts criterion represents the primary constraint at MCWP-MW03. In all cases, the injection capacity of any given well in the CCG aquifer is limited primarily by the shallow depths to water and limited amounts of available drawup (freeboard) in either the aquifer or the well casings.

CONCLUSIONS

Based on the findings from the Malibu Pilot Injection Testing Project, we conclude the following:

- The well redevelopment effort demonstrably improved the hydraulic performance of MCWP-MW01 and –MW02. Following initial injection operations, the hydraulic performance of MCWP-MW03 also improved significantly. These results indicate that the test wells were likely insufficiently developed following their construction in 2011.
- MCWP-MW01 displayed water-level drawup due to injection ranging between approximately 0.3 to 1.1 feet and specific injectivities ranging between approximately 100 to 170 gpm/ft, depending on the rate and duration of injection. No active or residual plugging occurred at this well as a result of pilot injection testing.
- MCWP-MW02 displayed water-level drawup due to injection ranging between approximately 1.4 to 8.3 feet and displayed specific injectivities ranging between approximately 12 to 26 gpm/ft, depending on the rate and duration of injection. A plugging rate of approximately 0.5 feet per day was observed at this well, and some residual plugging remained following the testing program.
- MCWP-MW03 displayed water-level drawup due to injection ranging between approximately 0.5 to 1.4 feet and specific injectivities ranging between approximately 77 to 100 gpm/ft, depending on the rate and duration of injection. The hydraulic performance of this well improved significantly as a result of injection, and no active or residual plugging occurred at this well.



- The SDI of the potable water used for injection testing was consistently in the range of 2.0 to 3.0 throughout the injection testing program, indicative of relatively low particulate levels. The difference in the plugging rate observed at MCWP-MW02 compared to –MW01 and -MW03 is attributable the presence of higher percentages of fine-grained materials in the aquifer matrix at this location, rather than differences in the particulate concentrations in the injectate. It should be noted that potable water was used for injection testing as surrogate for CCWTF effluent, which did not exist at time of pilot injection testing. For comparison, however, the Lumber Yard Wastewater Treatment Plant effluent displayed a comparable SDI of approximately 2.1.
- Aquifer response to injection at each test well was observed in both the proximate and more distant CCG monitoring wells. At the proximate (20 feet) monitoring wells, aquifer responses of approximately 0.7 to 1.2 feet of aquifer mounding was observed. At the more distant (1250 to 2450 feet), drawup responses of approximately 0.2 to 0.6 feet were observed. No discernable response to injection in the CCG was observed in the shallow aquifer monitoring wells.
- Backflushing at MCWP-MW01 and –MW03 was ineffective at particulate removal; however, given the lack of observed plugging (active or residual) at these wells, these results are not unexpected. These findings indicate that longer duration and/or higher rates of injection would be required for the aquifer matrix pore spaces to become blocked by particulates at these locations. Backflushing at MCWP-MW02 was effective at particulate removal; however, a small amount of residual plugging was observed at this well, suggesting that more thorough backflushing is required at this location.
- Water-level data collected at all three test wells shows the influence of tidal fluctuations. These observations, combined with variations in electrical conductivity (salinity) at MCWP-MW03¹⁴, are indicative of a hydraulic connection between the CCG aquifer and the Pacific Ocean.
- Aquifer parameter analyses resulted in average transmissivity values ranging between approximately 85,000 to 178,000 gpd/ft, depending on location and curve analyzed. These values indicate that the CCG aquifer is moderately to highly transmissive. Storage coefficient values in the central and western areas of the basin (i.e., MCWP-MW01 and –MW03) are on the order of 1×10^{-2} , indicative of unconfined to semi-confined aquifer conditions. The eastern area of the basin (i.e., MCWP-MW02) displays confined conditions, with storage coefficient values on the order of 1×10^{-5} .
- Based on analysis of the various factors affecting per-well injection capacities, including allowable drawup in the well casings and aquifer (freeboard), backflushing capacity, and hydrofracturing potential, long-term sustainable injection rates ranging

¹⁴ Discussed in a separate TM entitled *Malibu Groundwater Injection Feasibility Project – Phase 3; Geochemical Modeling Assessment*, prepared by PWR for RMC Water and Environment, dated February 4, 2014 (draft).



between approximately 120 to 280 gpm are possible, depending on location in the basin. In all cases, the injection capacity is limited primarily by the shallow depths to water and available freeboard in the CCG aquifer.

- In order to verify the long-term performance and capacity of permanent project injection wells, the pilot injection testing program documented herein needs to be repeated with the actual effluent from the CCWTF (or a suitable effluent proxy).

RECOMMENDATIONS

Based on the pilot injection testing program results, and our experience with similar injection well projects, we offer the following recommendations:

- If possible, permanent project injection wells should be located in the central to western portions of the basin (i.e., near MCWP-MW01 and -MW03) in order to limit plugging rates. Wells located in the eastern portion of the basin (i.e., near MCWP-MW02) can be expected to experience significantly higher rates of plugging, require more frequent backflushing, and have reduced service lives.
- For planning purposes, per-well injection rates should be limited to 120 to 280 gpm, depending on location in the basin, in order to avoid excessive water levels in either the aquifer or injection well casings that could lead to undesirable results (e.g., daylighting of water at the ground surface).
- Permanent project injection wells should be thoroughly developed following construction and prior to being placed into service. Development operations should utilize a variety of techniques (e.g., line swabbing, dual-swab air lifting, over-pumping, etc.) to ensure injection hydraulic efficiencies and capacities are maximized.
- For planning purposes, a bi-weekly backflushing schedule is recommended for injection wells located in the central and western portions of the basin. A more frequent backflushing schedule would be required to limit the effects of plugging and maintain injection capacity if wells were located in the eastern portion of the basin.
- Due to the unconfined to semi-confined aquifer conditions of the CCG in the central and western portions of the basin, injection well operational factors should include non-pressurized injection in order to avoid potential “daylighting” of water from the aquifer at the ground surface.
- The existing groundwater model of the Malibu Valley Groundwater Basin should be calibrated to the results of the subject pilot injection testing program. The model should then be utilized to establish optimal well spacing and long-term per-well injection rates for the permanent project, taking into consideration well interference and boundary condition effects (e.g., the Pacific Ocean and bedrock boundaries).
- The results of the pilot injection testing program should be replicated through injection trials at the permanent injection wells utilizing injectate sourced from the



CCWTF in order to confirm injection well performance, plugging rates, and per-well injection capacities established as part of the subject pilot testing program.

CLOSURE

This technical memorandum has been prepared exclusively for RMC Water and Environment for the specific application to the Malibu Groundwater Injection Project. The findings, conclusions, and recommendations presented herein were prepared in accordance with generally accepted hydrogeologic and civil engineering practices. No other warranty, express or implied, is made.

-- O --

FIGURES

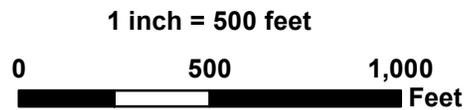
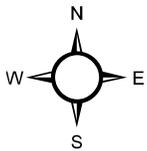
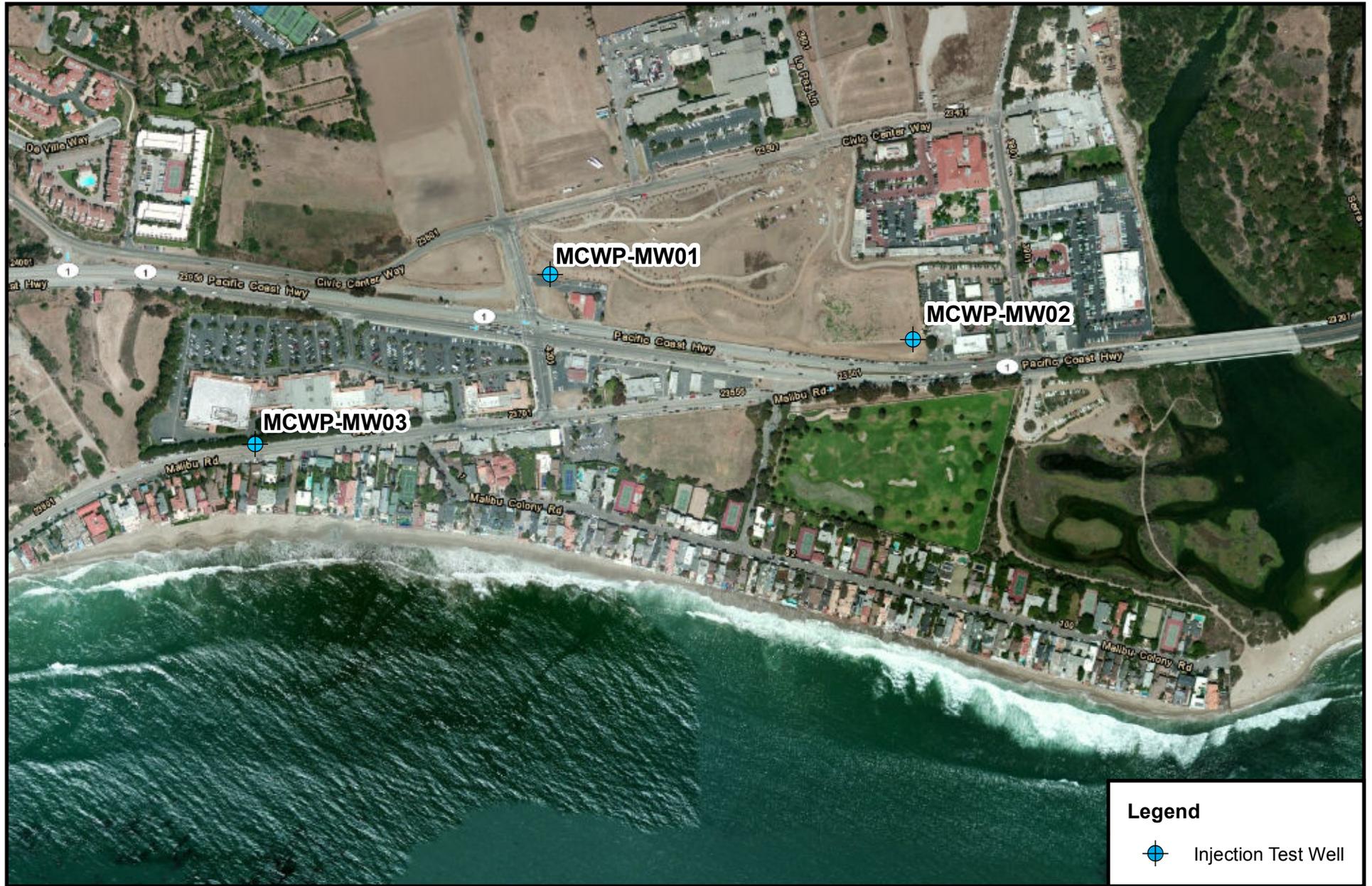
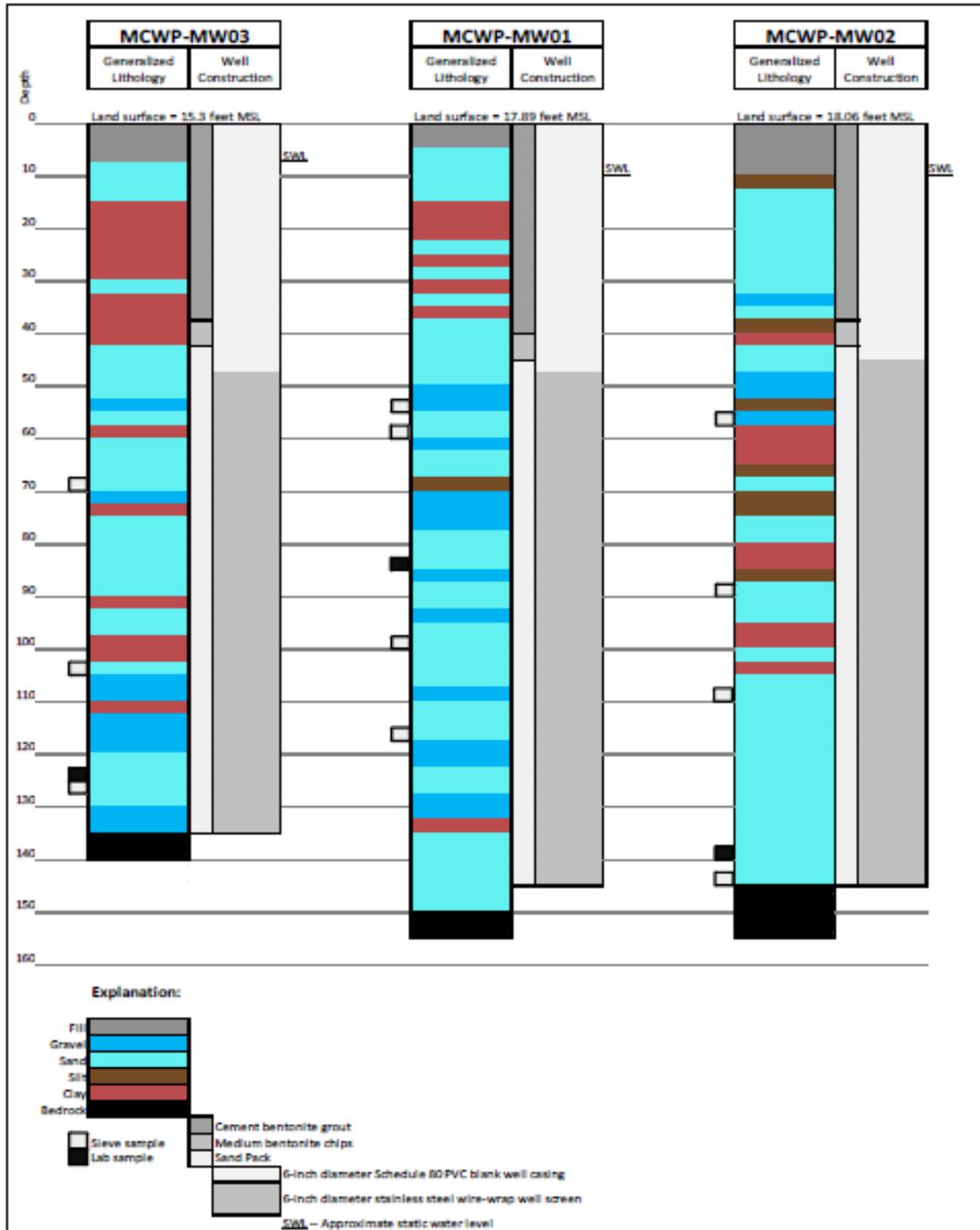


FIGURE 1. SITE LOCATION MAP
Malibu Pilot Injection Testing Project
RMC Water and Environment / City of Malibu



Source: Groundwater Dynamics (2012)



FIGURE 3. WELL LOCATION MAP - MCWP-MW01 TESTING WELLS
Malibu Pilot Injection Testing Project
RMC Water and Environment / City of Malibu

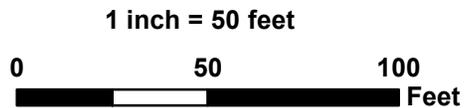
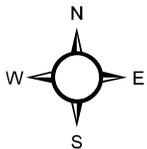


FIGURE 4. WELL LOCATION MAP - MCWP-MW02 TESTING WELLS
Malibu Pilot Injection Testing Project
RMC Water and Environment / City of Malibu

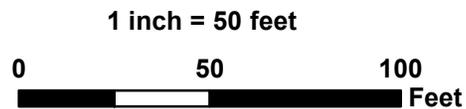
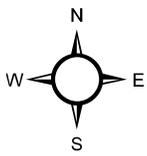


FIGURE 5. WELL LOCATION MAP - MCWP-MW03 TESTING WELLS
Malibu Pilot Injection Testing Project
RMC Water and Environment / City of Malibu

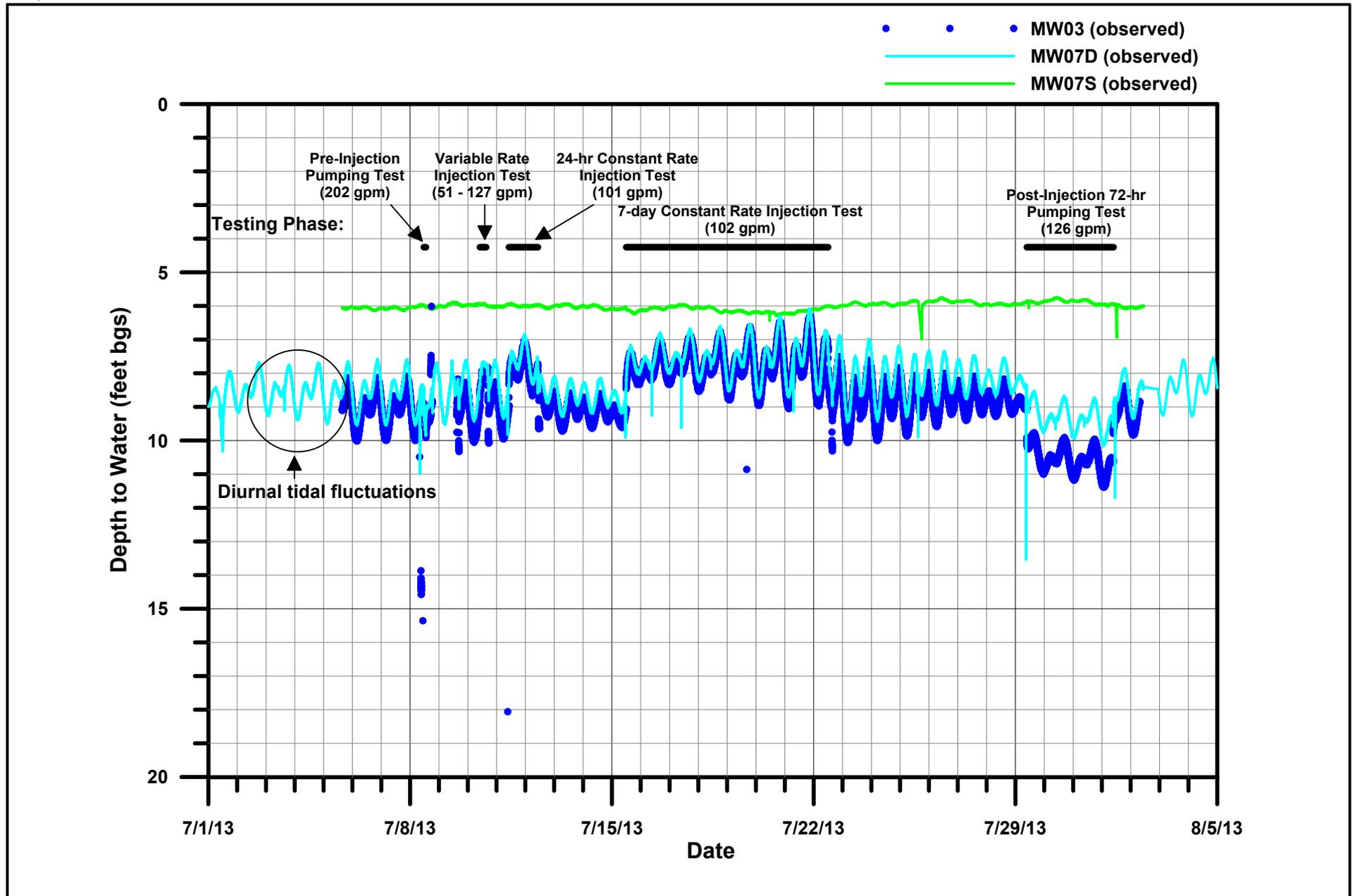


FIGURE 6. OBSERVED WATER-LEVEL DATA - MCWP-MW03 TESTING PROGRAM
Malibu Pilot Injection Testing Project
RMC Water and Environment / City of Malibu

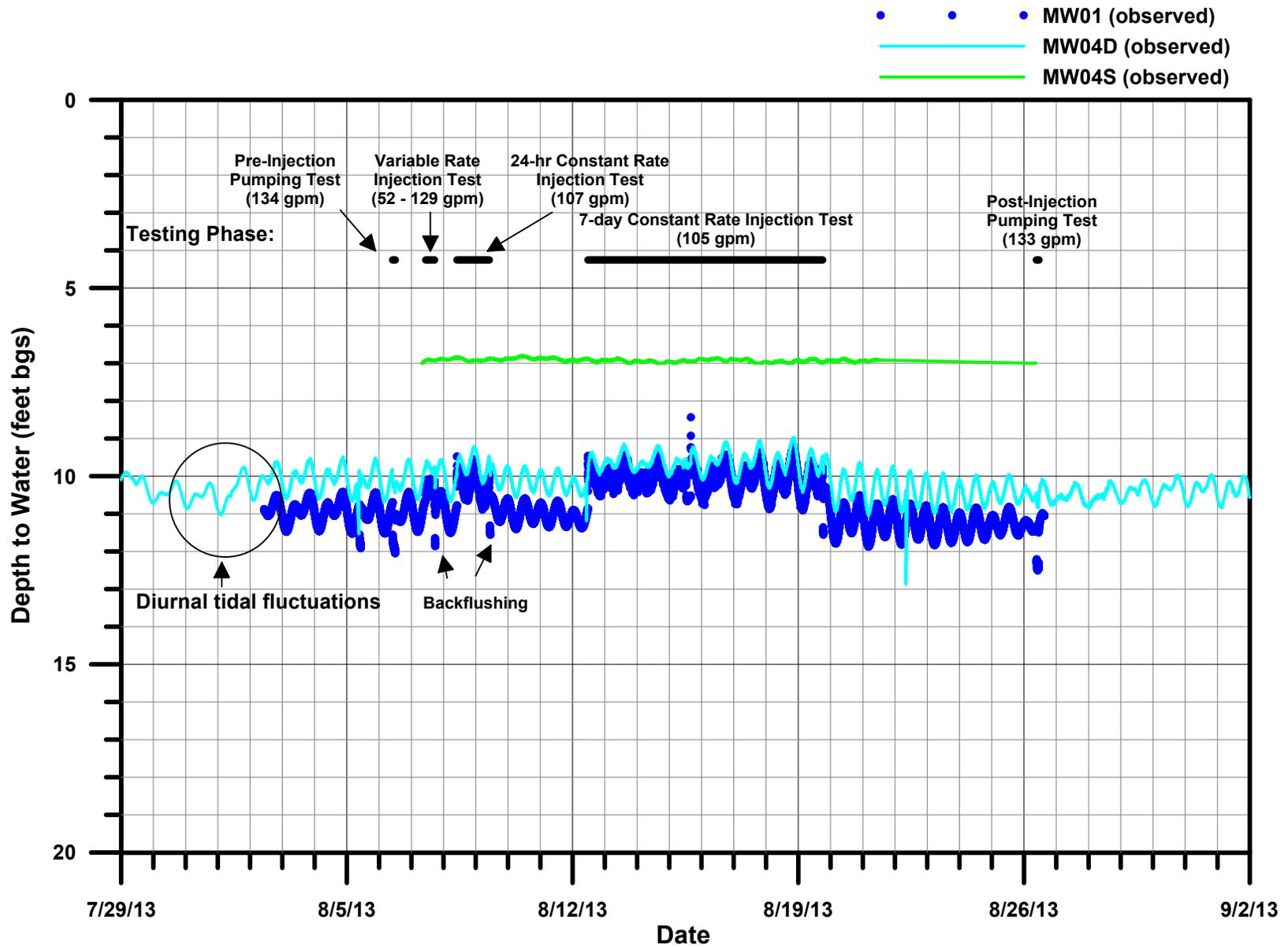


FIGURE 7. OBSERVED WATER-LEVEL DATA - MCWP-MW01 TESTING PROGRAM
Malibu Pilot Injection Testing Project
RMC Water and Environment / City of Malibu

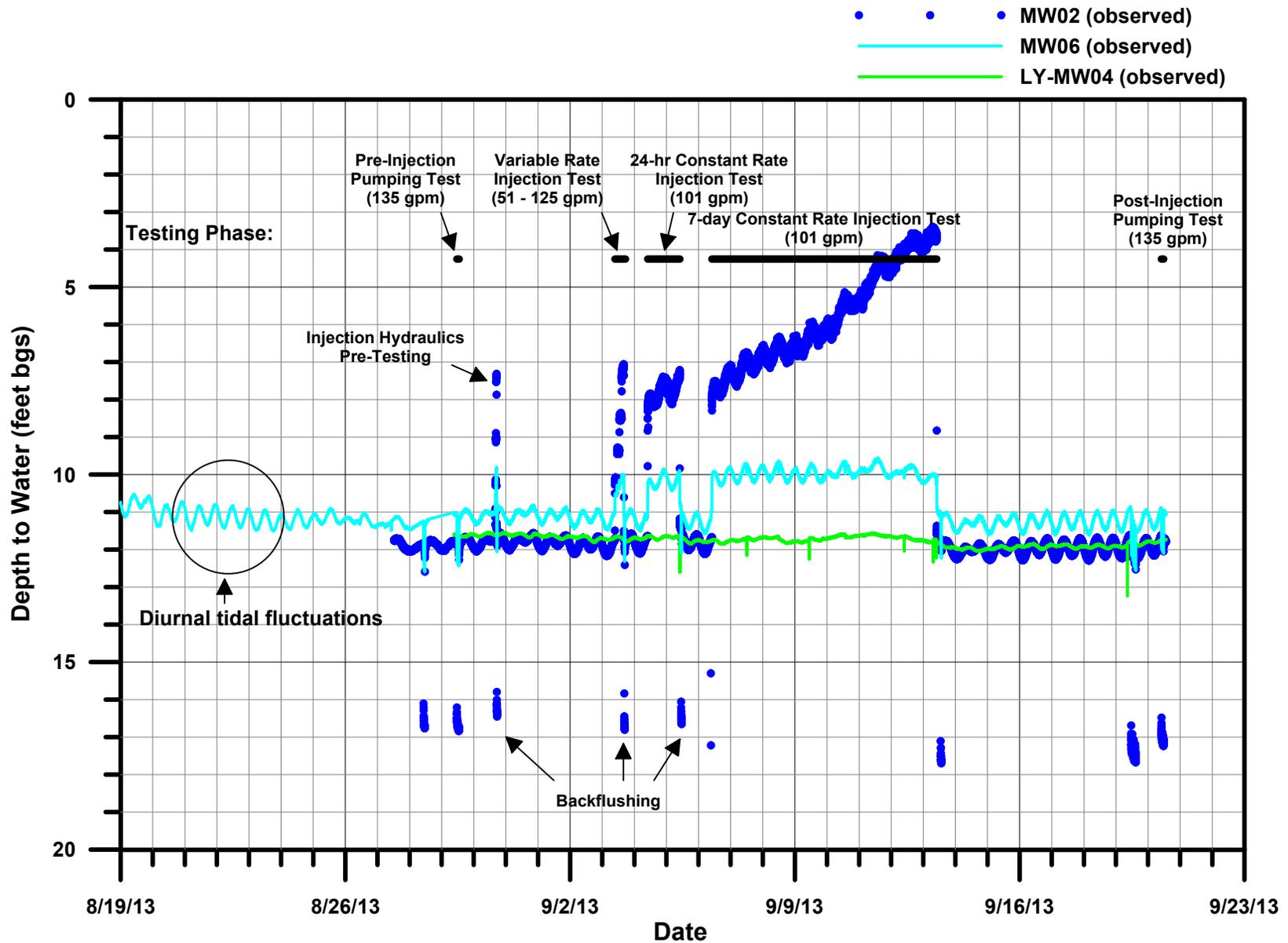


FIGURE 8. OBSERVED WATER-LEVEL DATA - MCWP-MW02 TESTING PROGRAM
Malibu Pilot Injection Testing Project
RMC Water and Environment / City of Malibu

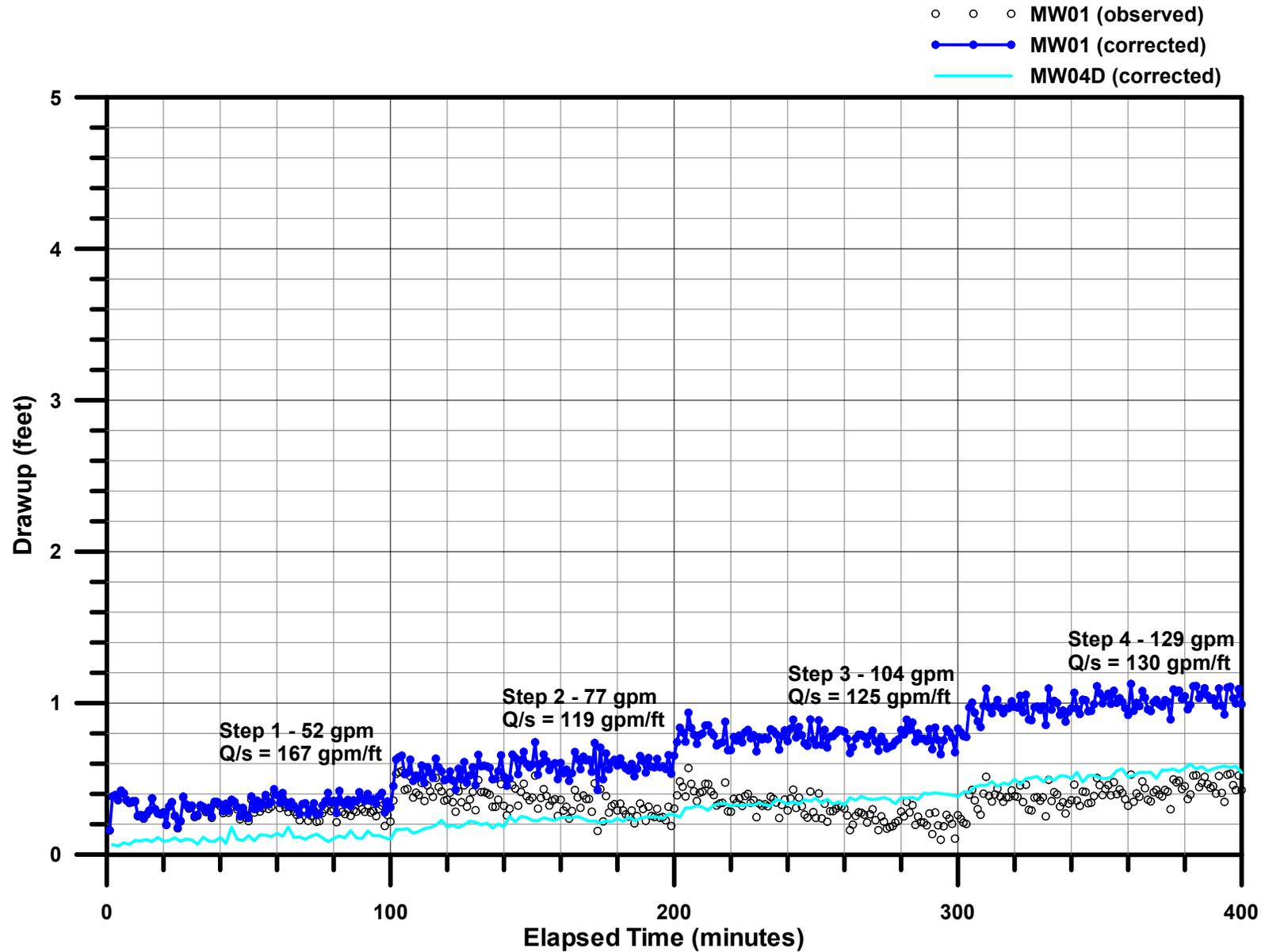


FIGURE 9. VARIABLE-RATE INJECTION TEST - MCWP-MW01
Malibu Pilot Injection Testing Project
RMC Water and Environment / City of Malibu

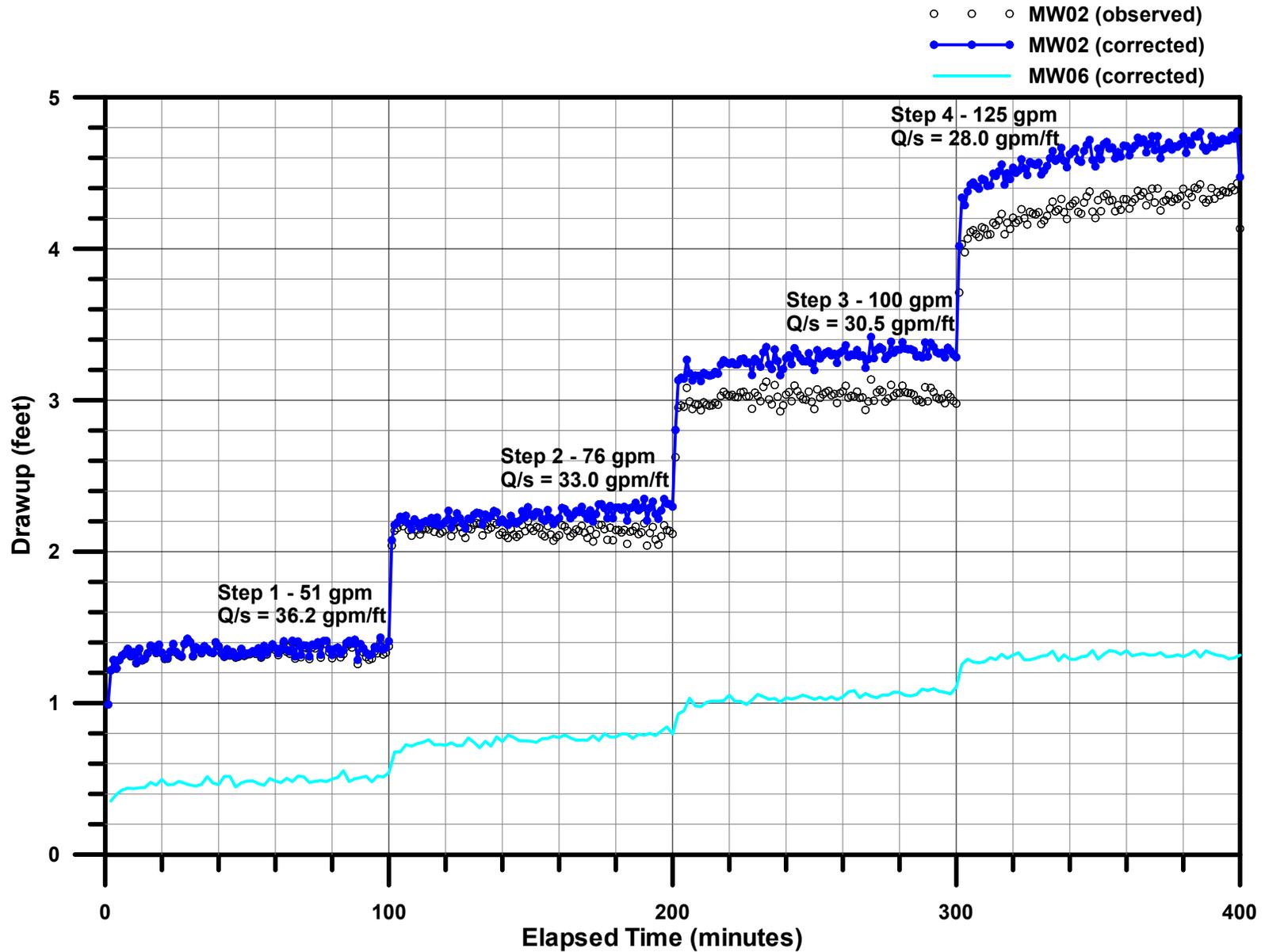


FIGURE 10. VARIABLE-RATE INJECTION TEST - MCWP-MW02
Malibu Pilot Injection Testing Project
RMC Water and Environment / City of Malibu

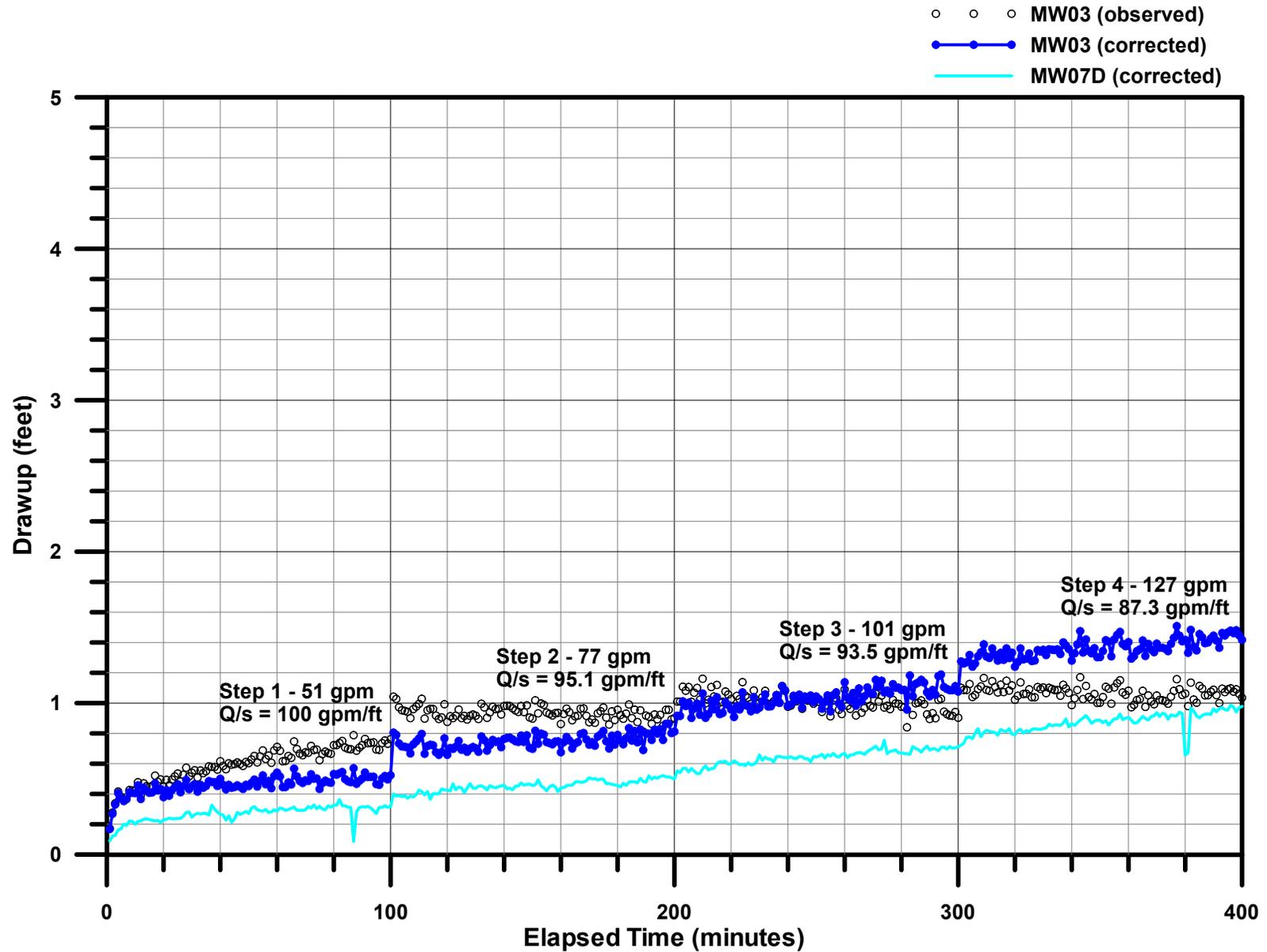


FIGURE 11. VARIABLE-RATE INJECTION TEST - MCWP-MW03
Malibu Pilot Injection Testing Project
RMC Water and Environment / City of Malibu

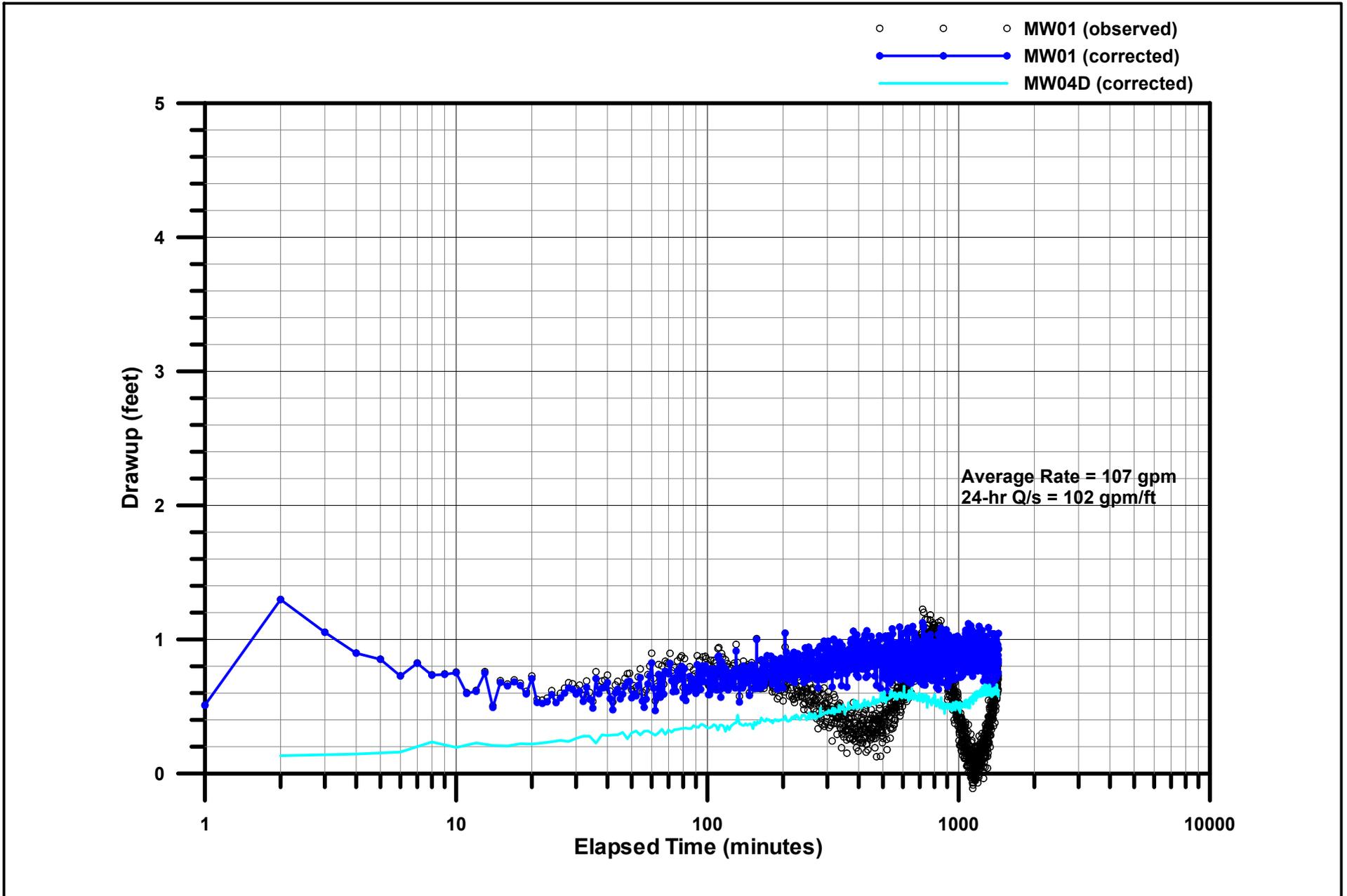


FIGURE 12. 24-HR CONSTANT RATE INJECTION TEST - MCWP-MW01
Malibu Pilot Injection Testing Project
RMC Water and Environment / City of Malibu

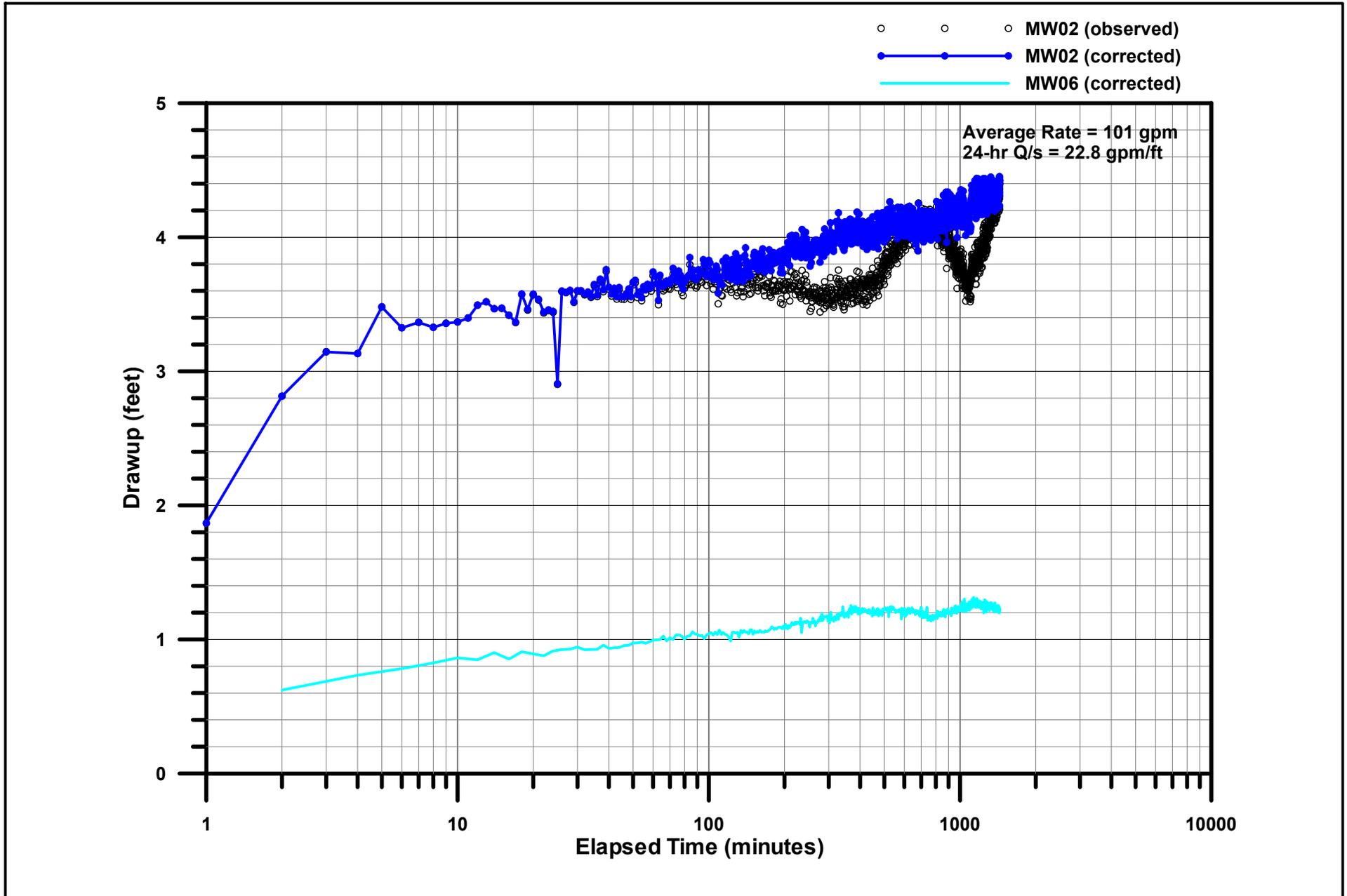


FIGURE 13. 24-HR CONSTANT RATE INJECTION TEST - MCWP-MW02
Malibu Pilot Injection Testing Project
RMC Water and Environment / City of Malibu

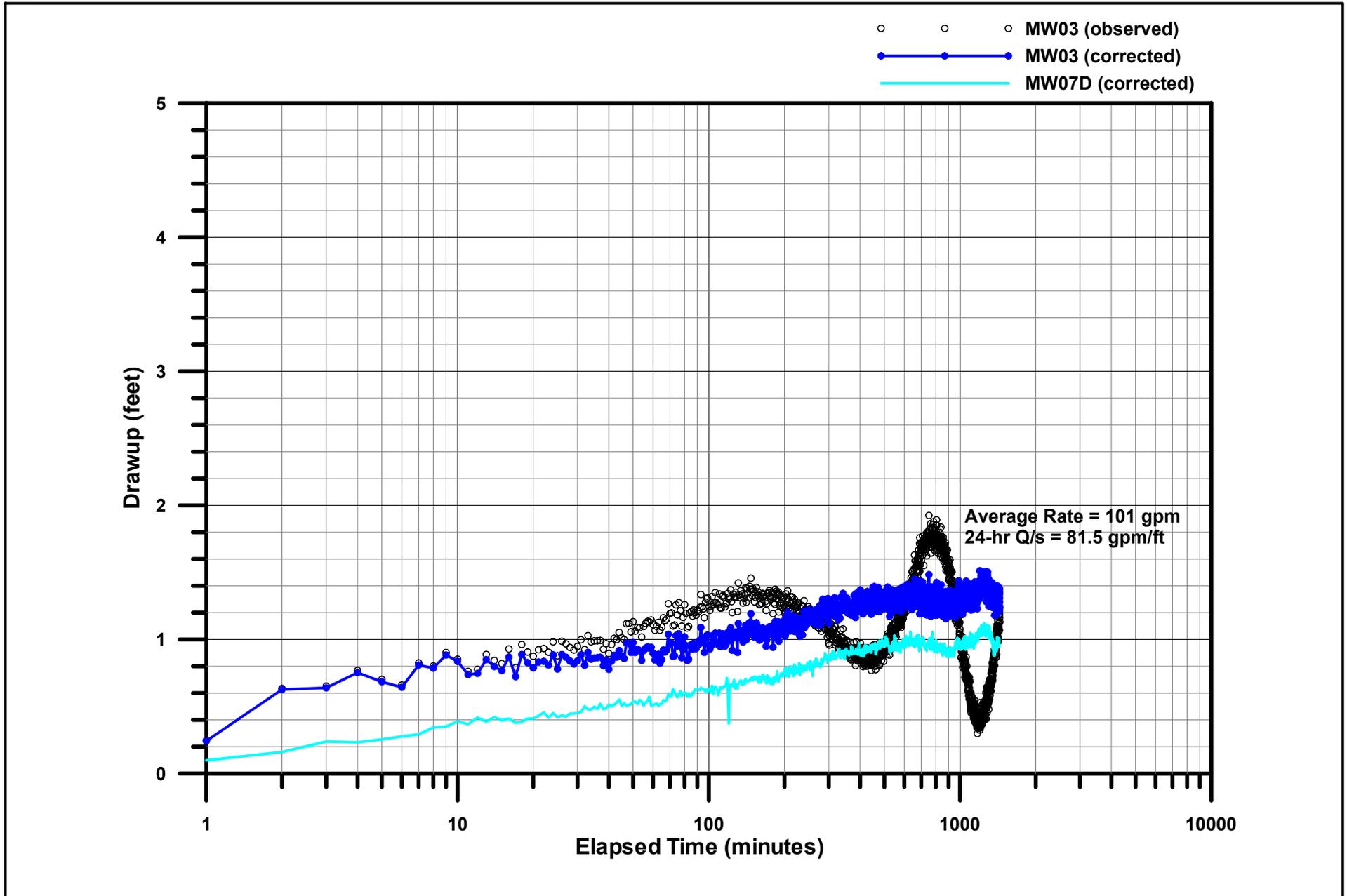


FIGURE 14. 24-HR CONSTANT RATE INJECTION TEST - MCWP-MW03
Malibu Pilot Injection Testing Project
RMC Water and Environment / City of Malibu

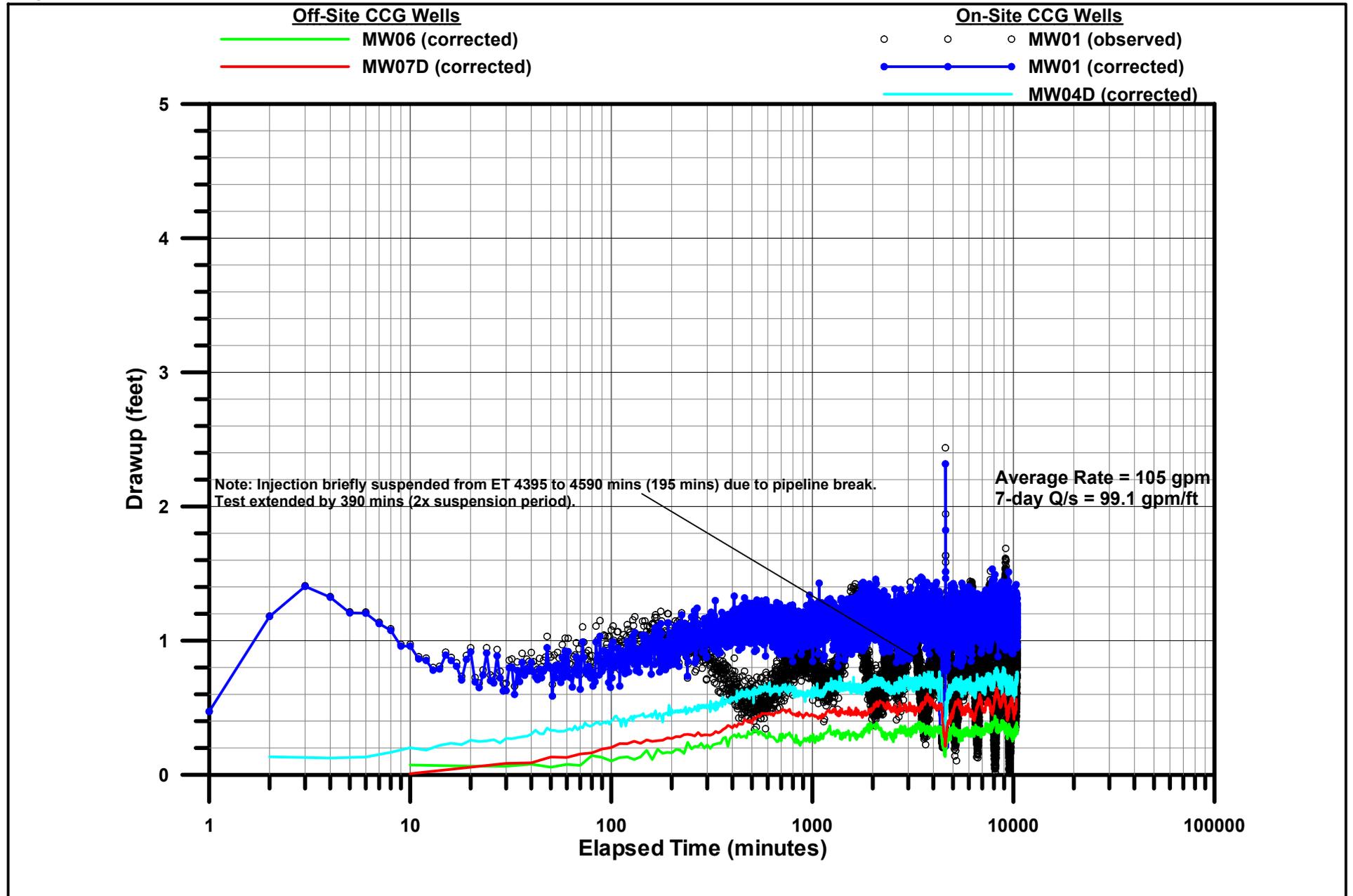


FIGURE 15. 7-DAY CONSTANT RATE INJECTION TEST - MCWP-MW01
Malibu Pilot Injection Testing Project
RMC Water and Environment / City of Malibu

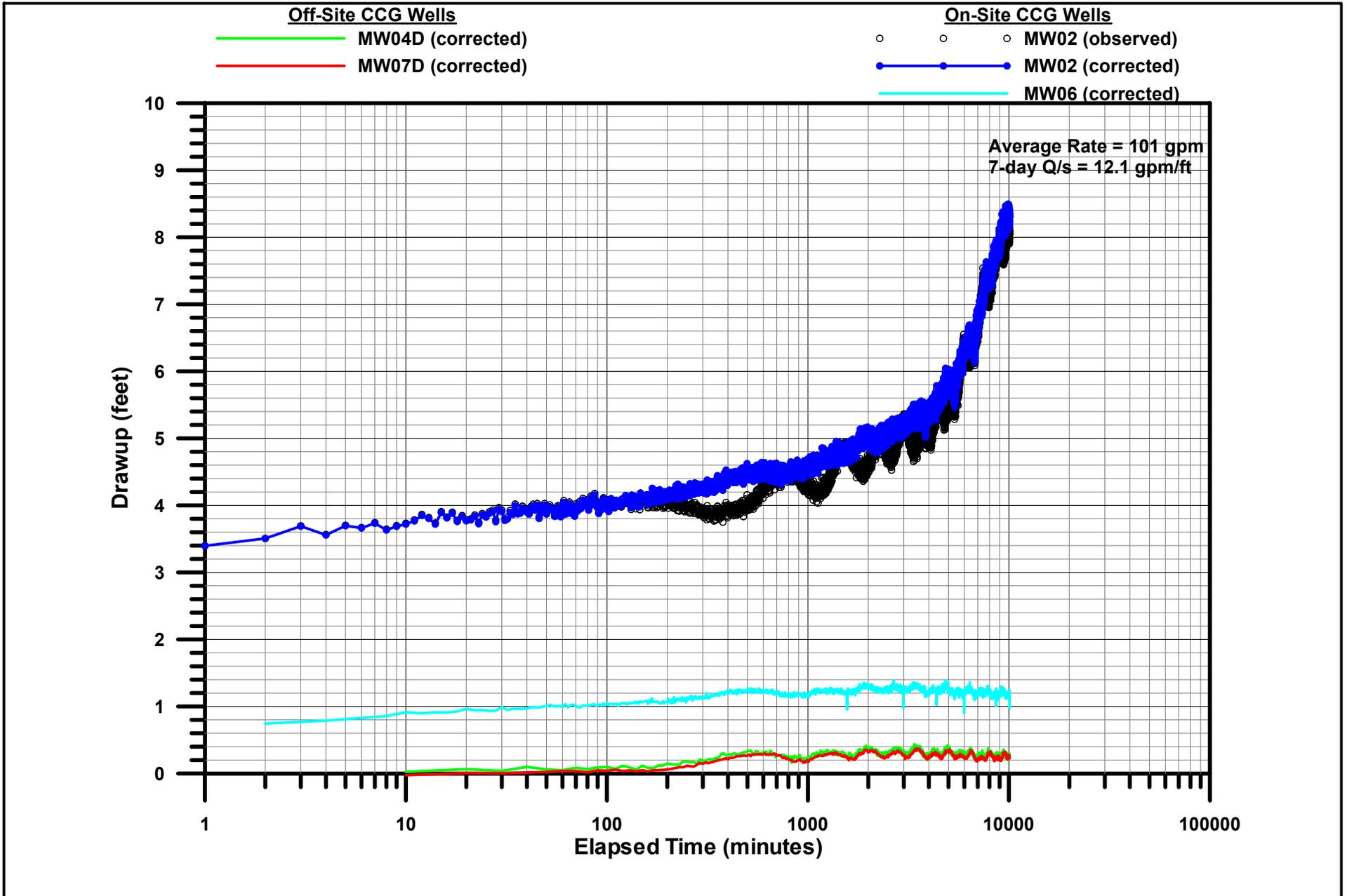


FIGURE 16. 7-DAY CONSTANT RATE INJECTION TEST - MCWP-MW02
Malibu Pilot Injection Testing Project
RMC Water and Environment / City of Malibu

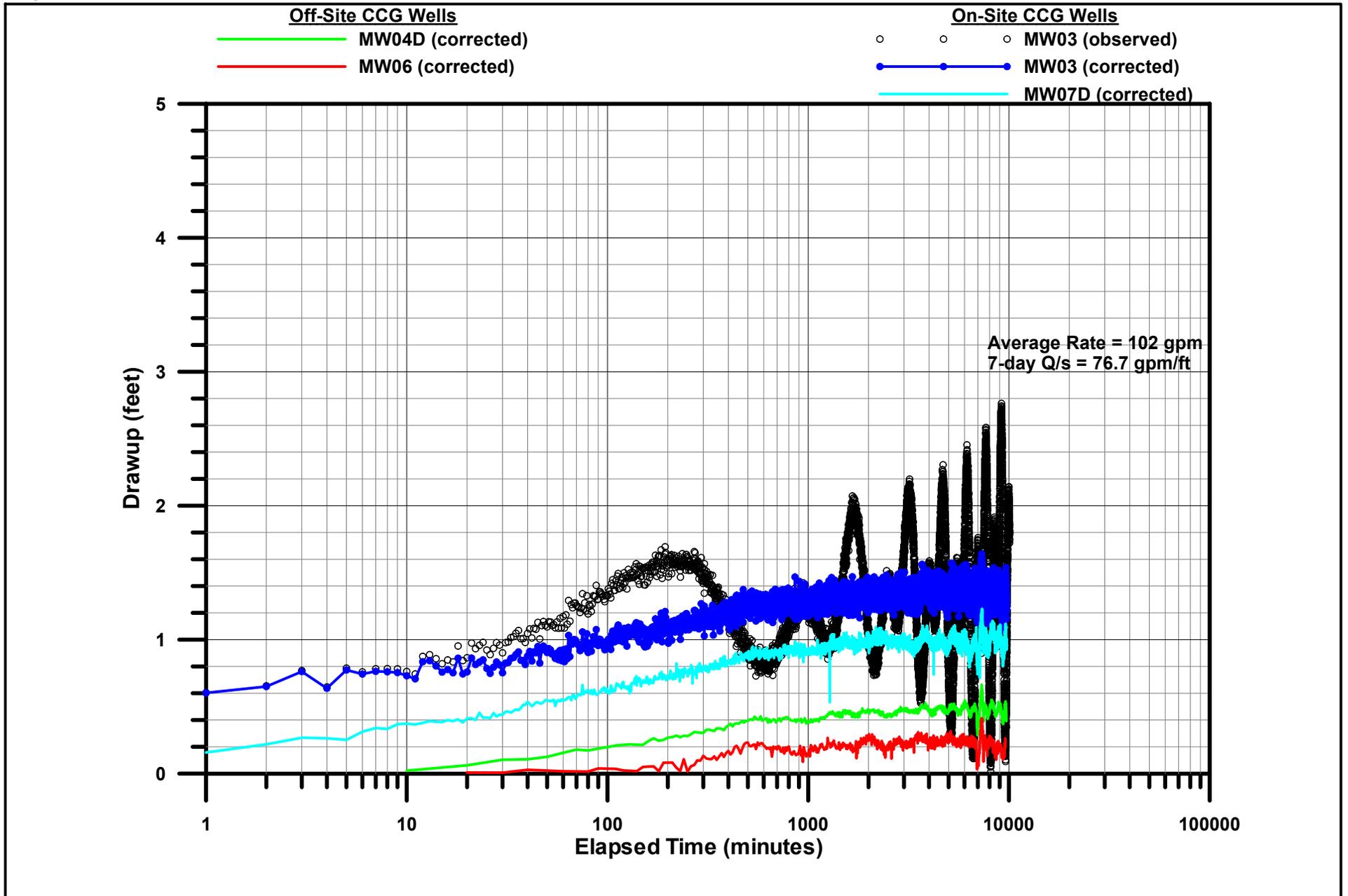


FIGURE 17. 7-DAY CONSTANT RATE INJECTION TEST - MCWP-MW03
Malibu Pilot Injection Testing Project
RMC Water and Environment / City of Malibu

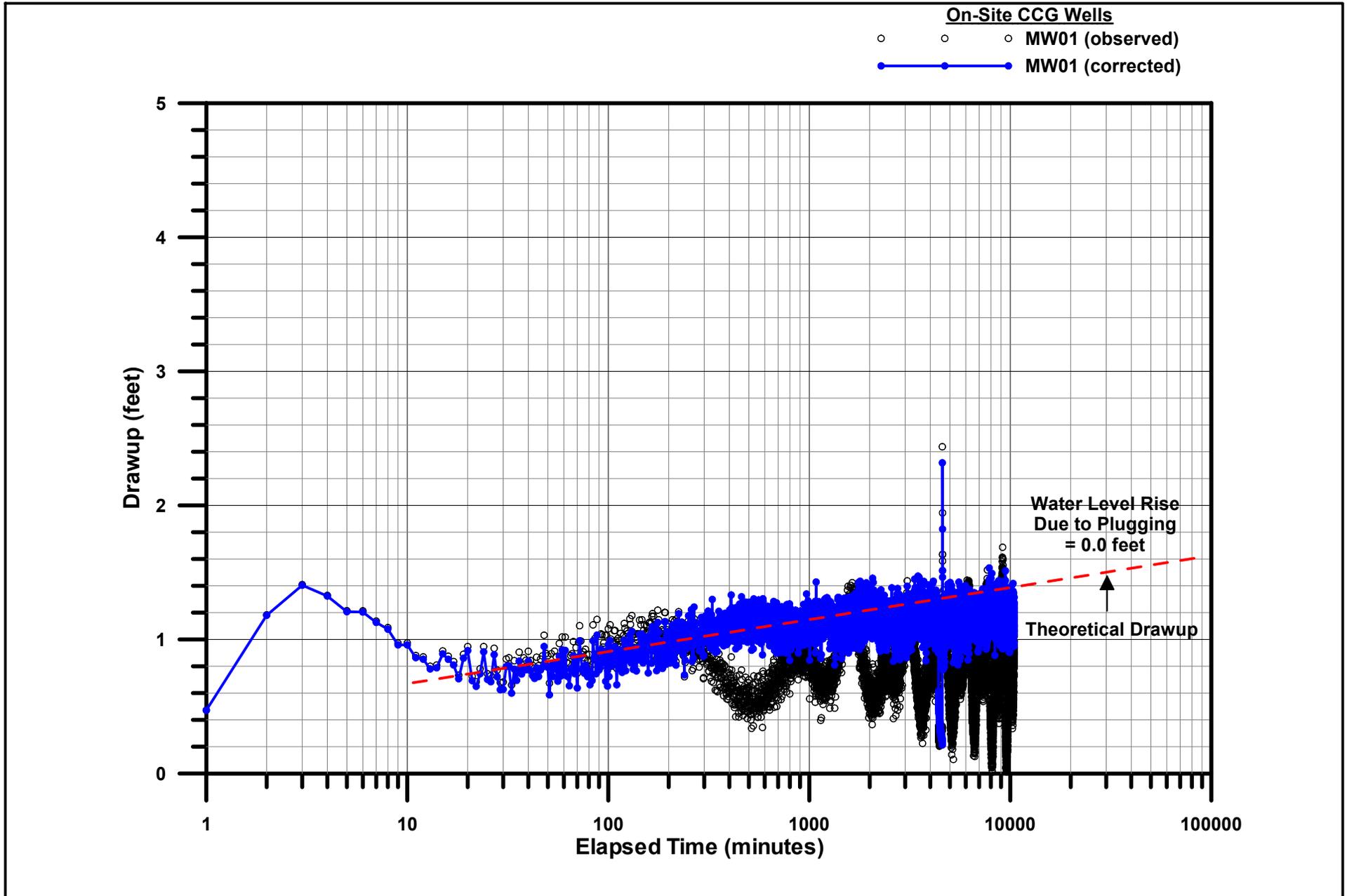


FIGURE 18. PLUGGING RATE ANALYSIS - MCWP-MW01
Malibu Pilot Injection Testing Project
RMC Water and Environment / City of Malibu

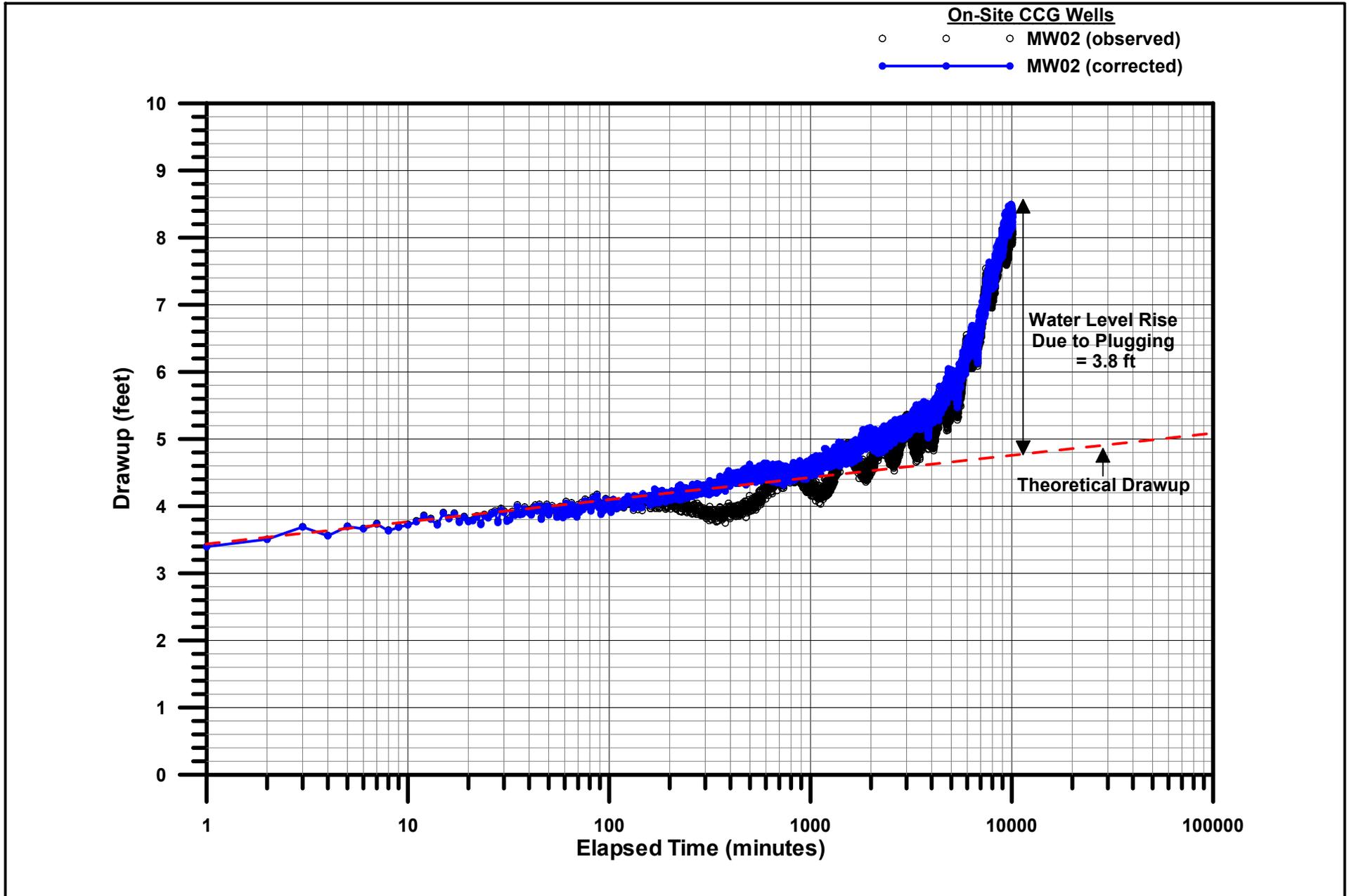
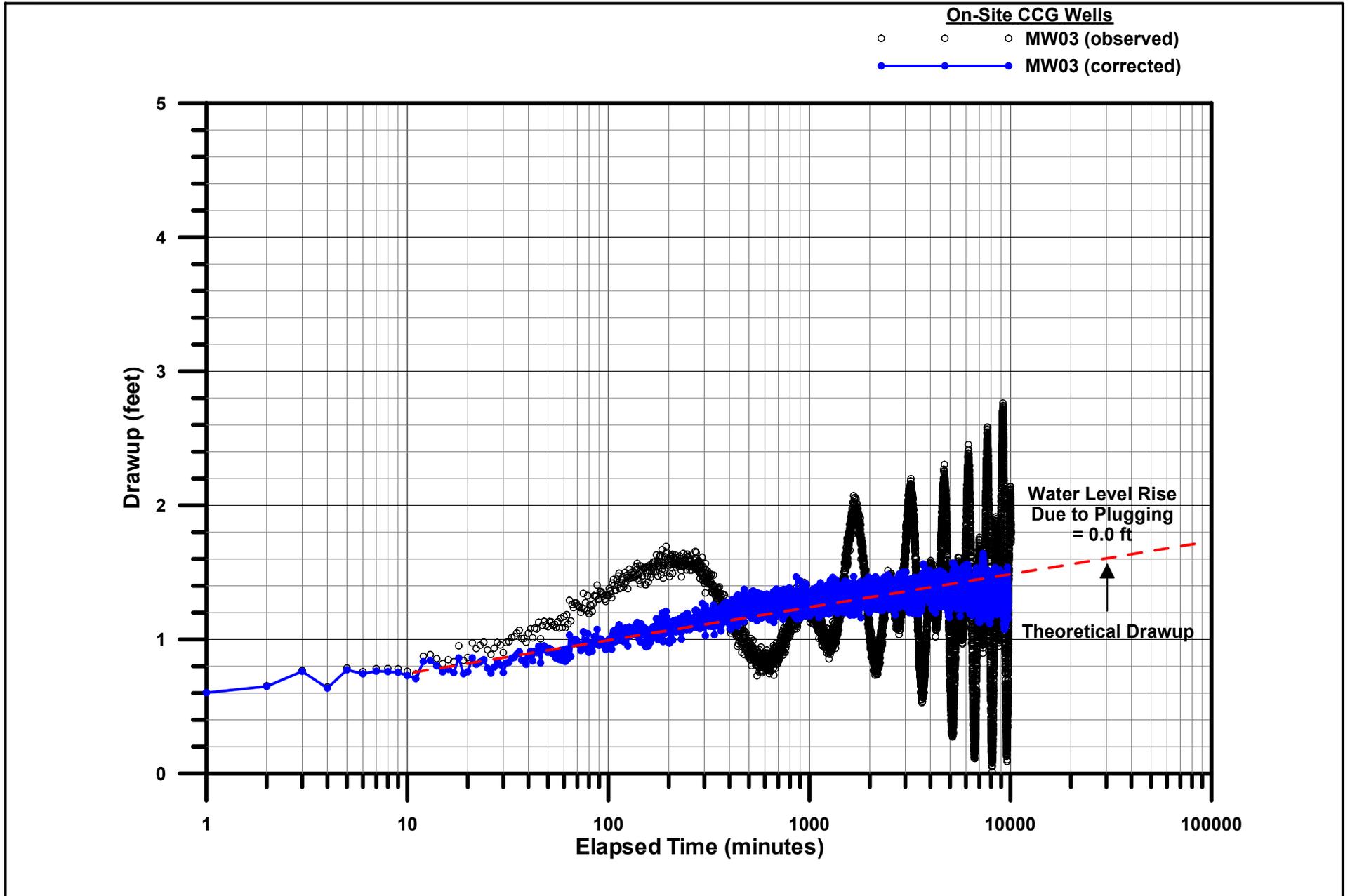


FIGURE 19. PLUGGING RATE ANALYSIS - MCWP-MW02
Malibu Pilot Injection Testing Project
RMC Water and Environment / City of Malibu



APPENDIX A – FIELD DATA SHEETS

PUMPING TEST DATA



Client: RMC / City of Malibu

Project: GW Injection Ph 3

Project No: 12-0051

Well: MLWP MW03

Reference Pt: Top of S. Tube (3.1' ags)

Date: 7/8/13

Static Water Level (ft): 12.12' 6tst

Test/Data Set I.D.: 100-min Q/s #2 (Redo)

Pump Setting (ft): ~42' 6tst

Observer: RCM

Well Depth (ft): ~138'

Clock Time	Elapsed Time	Fuji Rate (gpm)	Water Level (feet)	Sand (ml)	Other Observations (visual, odor, spec. capacity, totalizer, field wq, etc.)
11 ³⁰	0	0	12.12	-	Totalizers: RI = 150479 [13] gals
	1	205	29.85		Fuji = 7135 gals
	2	197	29.28		RF Mcrom = 794790 [00] gals
	4	200	29.62		
	6	200	29.83		
	8	200	29.95		56 psi RI = 105 gpm
11 ⁴⁰	10	200	29.98		Totalizers: RI = 150500 [10] gals
	12		30.00		Fuji = 9100 gals
	15		30.05		
	20	200	30.13		
12 ⁰⁰	30	200	30.26		EC = 250 uS, pH = 7.4, T = 22.1°C, ORP = +60 mV
	40		30.31		
	50	200	30.41		
12 ³⁰	60		30.47		EC = 2560 uS, pH = 7.3, T = 22.3, ORP = +26 mV
	70	200	30.56		
	80				
13 ⁰⁰	90	200	30.62		EC = 2660 uS, pH = 7.3, T = 22.6°C, ORP = +46 mV
13 ¹⁰	100		30.66		Stop pump. Totalizers: RI = 150685 [00] gals
					Fuji = 27296 gals
					Q Avg: RI = 206 gpm
					Fuji = 202 gpm
					Ag = 204 gpm

Q/s = 204 / 18.5
 = 11.0 gpm/ft

Notes: 12³⁰ Begin fill sample bottles for Eurofins Lab.



Subject: MW03 Variable Rate Inj. Test

Project: GW Injection Ph3

Client: RMC/City of Malibu

Project No.: 12-0051 By: RCM Date: 7/10/13 Sheet No.: 1 of 2

Date/Time	ET (min)	Q (gpm)	DTW (ft)	DUP (ft)	PSI				Min	Line
					0.505	0.600	0.700	0.810		
7/10/13 12:00	0	-	12.04	-	-	-	-	-	80	80
	1	50	11.75	-	-	-	-	-	40	70
	2	50	11.66	-	-	-	-	-	40	70
	4	52	11.58	-	-	-	-	-	40	70
	6	52	11.60	-	-	-	-	-	40	70
	8	50	11.57	-	-	-	-	-	40	72
	10	50	11.55	0.47	-	-	-	-	40	72
	12	15	11.57	-	-	-	-	-	40	72
	15	15	11.55	-	-	-	-	-	40	72
	20	20	11.53	-	-	-	-	-	40	72
	30	52	11.49	-	-	-	-	-	40	72
	40	40	11.46	-	-	-	-	-	40	72
	40	40	11.40	-	-	-	-	-	40	72
	50	50	11.36	-	-	-	-	-	40	72
	60	51	11.33	-	-	-	-	-	40	72
	70	70	11.31	-	-	-	-	-	40	72
	80	80	11.32	-	-	-	-	-	40	72
	90	51	11.32	0.72	-	-	-	-	40	72
	11:40	101	10.84	-	-	-	-	-	40	70
	11:50	102	10.69	-	-	-	-	-	40	70
		104	11.11	-	-	-	-	-	40	70
		106	11.08	-	-	-	-	-	40	70
		108	10.99	1.05	-	-	-	-	40	70
		110	11.03	-	-	-	-	-	40	70
		112	11.08	-	-	-	-	-	40	70
		115	11.06	-	-	-	-	-	40	70
		120	11.03	-	-	-	-	-	40	70
		130	11.03	-	-	-	-	-	40	70
		140	11.03	-	-	-	-	-	40	70
		150	11.05	-	-	-	-	-	40	70
		160	11.07	-	-	-	-	-	40	70
		170	11.07	-	-	-	-	-	40	70
		180	11.07	-	-	-	-	-	40	70

Comments / other
 Total Inj: 2" = 001423 [40] gals
 F_{0.5} = 0 gals
 Hydrant = 018580 [4.9] ft³

10-min a/s: 50 / 0.47 = 106 gpm/ft
 2" meter = 51 gpm.

SDF: $\frac{1}{2}$ $\frac{20}{5}$ $\frac{20}{10}$ $\frac{20}{15}$ $\frac{20}{37}$ $\frac{20}{37}$ SDF = 3.1

EC = 474 μ S, PH = 8.5, T = 18.4°C
 ORP = +334 mV
 MW07D = 7.99, MW07S = 6.04

Total Inj: 2" = 001423 [58] gals
 F_{0.5} = 5087 gals

a/s: 76 / 1.05 = 72 gpm/ft

2" meter = 76 gpm

SDF: $\frac{1}{2}$ $\frac{20}{5}$ $\frac{20}{10}$ $\frac{20}{15}$ $\frac{20}{39}$ $\frac{20}{39}$ SDF = 2.9

Subject: mu03 Variable Rate Inj. Test

Project: GW Injection Ph 3

Client: RMC / City of Malibu

Project No.: 12-0051 By: RCM Date: 7/10/13 Sheet No.: 2 of 2

Date/Time	ET	Q	DTW	DUP	PSI						Comments/Other
					0.525	0.600	0.700	0.810	Mem.	Line	
13 ³⁰	200	76	11.10	-	-	12	12	12	40	71	13 ³⁰ Total Inj: 2" = 001549 [75] gals Fuji = 12814 gals
13 ⁴⁰	201	105	10.88	-	12	12	12	12	45	64	
13 ⁴⁰	202	104	10.88	-	10	10	10	10	36	65	
13 ⁴⁰	206	101	10.98	-	10	10	10	10	36	66	
13 ⁴⁰	208	101	10.94	1.11	10	10	10	10	36	66	
13 ⁵⁰	212	102	10.88	-	10	10	10	10	36	66	
13 ⁵⁰	215	102	10.94	-	10	10	10	10	36	66	
13 ⁵⁰	220	101	10.91	-	10	10	10	10	36	66	
14 ¹⁰	230	101	10.90	-	10	10	10	10	36	65	
14 ¹⁰	240	101	10.95	-	10	10	10	10	36	65	
14 ¹⁰	250	101	10.98	-	10	10	10	10	36	65	
14 ⁴⁰	260	101	10.97	-	10	10	10	10	36	65	
14 ⁴⁰	270	101	10.98	-	10	10	10	10	36	65	
15 ⁰⁰	280	101	11.01	-	10	10	10	10	36	65	
15 ⁰⁰	290	101	11.02	-	10	10	10	10	36	65	
15 ⁰⁰	300	101	11.02	1.02	10	10	10	10	36	65	
15 ³⁰	301	127	10.92	-	10	10	10	10	41	56	
15 ³⁰	302	124	10.86	-	10	10	10	10	41	56	
15 ³⁰	304	124	10.88	-	10	10	10	10	41	54	
15 ³⁰	306	126	10.90	-	10	10	10	10	42	54	
15 ³⁰	308	126	10.87	-	10	10	10	10	42	55	
15 ⁴⁰	310	126	10.88	1.16	12	12	12	12	42	55	
15 ⁴⁰	312	126	10.87	-	11	11	11	11	42	55	
15 ⁴⁰	315	126	10.91	-	10	10	10	10	42	55	
15 ⁴⁰	320	127	10.86	-	10	10	10	10	42	55	
16 ¹⁰	340	126	10.88	-	10	10	10	10	42	55	
16 ¹⁰	350	126	10.90	-	10	10	10	10	42	55	
16 ¹⁰	360	126	10.83	-	10	10	10	10	42	55	
16 ¹⁰	370	126	10.88	-	10	10	10	10	42	55	
16 ¹⁰	380	126	10.90	-	10	10	10	10	42	55	
16 ¹⁰	390	126	10.90	-	10	10	10	10	42	55	
16 ¹⁰	400	126	10.90	-	10	10	10	10	42	55	

13³⁰
Total Inj: 2" = 001549 [75] gals
Fuji = 12814 gals

Q/s: 101/1.11 = 91 gpm/ft
2" = 101 gpm
SOI: $\frac{1}{2}$ $\frac{20}{28}$ SOI = 2.8
5 28
10 32
15 38

EC = 466 us, PH = 8.5, T = 18.2°C
ORP = 380 mV

15⁰⁰
Total Inj: 2" = 001649 [78]
Fuji = 22913

Q/s: 126/1.16 = 108 gpm/ft
2" = 126 gpm
SOI: $\frac{1}{2}$ $\frac{20}{27}$ SOI = 3.0
5 27
10 32
15 36

EC = 443 us, PH = 8.5, T = 17.9°C
ORP = 389 mV

16¹⁰ Stop injection.
Total Inj: 2" = 001775 [82] gals
Fuji = 25525 gals

Subject: MW03 24-hr Constant Rate Inj Test

Project: GW Injection Ph 3

Client: RMC / City of Malibu

Project No.: 12-0051 By: RLM Date: 7/11-12/13 Sheet No.: 1 of 1

Date/Time	ET (min)	Q. (gpm)	RTW (ft/d)	DUP (ft)	PSI					Line	
					0.505	0.600	0.700	0.800	Min		
7/11/13 10:00	0	-	12.00	-	-	-	-	-	22	22	62
10:30	1	110	11.11	-	-	-	-	-	20	20	62
10:40	4	95	11.27	-	-	-	-	-	22	24	62
10:50	6	103	11.18	-	-	-	-	-	22	40	62
11:00	8	102	11.17	0.86	-	-	-	-	22	40	62
11:10	10	102	11.14	-	-	-	-	-	24	40	62
11:20	12	102	11.16	-	-	-	-	-	24	41	62
11:30	15	103	11.14	-	-	-	-	-	24	41	62
11:40	20	102	11.07	-	-	-	-	-	24	41	62
11:50	30	102	11.00	-	-	-	-	-	24	41	62
12:00	40	102	10.97	-	-	-	-	-	24	41	62
12:10	50	102	10.89	-	-	-	-	-	24	41	62
12:20	60	102	10.88	-	-	-	-	-	24	41	62
12:30	70	103	10.79	-	-	-	-	-	24	41	62
12:40	80	102	10.69	1.31	-	-	-	-	22	41	62
12:50	90	102	10.65	-	-	-	-	-	22	41	62
1:00	102	102	10.85	1.15	-	-	-	-	22	41	62
1:10	110	102	11.11	-	-	-	-	-	22	42	62
1:20	120	102	10.79	1.21	-	-	-	-	24	42	62
1:30	130	102	10.79	-	-	-	-	-	24	42	62
1:40	140	102	10.79	-	-	-	-	-	24	42	62
1:50	150	102	10.79	-	-	-	-	-	24	42	62
2:00	160	102	10.79	-	-	-	-	-	24	42	62
2:10	170	102	10.79	-	-	-	-	-	24	42	62
2:20	180	102	10.79	-	-	-	-	-	24	42	62

24-hr Q/s: 101 gpm / 121 = 84 gpm/ft

Comments / other
Total Inj: 2" = 00177542 gals
Hydrant = 01906588 / 143

ORP 20 Balls Solus = 228 mV (22.9°C)

SDI: $\frac{t}{s}$ Secs
 1 20
 5 26
 10 32
 15 34
 SDI = 2.7

EC = 472 uS, PH = 8.6, T = 18.0°C
 ORP = 135 mV

Total Inj: 2" = 00187555 gals
 Hydrant = 01920000 / 143
 MW07D = 7.54 gals
 MW07S = 6.06 gals
 19:20 Total Inj: 2023788 gals
 SDI: $\frac{t}{s}$ Secs
 1 21
 5 29
 10 33
 15 37
 SDI = 2.9

SDI: $\frac{t}{s}$ Secs
 1 19
 5 28
 10 31
 15 34
 SDI = 2.9
 10:00 MW07D = 7.68 gals
 MW07S = 6.10 gals

EC = 468 uS, PH = 8.4, T = 17.5°C
 ORP = 136 mV
 10:00 Stop Inj!
 Total Inj: 2" = 00322883 gals
 Hydrant = 02810391 / 143



Subject: MW-3 ^{7-Day} Constant Rate Injection Test
 Project: Malibu GW Injection Phase 3
 Client: RMC Water / City of Malibu
 Project No.: 12-0051 By: MB/RM Date: 7/15/13 Sheet No.: 1 of 2

Date/Time	ET min	Q gpm	DTW ft tot	DW ft	PSI	Man	Line
7/15 11:59	0		12.07		0.700	0.810	
12:00	Start						
12:10	10	102.6	11.18	0.89	22	24	60
12:30	30	102	11.08	0.99	22.5	24.5	62
13:40	100	101	10.63	1.44	22.5	24.5	61
13:50	110	103.2			22.5	25	61
7/16 09:15	1275	102.6	11.10	0.97	22.5	25.5	61
7/17 09:40	2750	102.6	11.03	1.04	22.5	26	61
7/18 10:00	4200	103	10.88	1.19	22	26	61

Comments / Other

TOT 2" 322877 gal
 TOT Hyd. 210391.6 cfs

11:30 Deep MW 8.60'
 Shall MW 6.22'
 SDI $t_0=28.5, t_5=40, t_{10}=44$
 $t_{15}=54, s_{01}=3.8$
 SDI $t_0=20, t_5=28, t_{10}=34, t_{15}=35$
 $t_{30}=30, s_{01}=3.2$

TOT 333010 = 101.3 gpm
 in Q slightly

TOT Undercut 228090 (09:10)
 $L_9 = 104.9$ gpm
 TOT 2" 453575 = 104.9 gpm (09:15)
 DMW = 7.90' SMW = 6.15'
 SDI $t_0=20, t_5=28, t_{10}=31, t_{15}=35$
 SOT = 2.9

TOT 2" 662700 = 101.8 gpm
 TOT Hyd 248560 = 104.2
 $t_0=21, t_5=28, t_{10}=32, t_{15}=37$
 SDI = 2.9
 DMW = 7.90' SMW = 6.11'

Total X-axis: $a'' = 007519$ [2]
 Hydraulics = 026588 [2]

SDI: $\frac{L}{t}$ Secs
 U 22 SDI = 2.4
 S 27
 10 31
 15 34

10⁵ MW070 = 7.71' bwc
 MW075 = 6.16' bwc

Subject: MW03 7-Day Constant Rate Inj. Test

Project: GW Injection Ph 3

Client: RMC / City of Malibu

Project No.: 12-0051 By: MB/RCM Date: 7/15 - 7/22 Sheet No.: 2 of 2

Date/Time	ET Min	Q gpm	DTW ftst	DUP ft	PSI			Line	Comments / other
					0.700	0.810	Man.		
7/19 1600	6000	103	10.21	1.46	22	26	44	63	SDI: $\frac{L}{S}$ Sees L 5 27 10 31 15 36 Totalizers: 2" = 029360 [83] gals Hydant = 029390 [5.9] ft ³
7/20 1110	7150	103	10.64	1.43	22	26	44	62	EC = 460 us, pH = 8.6 T = 18.3°C ORP = 329 mV SDI: $\frac{L}{S}$ Sees L 5 28 10 32 15 35 Totalizers: 2" = 010542 [82] gals Hydant = 030995 [8.5] ft ³
7/21 07:00	8340	103	10.55	1.34	22.5	26	44	62	11:30 MW03D = 7.60' gtc MW03S = 6.21' gtc 2" 1175440 Hyd 326470, 10.5 ft / 43 sec = 104 gpm SDI L ₀ = 23, L ₅ = 33, T ₁₀ = 37, T ₁₅ = 40 SDI = 2.8 MW03 7.33' MW05 - 6.24
7/22 0900	9920	102	10.09	1.98	22	26	44	63	Totalizers: 2" = 013392 [45] gals Hyd = 034851 [17.1] ft ³ 1000 EC = 481 us, pH = 8.6 T = 18.5°C, ORP = 319 MW03D = 7.11' gtc, MW03S = 6.13' gtc 1800 stop Injection. Totalizers End: 2" = 013336 [44] gals (102 gpm) Hyd = 035075 [8.3] ft ³ (104 gpm)

PUMPING TEST DATA



Client: RMC / City of Malibu
 Project: GW Injection Ph 3
 Project No: 12-0051

Well: MWP - MW03
 Date: 7/29 - 8/1/13
 Test/Data Set I.D.: 72-hr Pumping Test
 Observer: RLM

Reference Pt: Top of S.Tube (3.1' ags)
 Static Water Level (ft): 12.09' Gtst
 Pump Setting (ft): ~43
 Well Depth (ft): 134

Clock Time	Elapsed Time	Rate (gpm)	Water Level (feet)	Sand (ml)	Other Observations (visual, odor, spec. capacity, totalizer, field wq, etc.)
9 ³⁰	0	-	12.09	-	Totalizer: 150849 [60] gals
	1		12.98		
	2	130	13.15		20 psi, close valve slightly
	4	125	13.03		35 psi
	6	125	13.12		
	8		13.16		
9 ⁴⁰	10		13.09		Totalizer = 150862 [34] gals (127 gpm)
	12		13.14		
	15	125	13.13		
	20		13.16		
10 ⁰⁰	30	125	13.21		
	40		13.24		
	50		13.28		
10 ³⁰	60	125	13.30		
	70		13.32		
	80		13.32		
11 ⁰⁰	90		13.30		
11 ¹⁰	100	125	13.28		Totalizer = 150975 [70] gals (126 gpm) MW070 = 9.16' Gtst, MW075 = 6.05' Gtst
14 ³⁰	300	125	12.90		EC = 863 uS, pH = 8.2, T = 18.7°C
					ORP = 17 mV
21 ¹⁵	705	125	13.84		Totalizer = 151734 [86] gals (126 gpm)

Notes:

PUMPING TEST DATA



Client: RMC / City of Malibu

Project: GW Injection Ph 3

Project No: 12-0051

Well: MCWP-MW03

Reference Pt: Top of S. Tube (3.1' ags)

Date: 7/29/13 - 8/1/13

Static Water Level (ft): 12.09

Test/Data Set I.D.: 72-hr Pumping Test

Pump Setting (ft): -43

Observer: RCM

Well Depth (ft): 134

Clock Time	Elapsed Time	Rate (gpm)	Water Level (feet)	Sand (ml)	Other Observations (visual, odor, spec. capacity, totalizer, field wq, etc.)
7/30 8 ³⁰	1380	125	13.87	-	Totalizers: 3" RE = 152588[70] gals
9 ³⁰	1440	125	13.89	-	Totalizers: 3" RE = 152664[25] gals (126gpm) 4" McCrom. = 797212[00] gals 24-hr Q/s: 126 gpm / 1.8' = 70 gpm/ft mw07D = 9.69' btoe mw07S = 6.06' btoe
16 ³⁰	1860	125	13.05	-	
20 ³⁰	2100	125	13.69		
7/31 9 ³⁰	2880	125	13.85	-	Totalizers: 3" RE = 154477[52] gals 4" McCrom. = 799443[00] gals mw07D = 9.65' btoe mw07S = 6.09' btoe EC = 1467 us, pH = 7.9, T = 19.0°C ORP = ⊕55 mV, Cl ₂ = ND
14 ⁰⁰	3150	125	13.64	-	
20 ³⁰		125	13.44	-	Totalizer = 155309[00] gals

Notes:

PUMPING TEST DATA



Client: RMC / City of Malibu

Project: GW Injection Ph 3

Project No: 12-0051

Well: MWPA - MW01

Reference Pt: Top of S. Tube (3.8' ags)

Date: 8/6/13

Static Water Level (ft): 14.57' Gfst

Test/Data Set I.D.: 100-min Q/s

Pump Setting (ft): ~43' Ggs

Observer: RCM

Well Depth (ft): 148' Ggs

Clock Time	Elapsed Time	Rate (gpm)	Water Level (feet)	Sand (ml)	Other Observations (visual, odor, spec. capacity, totalizer, field wq, etc.)
10 ⁰⁰	0	-	14.57	-	Totalizers! 3" RI = 156363 [06] gals
	1		15.41		4" McCrom = 80173 [00] gals
	2		15.47		
	4		15.49		
	6	~135	15.51		
	8		15.51		
10 ¹⁰	10	~133	15.54		Totalizer: 3" RI = 156376 [15] gals (134 gpm)
	12		15.55		10-min Q/s: 134 gpm / 0.98 = 138 gpm/ft.
	15		15.55		
10 ²⁰	20	134	15.57		
	30		15.63		
	40		15.63		
	50		15.68		
11 ⁰⁰	60		15.70		EC = 2070 μ S, pH = 7.3, T = 20.5°C
	70		15.72		ORP = 87 mV, Cl ₂ = 0.05 mg/L, DO = 0.0 mg/L
	80		15.72		
11 ³⁰	90		15.77		
11 ⁴⁰	100	134	15.79		
12 ⁰⁰	120		15.84		Stop. 100-min Q/s = 154 gpm / 1.2 = 112 gpm/ft.
					Totalizers End: 3" RI = 156523 [75] gals
					4" McCrom = 80188 [60] gals

Notes: 3" RI = MW01 pump
4" McCrom = PE treatment (E-1)

11⁰⁰ Collect NGS Samples.

Subject: mwd1 Variable Rate Inj. Test

Project: GW Injection ph 3

Client: RMC/City of Malibu

Project No.: 12-0051 By: RCM Date: 8/7/13 Sheet No.: 1 of 2

Date/Time	ET Min	Q gpm	DTW GtF	DUP ft	PSI	Min.	Line
8/7/13 10:40	0	~65	14.55	-	-	86	46
	1	~65	14.23	-	-	41	42
	2	~60	13.92	-	-	46	41
	4	~60	14.16	-	-	46	41
	6	~60	14.16	-	-	46	41
	8	~60	14.21	-	-	46	41
10:50	10	52	14.23	0.32	-	56	76
	12	52	14.26	-	-	56	76
	15	51	14.27	-	-	56	76
	20	51	14.23	-	-	56	76
	30	51	14.25	-	-	56	76
	40	51	14.25	-	-	56	76
	50	51	14.24	-	-	56	76
11:40	60	51	14.23	0.32	-	56	74
	70	51	14.23	-	-	56	74
	80	51	14.25	-	-	56	74
12:40	90	52	14.26	-	-	58	76
	100	~80	14.25	0.30	-	58	76
	101	~80	13.82	-	-	58	76
	102	80	14.06	-	-	58	76
	104	80	14.12	-	-	58	76
	106	80	14.12	-	-	58	76
	108	80	14.10	-	-	58	76
	110	76	14.10	0.45	-	58	76
12:30	115	76	14.10	-	-	58	76
	120	76	14.11	-	-	58	76
	130	76	14.14	-	-	58	76
	140	76	14.14	-	-	58	76
	150	76	14.14	-	-	58	76
	160	76	14.14	-	-	58	76
	170	76	14.20	-	-	58	76
	180	76	14.21	-	-	58	76
	190	76	14.21	-	-	58	76
14:00	200	76	14.21	0.34	-	58	76

Comments/Other
 Totalizers: 2" Inj = 01378542 gals
 Hydrant = 03529782 gals

Close value slightly
 " " "

Totalizer: 2" Inj = 01379122 gals
 (63 gpm)

SDI: $\frac{E}{S}$ $\frac{18}{5}$ $\frac{36}{10}$ $\frac{28}{15}$
 SDI = 2.4

EC = NA PH = 8.3 T = 20.4°C
 ORP =

12:00 Totalizers: 2" Inj = 01383716 gals
 Hydrant = 03535387 gals
 (42 gpm)

Close values slightly

Totalizer: 2" Inj = 01384418 gals
 (77 gpm)

SDI: $\frac{E}{S}$ $\frac{36}{10}$ $\frac{28}{15}$
 SDI = 2.4

14:00 Totalizers: 2" Inj = 01391405 gals
 Hydrant = 03544171 gals
 (77 gpm)
 (66 gpm)

Subject: MW01 Variable Rate Injection Test

Project: GW Injection Ph3

Client: RMC/City of Malibu

Project No.: 12-CUS1 By: RCM Date: 8/7/13 Sheet No.: 2 of 2

Date/Time	ET min	Q gpm	RTW 'tst	Dup ft	PSI						
					0.505	0.600	0.700	0.810	Man	Line	
8/7/13 1401	201	-104	13.75		-	8	8	8	8	42	52
	202		14.05								
	204		14.05								
	206	104	14.09								
	208		14.04								
1410	210		14.05	0.50						42	50
	212	110	14.10		-	6	8	6	8	44	54
	215	106	14.13								
	220		14.13								
1430	230		14.17								
1440	240		14.15								
	250	108	14.14							48	56
1500	260	104	14.21		-	5	5	5	5	48	56
	270										
1530	280	102	14.24			5	5	5	5	48	56
1540	290		14.24								
	300		14.26	0.29							
	302	120	14.18		-	10	10	10	10	30	40
	304										
	306	130	14.08		-	12	12	12	12	30	40
	308		14.10								
1550	310	128	14.04	0.51		12	12	12	12	30	40
	312										
	315		14.03								
1600	320	127	14.06		-	12	12	12	12	30	40
	330										
1630	340	128	14.02		-	12	12	12	12	30	40
1640	350		14.06								
	360		14.05								
	370										
1700	380	126	13.98		-	12	12	12	12	30	40
	390										
1720	400		13.99	0.56							

Comments / other

Totalizer: 2" Inj = 013924 35 gal
Adj's Q ↓

SOI: $\frac{E}{Q} = \frac{Set}{AI}$
 $\frac{2.1}{85} = \frac{Set}{83}$
SOI = 2.1
Adj's Q ↓

1540 Totalizer: 2" Inj = 014018 7 gal
Hydrant = 035555 0.4
(85 gpm)
Adj's Q ↑

Totalizer: 2" Inj = 014050 15 gal

SOI: $\frac{E}{Q} = \frac{Set}{AI}$
 $\frac{2.1}{85} = \frac{Set}{83}$
SOI = 2.1

EC = 482 uS/pH = 8.4 T = 19.5 °C
ORP = +155 mV

1720 Stop Injection. (129 gpm)
Totalizer: 2" Inj = 014147 25 gal
Hydrant = 035701 0.8 gal
(109)



Subject: MW01 24-hr Constant Rate Inj Test

Project: GW Injection Ph 3

Client: RMC/City of Malibu

Project No.: 12-0051 By: REM Date: 8/8-9/13 Sheet No.: 1 of 1

Date/Time	ET min	Q gpm	DTW 'ftst	DUP ft	PSI				Man	Line
					0.505	0.600	0.700	0.810		
8/8/13 10:00	0	112	14.57	-	-	-	-	-	84	84
	2	108	15.70	-	20	-	-	38	58	
	4	108	15.73	-	18	-	-	46	60	
	6	108	15.76	-	18	-	-	46	60	
	8	110	15.83	-	18	-	-	46	60	
	10	110	15.84	0.73	18	-	-	46	60	
	12	105	15.88	-	16	-	-	34	62	
	15	105	15.91	-	16	-	-	34	62	
	20	105	15.92	-	16	-	-	34	62	
	30	105	15.92	-	16	-	-	34	62	
8/9/13 9:10	10	105	13.85	-	16	-	-	34	63	
	15	105	13.85	-	16	-	-	34	63	
	20	105	13.85	-	16	-	-	34	63	
	30	105	13.85	-	16	-	-	34	63	
8/9/13 10:00	10	110	13.85	0.74	16	-	-	34	62	
	14	110	13.85	0.74	16	-	-	34	62	

Comments/Other
 Total Inj: 2" Inj = 01414785 gals
 Hydrant = 03570159 ft³

Total Inj: 2" Inj = 01415778 (105 gpm)
 Adj. Q ↓

SOI: $\frac{t}{s} = \frac{sec}{16}$
 $\frac{10}{15} = \frac{20}{15}$
 SOI = 2.0

Total Inj: 2" Inj = 014251151 gals (104 gpm)
 Hydrant = 035818101 ft³ (87 gpm)

SOI: $\frac{t}{s} = \frac{sec}{16}$
 $\frac{10}{15} = \frac{20}{15}$
 SOI = 2.2

950 MW04D = 9.54' stor
 MW04S = 6.90' stor
 Stop Injection.
 Total Inj End:
 2" Inj = 015682051 gals (107 gpm)
 Hydrant = 037366811 ft³ (87 gpm)



Subject: MCWP-MW01 7-day CR Inj Test
 Project: GW Injection Ph 3
 Client: RMC/City of Malibu

Project No.: 12-0051 By: REM Date: 8/12-14/13 Sheet No.: 1 of 4

Date/Time	ET min	Q gpm	DTW 'ftst	DUP ft	PSI								
					0.505	0.600	0.700	0.810	Max	Line			
8/12 1130	0	80	14.68	-	-	-	-	-	26	26	46	60	86
	2	80			-	-	-	-	26	26	46	60	86
	4	90	13.40		-	-	-	-	26	26	46	60	86
	6	90			-	-	-	-	26	26	46	60	86
	8	100	13.60		-	-	-	-	26	26	46	60	86
	10	101	13.69	0.99	-	-	-	-	26	26	46	60	86
	12	101	13.70		-	-	-	-	26	26	46	60	86
	15	101	13.74		-	-	-	-	26	26	46	60	86
	20	101	13.70		-	-	-	-	26	26	46	60	86
	30	102	13.80		-	-	-	-	26	26	46	60	86
	40		13.79		-	-	-	-	26	26	46	60	86
	50		13.76		-	-	-	-	26	26	46	60	86
	60		13.72		-	-	-	-	26	26	46	60	86
	70		13.67		-	-	-	-	26	26	46	60	86
	80				-	-	-	-	26	26	46	60	86
	90				-	-	-	-	26	26	46	60	86
	100	101	13.62	1.06	-	-	-	-	26	26	46	60	86
8/13 1000	1350	101	13.86	0.82	-	-	-	-	26	26	46	60	86

Comments / Observations

Total Inj: 2" Inj = 015682 **85** gal
 F₅₀' = 0 gal
 Hydrant = 037367 **33** ft³

Total Inj: 2" Inj = 015693 **82** (104)
 F₅₀' = 920 (92 gpm)

SOI: $\frac{E}{S} = \frac{92}{107}$ SOI = 2.0

Total Inj: 2" Inj = 015798 **84** gals
 F₅₀' = 10015 gals
 Hydrant = 037508 **12** ft³

100-min Avg: 2" Inj = 116 gpm
 F₅₀' = 100 gpm
 Hydrant = 105 gpm

100-min Q/S: $\frac{107 \text{ gpm}}{1.06'}$ = 101 gpm/ft.

SOI: $\frac{E}{S} = \frac{92}{107}$ SOI = 2.1

10³⁰ Total Inj: 2" Inj = 017325 **10** gal
 Hydrant = 039346 **53** ft³

10³⁵ MW01 D = 9.62' 640C
 MW01 S = 8.93' 640C

Subject: MW0P-MW01 7-day CR Inj. Test

Project: GW Injection Ph 3

Client: RMC/City of Malibu

Project No.: 12-0051 By: RCM Date: 8/12-19/17 Sheet No.: 2 of 4

Date/Time	ET min	Q gpm (Fug.)	DTW '64st	DUP ft	PSI	Man. Line
					0.505 0.600 0.700 0.810	
8/14 1100	2850	1850	13.76	0.92	26	46
8/15 10'0	4240	1000	13.82	0.85	26	46
8/15 1400		0				
1530		0	14.22			
1600	4590					
1610		100			26	46
1630		101	13.44		26	46
1700		100	13.34	1.34	26	46

Comments / etc.

Totalizers: 2' Inj = 01915183 gals
Hydrant = 04144603 gals

SDI: $\frac{t}{Sec}$
 $\frac{3}{15} = \frac{2.1}{85}$ SDI = 2.1

1" MW04D = 9.59' g/toc
MW04S = 6.94' g/toc

Totalizers: 2' Inj = 02087822 gals
Hydrant = 04342472 gals

SDI: $\frac{t}{Sec}$
 $\frac{3}{10} = \frac{2.2}{27}$ SDI = 2.2

1" MW04D = 9.68' g/toc
MW04S = 6.93' g/toc

1045
EC = 502 uS/pH = 8.4 T = 19.6°C
ORP = 174 mV Cl₂ = 0.19 mg/L
20 Bell Soln ORP = 232 mV (0.201%)

Hydrant closed by City due to P. pipeline/hose leak.
Totalizers: 2' Inj = 02106848 gals
Hydrant = 04367957 gals

1600 Resume injection

Subject: MWDP-MW01 7-day CR Inj. Test

Project: GW Injection Ph 3

Client: RMC/City of Malibu

Project No.: 12-0051 By: Rcm Date: 8/12-19/13 Sheet No.: 3 of 4

Date/Time	ET min	Q gpm	DTW 'Hst	DUP Ft	DS1				Line	
					0.50s	0.60s	0.70s	0.810		
8/16 9:50	5660	150	13.86	0.72	-	-	26	26	45	60
11:00	5730	100	13.89	0.79	-	34	-	30	46	60
11:10	5740	100	13.89	0.79	-	34	-	30	46	60
11:30	5760	100	13.89	0.79	-	34	-	30	46	60
8/17 11:10	7180	99	13.80	0.88	-	33	-	30	44	56"
16:00	6030	100	13.42	1.26	-	34	-	30	46	60
8/18 14:30	8820	99	13.95	0.73	-	33	-	30	44	58"

Common ends / 0.4 in.

Totalizers: 2" Inj = 022344 27 gals
Hydrant = 045193 3.3 gals
Close 0.700 DT / open 0.600"

Totalizers: 2" Inj = 022465 13 gals
Hydrant = 045334 5.9 gals

SDE: $\frac{L}{S} = \frac{Sgs}{RA}$
 $\frac{0}{10} = \frac{RA}{RB}$
 SDE = 2.5

Totalizers: 2" Inj = 022797 13 gals
Hydrant = 045714 6.2 gals

SDE: $\frac{L}{S} = \frac{Sgs}{RA}$
 $\frac{0}{10} = \frac{RA}{RB}$
 SDE = 2.3

11:30 MW04D = 9.68' b/c
MW04S = 6.89' b/c

Totalizers: 2" Inj = 026332 15 gals
Hydrant = 046106 5.4 gals

SDE: $\frac{L}{S} = \frac{Sgs}{RA}$
 $\frac{0}{10} = \frac{RA}{RB}$
 SDE = 1.9

14:30
MW04D = 9.75' b/c
MW04S = 6.87' b/c



Subject: MCWP-mw01 7-day CR Inj. Test

Project: GW Injection ph3

Client: RMC/City of Malibu

Project No.: 12-0051 By: RCM Date: 8/12-19/13 Sheet No.: 4 of 4

Date/Time	ET	Q (gpm)	DTW (ft)	DUP (ft)	PS (ft)	Man. Line
8/19 1430	10,200	100	14.05	0.63	0.505	34
1730	10,440	100	13.64	1.04	-	34
1800	10,500				-	30
					-	44
					-	58

Comments/Other
 Totalizers: 2" Inj = 02816508 gals
 Hydrant = 0516128.41 gals
 *Low Tide
 SOI: $\frac{1}{2}$ $\frac{5.12}{17}$ SOI = 1.9
 $\frac{10}{20}$ $\frac{23}{24}$
 $\frac{15}{24}$
 15" MUDWD = 9.88' bwc
 MUDYS = 6.91' bwc
 18" Stop Inj section.
 Totalizers: 2" Inj = 02843522 gals
 Hydrant = 05140741.34 gals

PUMPING TEST DATA



Client: RMC / City of Malibu

Project: GW Injection Ph 3

Project No: 12-0051

Well: MCWP-MW01

Reference Pt: Top of S. Tube (3.8' ags)

Date: 8/26/13

Static Water Level (ft): 15.04

Test/Data Set I.D.: Post-Inj Q/S

Pump Setting (ft): -43

Observer: RCM

Well Depth (ft): 148

Clock Time	Elapsed Time	Rate (gpm)	Water Level (feet)	Sand (ml)	Other Observations (visual, odor, spec. capacity, totalizer, field wq, etc.)
9 ²⁰	0	-	15.04		Totalizers: 3" RI = 156604(09) gals
	2		16.03		4" McCrom = 802117(00) gals
	4	134	15.99		
	6		15.97		
	8		16.01		
9 ³⁰	10		16.02		Totalizer: 3" RI = 156617(25) gals (132 gpm)
	12		16.02		
	15		16.03		
9 ⁴⁰	20		16.06		
	30		16.08		
	40		16.09		
	50		-		change Bag Filters
10 ²⁰	60	134	16.09		
	70		16.09		Collect treatment effluent (E-1) samples
	80		16.09		E-1 pH = 6.8, Temp = 22.1°C
10 ⁵⁰	90		16.10		
11 ⁰⁰	100		16.08		stop pump

Notes: Totalizers End: 3" RI = 156737(44) gals (133 gpm) 100-min q/s;
 4" McCrom = 802232(00) gals
 133 gpm / 1.04 = 128 gpm/ft

PUMPING TEST DATA



Client: RMC/City of Malibu

Project: GW Injection Ph 3

Project No: 12-0051

Well: MCWP-MW02

Reference Pt: Top of S.Tube (3.2' ags)

Date: 8/29/13

Static Water Level (ft): 15.03

Test/Data Set I.D.: Pre-injection Q/S

Pump Setting (ft): -43'

Observer: RCM

Well Depth (ft): 145

Clock Time	Elapsed Time	Rate (gpm)	Water Level (feet)	Sand (ml)	Other Observations (visual, odor, spec. capacity, totalizer, field wq, etc.)
11 ²⁰	0	-	15.03		Totalizer = 156810 [43] gals
	2		19.61		
	4	~135	19.27		
	6		19.77		
	8		19.81		
11 ³⁰	10		19.82		Totalizer = 156824 [24] gals (136 gpm)
	12		19.84		
	15		19.85		
	20		19.89		
	30		19.93		
12 ⁰⁰	40		19.95		
	50		-		
12 ²⁰	60	135	19.98		EC = 2100 mS, pH = 7.6, T = 21.2°C
	70		-		ORP = 187 mV, DO = 0.1 mg/L, Cl ₂ = ND
	80		20.02		
12 ³⁰	90		20.03		
13 ⁰⁰	100		20.03		Stop Pump. Totalizer = 156945 [21] gals
					135 gpm
					100 min Q/S = 135 gpm / 5.0 = 27 gpm/ft

Notes:

Subject: MW02 Variable Rate Injection Test

Project: GW Injection Ph 3

Client: RMC / City of Malibu

Project No.: 12-0051 By: Rcm Date: 9/3/13 Sheet No.: 1 of 2



Date/Time	ET min	Q (F _{inj}) gpm	DTW 1st	DUP ft	PSI					
					0.505	0.600	0.700	0.810	Man.	Line
9/3/13 9:30	0	50	14.89	-	-	-	-	-	-	84
	2		13.43					22	46	76
	4		13.40							
	6		13.37							
	8		13.35	1.54				22	46	76
	10	50	13.34							
	12		13.33							
	15		13.32							
	20		-							
	30		-							
	40		-							
	50	50	13.31					22	47	76
	60		13.30							
	70		13.29							
	80		13.30							
	90	50	13.30	1.58				22	46	76
	100		13.31							
	110		13.52							
	102	75	12.50					12	36	72
	104		12.51							
	106		12.49							
	108		12.48							
	110	75	12.48	2.40				12	36	72
	112		12.48							
	115		12.48							
	120		12.49							
	130		12.50							
	140		12.49							
	150	75	12.49					12	36	72
	160		12.49							
	170		12.49							
	180		12.50							
	190		12.49							
	200		12.49	2.40						

Comments / Other
 Total Inj: 2' Inj = 02847698 gals
 F_{inj} = 0 gals
 Hydrant = 0520730.4 12.3

Total Inj: 2' Inj = 02848100 gals
 F_{inj} = 480 gals

SDI: $\frac{6}{10} = \frac{36}{15}$ SDF = 4.4
 Hydrant: 10 ft³/84 sec = 53 gpm

Total Inj: 2' Inj = 02852775 (50.5)
 F_{inj} = 5036 (504 gpm)

Hydrant: 10 ft³/58 sec = 77 gpm
 SDI: $\frac{6}{10} = \frac{36}{13}$ SDF = 3.4

Total Inj: 2' Inj = 02860290 (75.4)
 F_{inj} = 12613 (75.8 gpm)

Subject: MWO2 Variable Rate Injection Test

Project: GW Injection Ph3

Client: RMC/City of Pueblo

Project No.: 12-0051 By: RCM Date: 9/3/13 Sheet No.: 2 of 2

Date/Time	ET min	Q gpm	DTW 1st	Tup ft	0.505	0.600	0.700	0.800	Man. Line	Line
9/3/13	202	100	11.64		-	12	12	12	34	66
13 ⁰⁰	204		11.68							
13 ⁰⁰	208		11.63							
13 ⁰⁰	212		11.62	3.27	-	12	12	12	34	66
13 ¹⁰	215		11.60							
13 ¹⁰	220		11.59							
13 ³⁰	230		11.58							
13 ³⁰	240		11.55							
13 ³⁰	250		11.56							
14 ⁰⁰	260		11.58							
14 ⁰⁰	270	100	11.55		-	12	12	12	34	66
14 ⁰⁰	280		11.56							
14 ³⁰	290		11.56							
14 ³⁰	300		11.55	3.34						
14 ³⁰	302	125	10.58		12	12	12	12	34	56
14 ³⁰	304		-							
14 ³⁰	306		10.50							
14 ⁴⁰	308		10.48							
14 ⁴⁰	310	125	10.46	4.43	12	12	12	12	34	56
15 ⁰⁰	312		10.43							
15 ⁰⁰	315		10.40							
15 ⁰⁰	320		10.39							
15 ⁰⁰	330		10.38							
15 ⁰⁰	340		10.28							
15 ³⁰	350		10.24							
15 ³⁰	360	125	10.20		12	12	12	12	34	56
16 ⁰⁰	370		10.21							
16 ⁰⁰	380		10.19							
16 ¹⁰	390		10.14							
16 ¹⁰	400		10.11							

Comments/Other

Hydrant = 10 ft³/43 secs = 104 gpm

SDI: $\frac{L}{S}$ $\frac{secs}{ft^3}$ SDI = 3.0

14³⁰
Total Injection 12" Inj = 22870 (99 gpm) (3) gals
F_{uji} = 22652 gals (100%)

Hydrant = 10 ft³/35 secs = 128 gpm

SDI: $\frac{L}{S}$ $\frac{secs}{ft^3}$ SDI = 2.9

Stop Injection.

Totalizers End:
2" Inj = 228825 (7) gals (124)
F_{uji} = 25236 gals (125.8)
Hydrant = 052559 (2) ft³

Subject: MWO2 24-hr CR Injection Test

Project: GW Injection Ph 3

Client: RMC / City of Pueblo

Project No.: 12-0051 By: RCM Date: 9/4-5/13 Sheet No.: 1 of 1

Date/Time	ET Min	Q (F ³) gpm	DTW ft	DUP ft	0.505	0.600	0.700	0.810	Mon.	Line
9/4/13 10 ⁰⁰	0	98	14.84	-	-	-	-	-	-	84
	2	98	11.63	-	-	-	22	22	50	64
	4	100	-	-	-	-	24	24	36	64
	6	100	11.52	-	-	-	24	24	36	64
	8	100	11.45	3.46	-	-	24	24	36	64
	10	100	11.38	-	-	-	24	24	36	64
	12	100	11.34	-	-	-	24	24	36	64
	15	100	11.32	-	-	-	24	24	36	64
	20	100	11.27	-	-	-	24	24	36	64
	30	100	11.19	-	-	-	24	24	36	64
	40	100	11.15	-	-	-	24	24	36	64
	50	100	-	-	-	-	24	24	36	64
	60	100	-	-	-	-	24	24	36	64
9/5/13 9 ⁰⁰	14 ¹⁰	250	11.10	-	-	12	12	12	38	65
	18 ⁰⁰	1440	10.46	4.38	-	12	12	12	38	64

Comments/other
 Totalizations: 2" Inj = 028825 [21] gal
 Hydrant = 052359 [32] A³
 F_{inj} = 0 gals

Totalization: 2" Inj = 028835 [22] gals (95)
 F_{inj} = 949 gals (95.1)

10³⁵ open 0.600' DT to reduce vibration.
 SDE: $\frac{t}{s}$ $\frac{secs}{ft}$
 $\frac{0}{10}$ $\frac{10}{30}$ SDE = 2.9

Totalizations: 2" Inj = 028845 [27]
 F_{inj} = 6004

Hydrant: 10 A³/48 secs = 124 gpm
 Totalizations: 2" Inj = 029079 [28] gals (101 gpm)

Totalization: 2" Inj = 030226 [29] gals (101 gpm)
 SDE: $\frac{t}{s}$ $\frac{secs}{ft}$
 $\frac{0}{15}$ $\frac{15}{28}$ SDE = 2.4

Stop Injection
 Totalizations end:
 2" Inj = 030288 [29] gals (101 gpm)
 Hydrant = 054586 [29] A³ (105 gpm)
 24-hr A/s: 101/4.38 = 231 gpm/ft

Subject: MW02 7-Day CR Injection Test
 Project: GW Injection Ph 3
 Client: RMC / City of Malibu

Project No.: 12-0051 By: RCM Date: 9/6-13/13 Sheet No.: 1 of 3

Date/Time	ET min	Q (gpm)	DTW (ft)	DUP (ft)	0.555	0.600	0.700	0.810	Man	Line
9/6/13 10:00	0	0	14.84	-	-	-	-	-	-	84
	2	100	11.26	-	-	12	12	12	44	64
	4		11.18							
	6		11.12							
	8		11.08	3.79	-	12	12	12	45	64
	10		11.05							
	12		10.98							
	15		10.97							
	20		10.94							
10:30	30		-							
	40		10.84							
	50		-							
	60		10.74		-	12	12	12	46	64
11:00	70		-							
	80		-							
	90		10.75							
	100		10.72	4.14	-	12	12	12	46	64
9/7 12:00	1560	100	9.94	4.90	-	13	12	12	46	60
9/8 12:00	3000	100	9.56	5.28	-	13	12	12	46	66

Comments / other
 Totalization: 2" Inj = 030288 [21] gals
 Hydrant = 054586 [28] gals

Totalization: 2" Inj = 030299 [15] (99 gpm)
 Hydrant = 104 ft³ / 43 sec = 104 gpm

SDF: $\frac{t}{s}$ $\frac{Secs}{ft}$ SDF = 2.8
 $\frac{0}{10}$ $\frac{17}{25}$
 $\frac{15}{85}$ $\frac{29}{29}$

EC = 508 us, PH = 8.3, T = 21.8°C
 ORP = 269 mV

Totalization: 2" Inj = 050389 [27] gals (101 gpm)
 Hydrant = 054725 [30] gals (106 gpm)

Totalization: 2" Inj = 031865 [22] gals
 Hydrant = 056774 [24] gals

SDF: $\frac{t}{s}$ $\frac{Secs}{ft}$ SDF = 2.1
 $\frac{0}{10}$ $\frac{17}{25}$
 $\frac{15}{85}$ $\frac{29}{29}$

MW06D = 9.66' bwc
 MW06D = 11.56' bwc
 Totalization: 2" Inj = 033320 [5] gals
 Hydrant = 058795 [24] gals
 SDF: $t_0 = 16$, $t_s = 20$, $t_{10} = 22$, $t_{15} = 25$ ms
 SDF = 2.4
 MW06D = 9.59' bwc
 LW-MW04 = 11.58' bwc

Subject: MW02 7-Day CR Injection Test

Project: GW Injection Ph 3

Client: RMC City of Malibu

Project No.: 12-0051 By: RLM Date: 9/6-13/13 Sheet No.: 2 of 3

Date/Time	ET	Q	DTW	DTW	PSI	Line
	Min	gpm	64ft	ft		
9/9 1:00	43:00	1150	9.36	5.48	13	65
9/10 13:40	59:00	1000	8.47	6.37	14	65
9/11 10:30	72:30	1000	8.02	6.82	14	65

Comments / Notes

Total Inj = 034708 $\frac{1}{2}$ gal
 Hydrant = 060727 $\frac{1}{2}$ gal
 10 ft³/43 sec = 104 gpm
 SDF: $\frac{0}{5}$ $\frac{16}{20}$ $\frac{23}{23}$ SDF = 2.9
 10 15 20 23
 MW06D = 9.70' btlc
 LY-MW04 = 11.57' btlc

Total Inj = 2" Inj = 036314 $\frac{1}{2}$ gal
 Hydrant = 062964 $\frac{1}{2}$ gal
 10 ft³/43 sec = 104 gpm
 SDF: $\frac{0}{5}$ $\frac{20}{20}$ $\frac{23}{23}$ SDF = 2.4
 10 15 20 23
 MW06D = 9.63' btlc
 LY-MW04 = 11.57' btlc
 EC = 527 us pH = 8.3 T = 21.7°C
 ORP = 211 mV DO = 9.7 mg/L CL₂ = 0.11 mg/L

Total Inj = 2" Inj = 037570 $\frac{1}{2}$ gal
 Hydrant = 064709 $\frac{1}{2}$ gal
 10 ft³/43 sec = 104 gpm
 SDF: $\frac{0}{5}$ $\frac{20}{20}$ $\frac{23}{23}$ SDF = 2.4
 10 15 20 23
 MW06D = 9.80' btlc
 LY-MW04 = 11.60' btlc
 Hydrant 10 ft³/43 sec = 104 gpm



Subject: MW02 7-Day CR Injection Test

Project: GW Injection Ph 3

Client: RMC / City of Malibu

Project No.: 12-0051 By: RCM Date: 9/6-13/13 Sheet No.: 3 of 3

Date/Time	FT Min	Q gpm	DTW 1st	DUP Ft	PSI	Man Line
9/12 9:40	8620	100	7.22	7.62	-	65
9/13 9:30	10050	100	6.63	8.21	14	65
	10080	100	6.69	8.14	14	65
	10090	100	6.69	8.14	14	65
	10090	100	6.69	8.14	14	65
	10090	100	6.69	8.14	14	65
	10090	100	6.69	8.14	14	65
	10090	100	6.69	8.14	14	65
	10090	100	6.69	8.14	14	65
	10090	100	6.69	8.14	14	65

Comments / other

Totalizer 5:2" Inj. = 03896631 (100gpm)

Hydrant = 06655.3

Hydrant: 10 FT / 43 sec = 104 gpm

SDI: $\frac{e}{\frac{1}{10} \frac{1}{15}}$ Secs

SDI = 2.3

9:45 MW06 = 9.89' gloc

LY-MW04 = 11.57' gloc

Totalizer 5:2" Inj. = 04039918

Hydrant = 0686391.6

SDI: $\frac{e}{\frac{1}{10} \frac{1}{12}}$ Secs

SDI = 2.1

9:50 MW06 = 9.89' gloc

LY-MW04 = 11.57' gloc

Totalizer 5:2" Inj. = 04042951

Hydrant = 0686819.7

SDI: $\frac{e}{\frac{1}{10} \frac{1}{12}}$ Secs

SDI = 2.1

Stop Injection

Totalizer 5:2" Inj. = 04042951 gals

Hydrant = 0686819.7 gals

(101 gpm) (105 gpm)

PUMPING TEST DATA



Client: RMC/City of Malibu

Project: GW Injection Ph 3

Project No: 12-0051

Well: MCWP-MW02

Reference Pt: Top of S. Tube (3.1' ags)

Date: 9/20/13

Static Water Level (ft): 14.78

Test/Data Set I.D.: Post-Inj. Q/s Test

Pump Setting (ft): _____

Observer: RLM

Well Depth (ft): _____

Clock Time	Elapsed Time	Rate (gpm)	Water Level (feet)	Sand (ml)	Other Observations (visual, odor, spec. capacity, totalizer, field wq, etc.)
10 ⁰⁰	0	-	14.78		Totalizer = 157228[13] gals
	2		14.91		Tu = 46 NTU
	4		19.98		
	6	133	20.05		Tu = 20 NTU
	8		20.07		
10 ¹⁰	10	135	20.09		Totalizer = 157241[93] gals, Tu = 10 NTU
	12		20.11		
	15		20.14		Tu = 6 NTU
	20		20.17		Tu = 6
10 ³⁰	30		20.20		Tu = 6
	40		20.23		Tu = 9
	50		20.26		
11 ⁰⁰	60		20.28		Tu = 0 NTU
	70		20.32		
	80		20.34		
11 ³⁰	90		20.36		
11 ⁴⁰	100		20.37		Stop pump.
					Totalizer = 157363[66] gals (135 gpm)
					100-min Q/s: 135/5.59 = 24.2 gpm/A

Notes:

APPENDIX B – AQUIFER PARAMETER ANALYSES

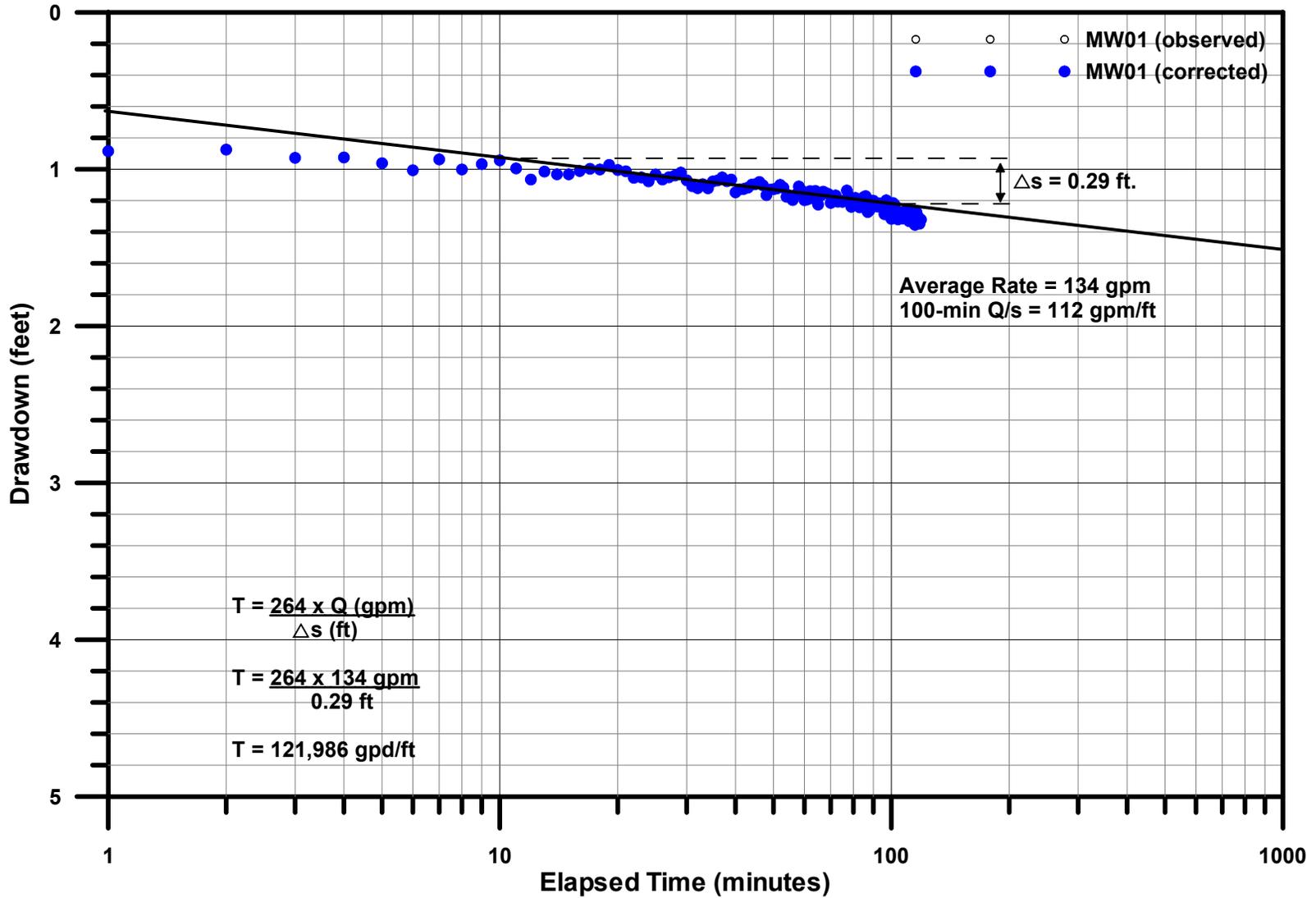


FIGURE B1. MCWP-MW01 PRE-INJECTION PUMPING TEST - MW01 DRAWDOWN DATA
Malibu Groundwater Injection Feasibility Project - Phase 3
RMC Water and Environment / City of Malibu

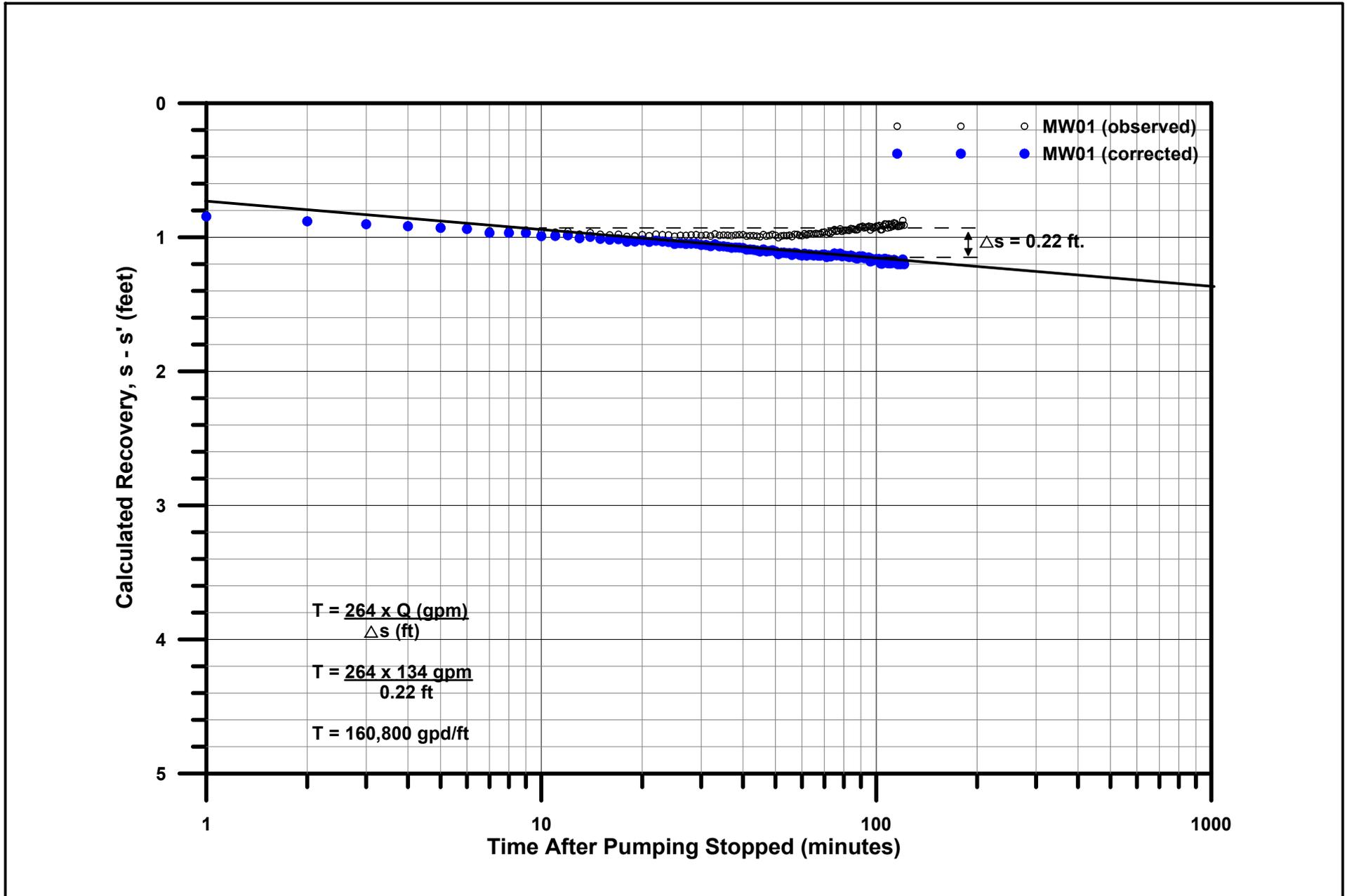


FIGURE B2. MCWP-MW01 PRE-INJECTION PUMPING TEST - MW01 RECOVERY DATA
Malibu Groundwater Injection Feasibility Project - Phase 3
RMC Water and Environment / City of Malibu

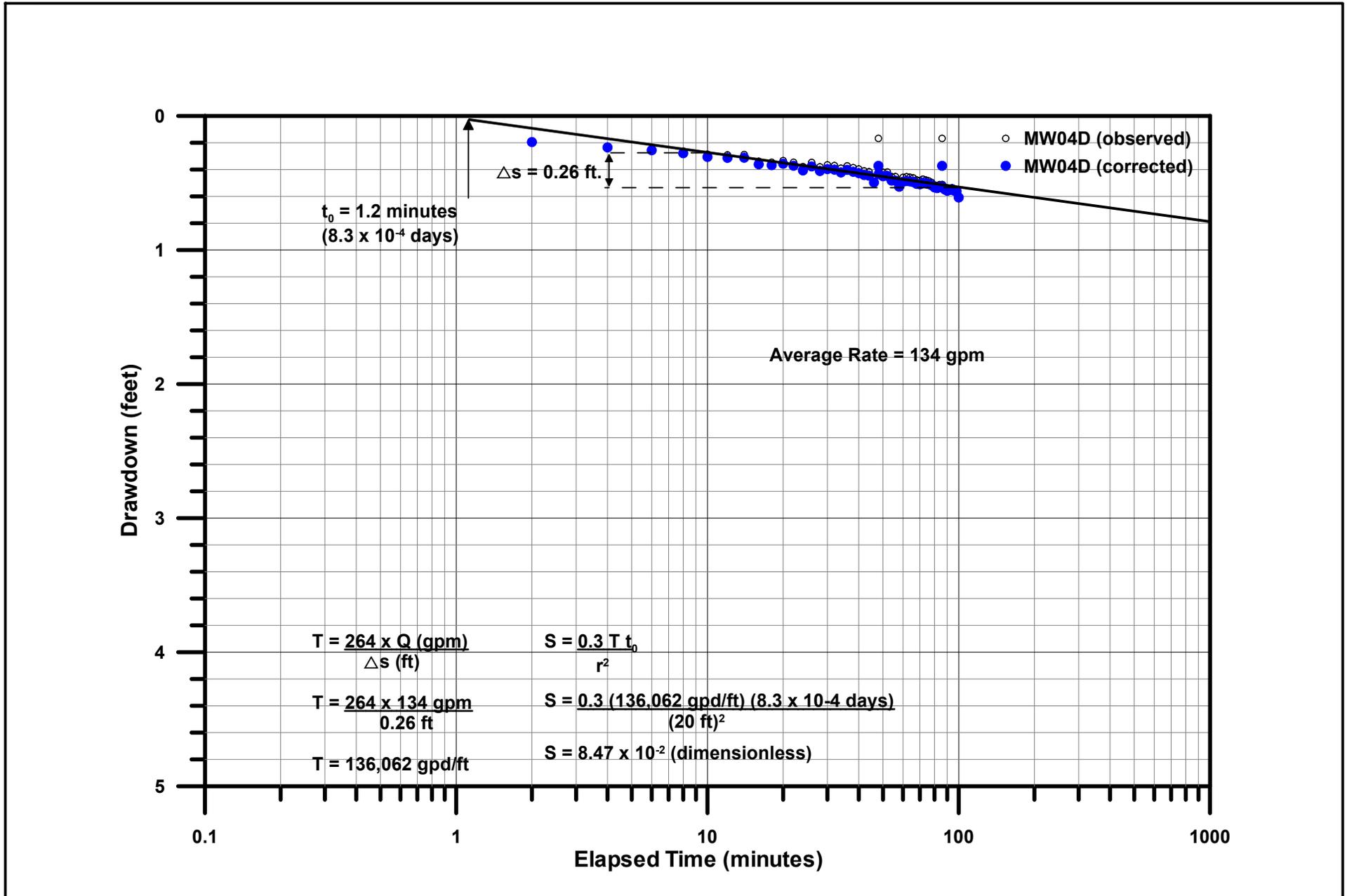


FIGURE B3. MCWP-MW01 PRE-INJECTION PUMPING TEST - MW04D DRAWDOWN DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

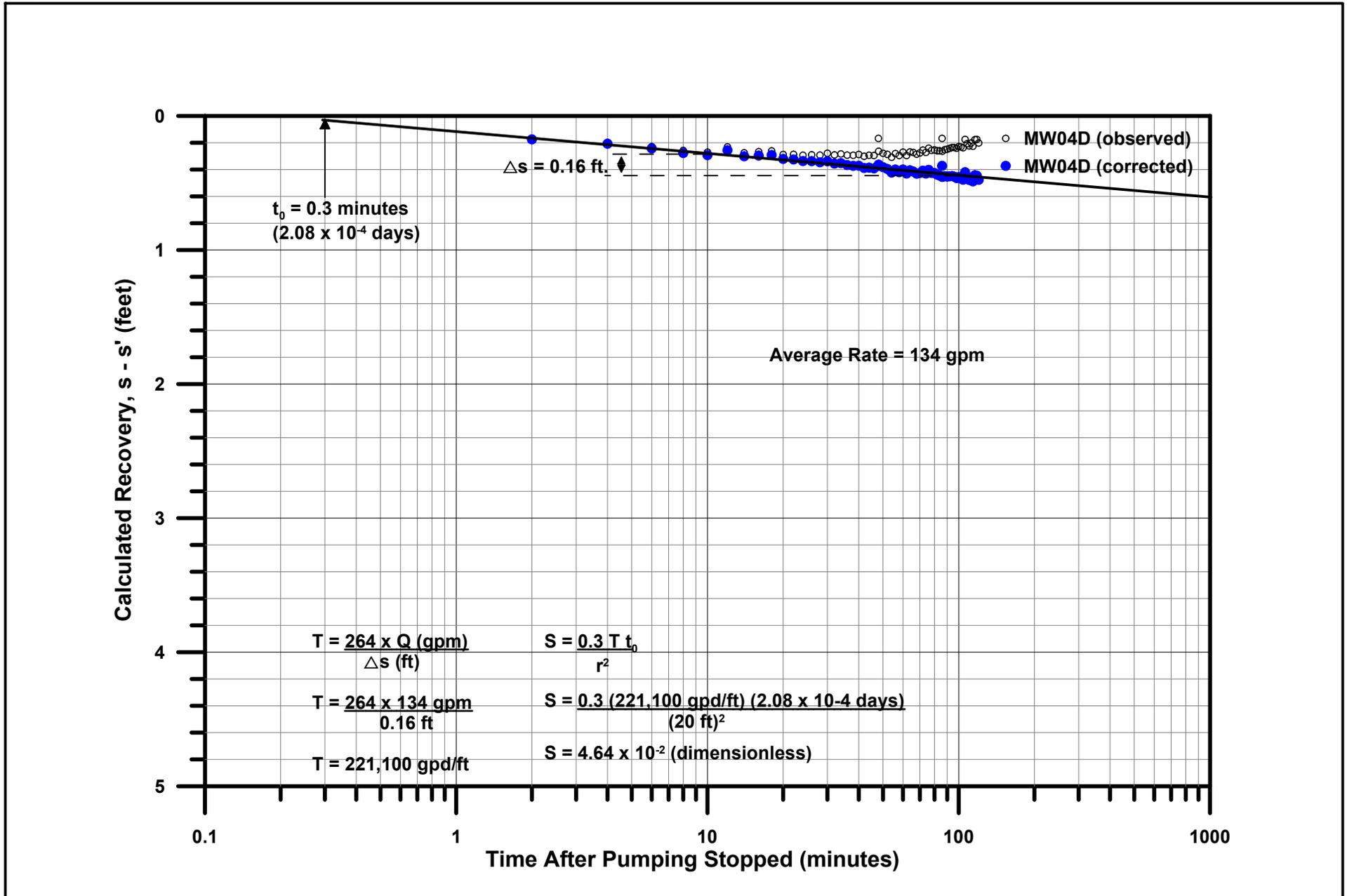


FIGURE B4. MCWP-MW01 PRE-INJECTION PUMPING TEST - MW04D RECOVERY DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

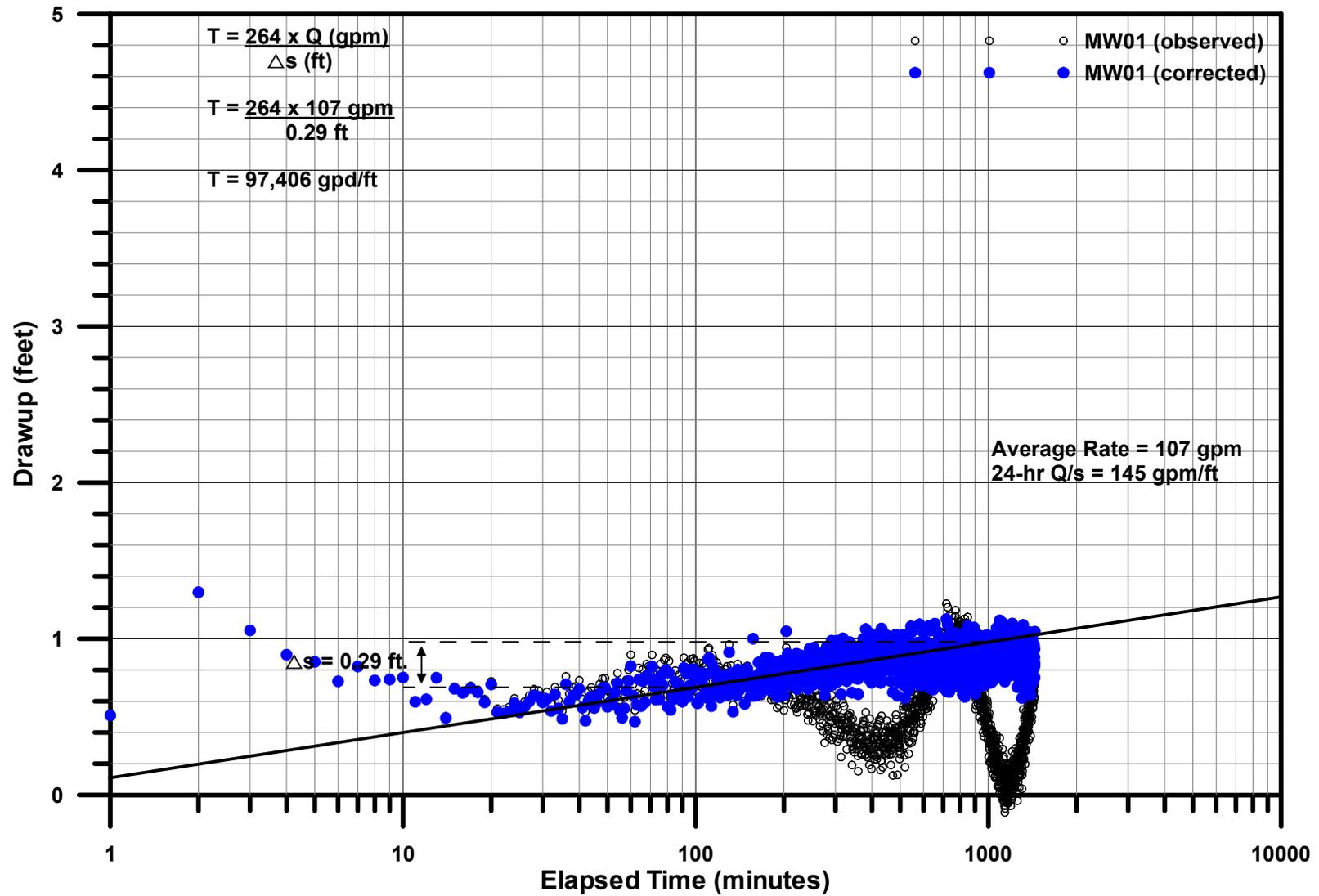


FIGURE B5. MCWP-MW01 24-HR INJECTION TEST - MW01 DRAWUP DATA
Malibu Pilot Injection Testing Project
RMC Water and Environment / City of Malibu

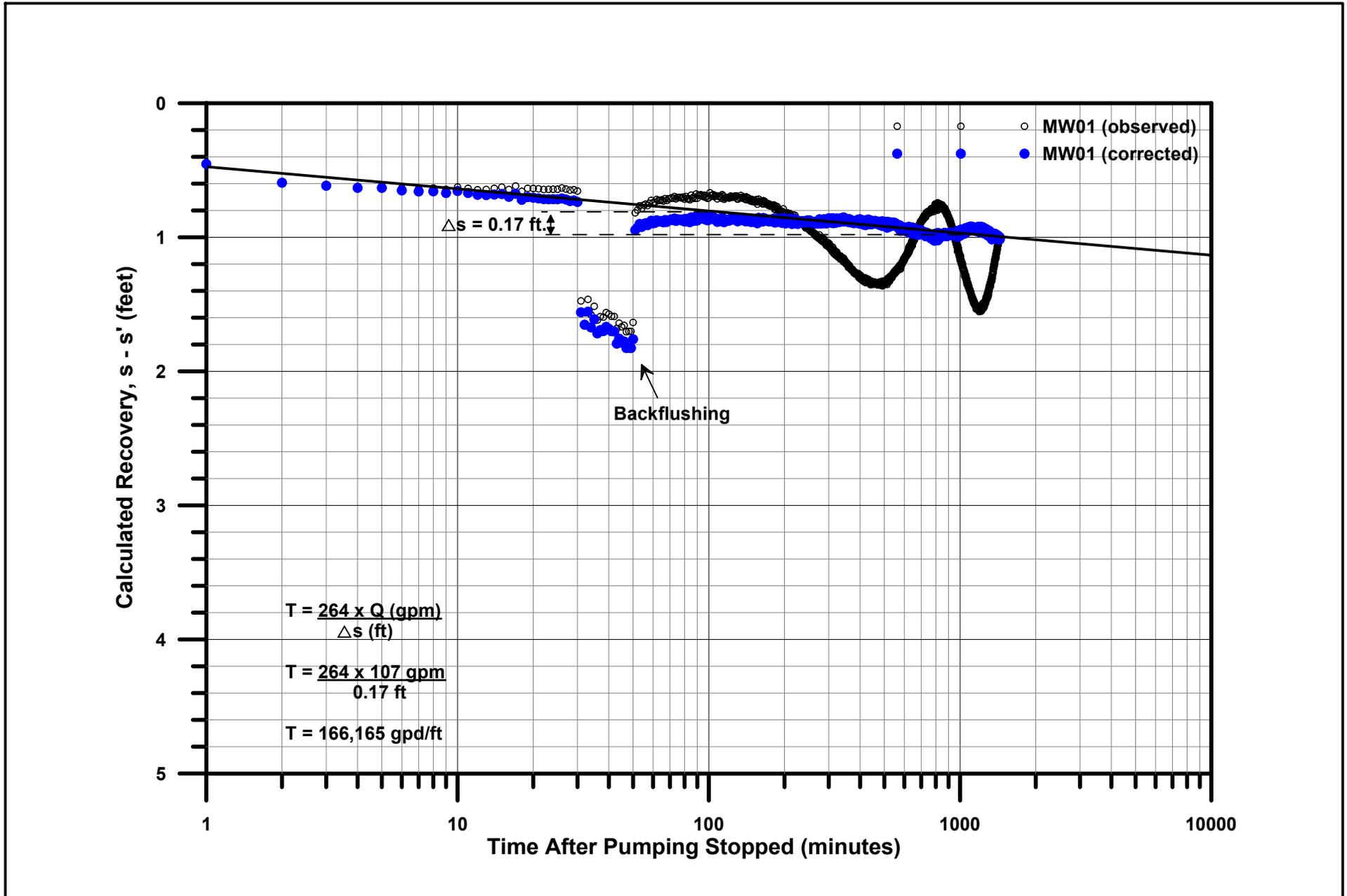


FIGURE B6. MCWP-MW01 24-HR INJECTION TEST - MW01 RECOVERY DATA
Malibu Groundwater Injection Feasibility Project - Phase 3
RMC Water and Environment / City of Malibu

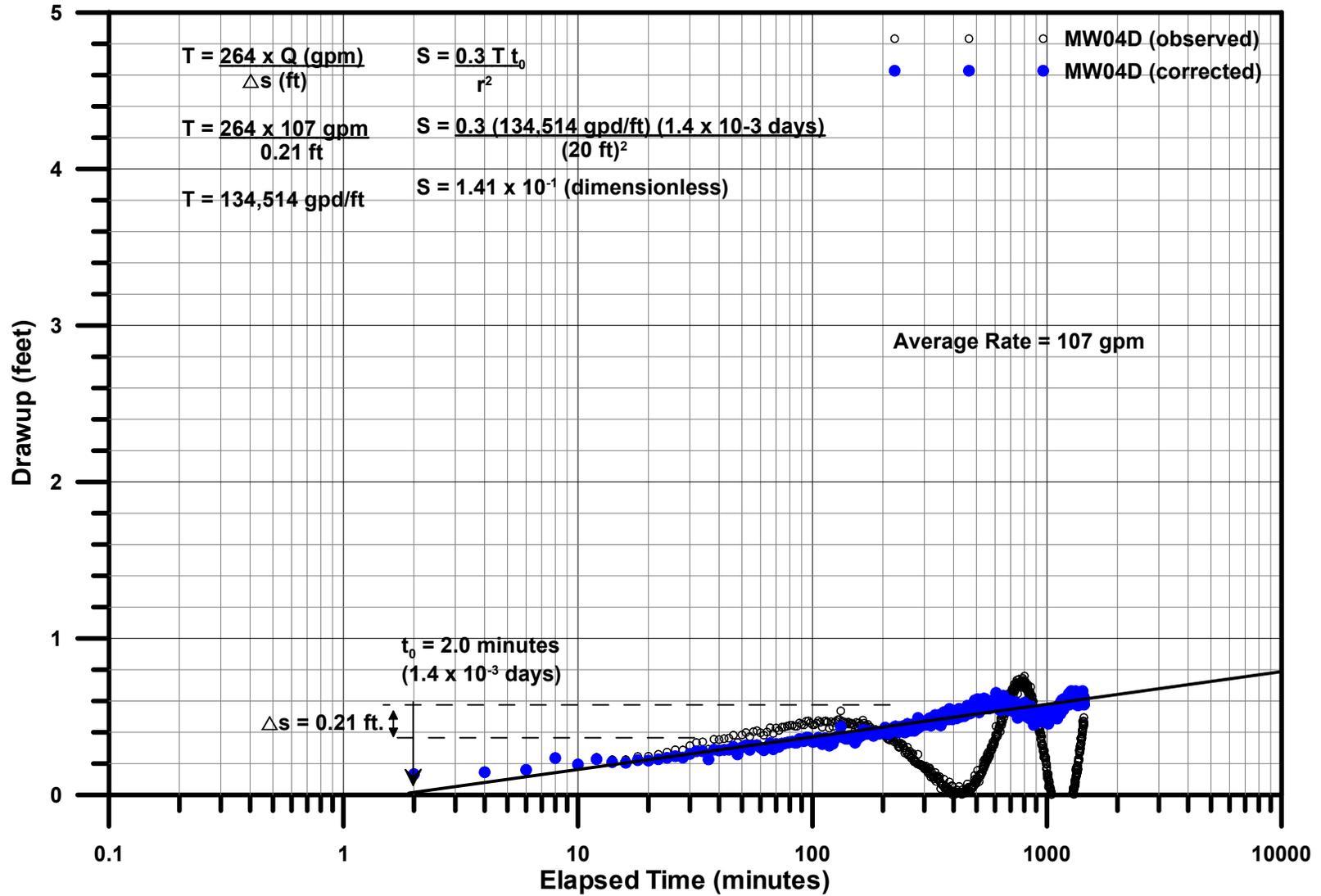


FIGURE B7. MCWP-MW01 24-HR INJECTION TEST - MW04D DRAWUP DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

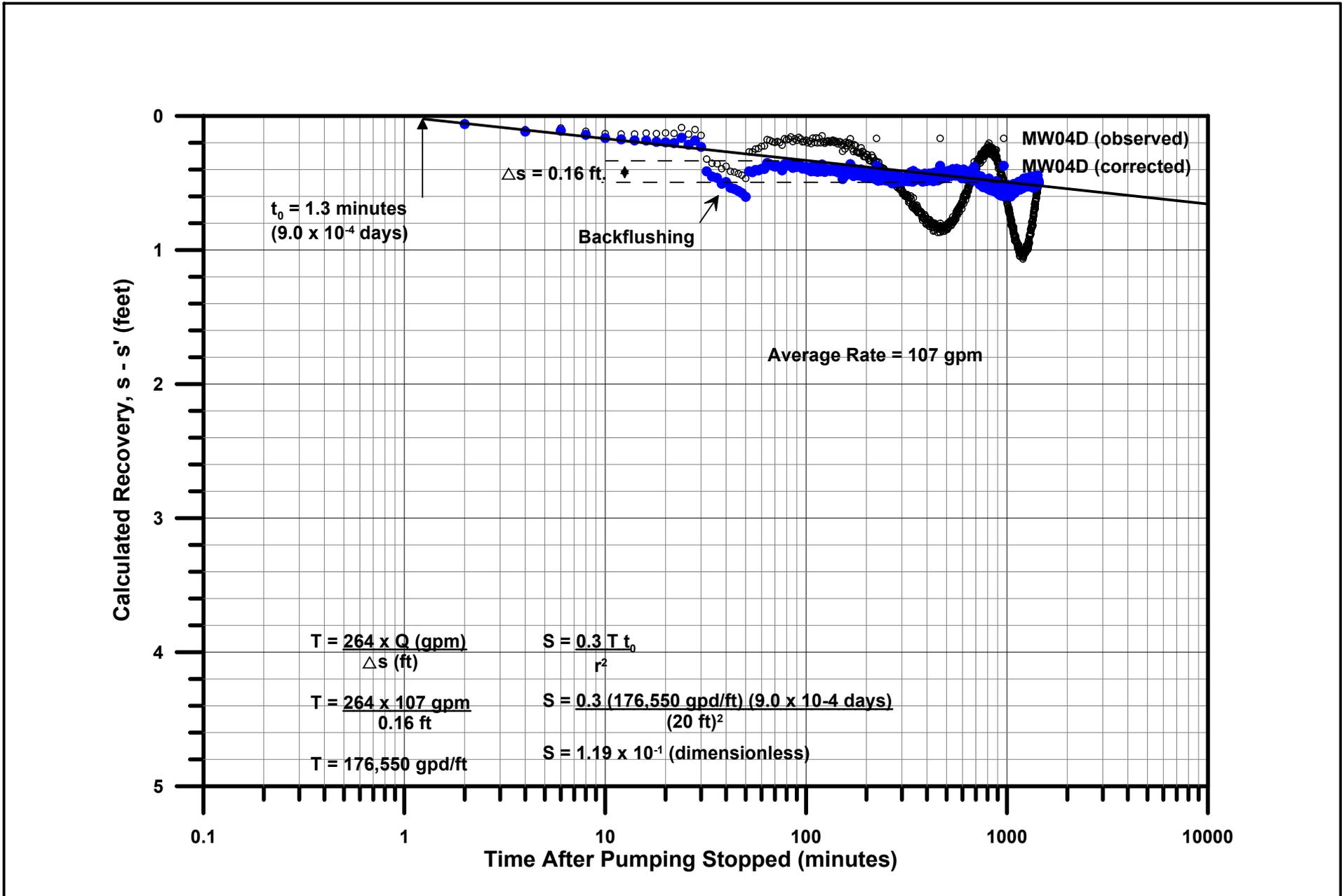


FIGURE B8. MCWP-MW01 24-HR INJECTION TEST - MW04D RECOVERY DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

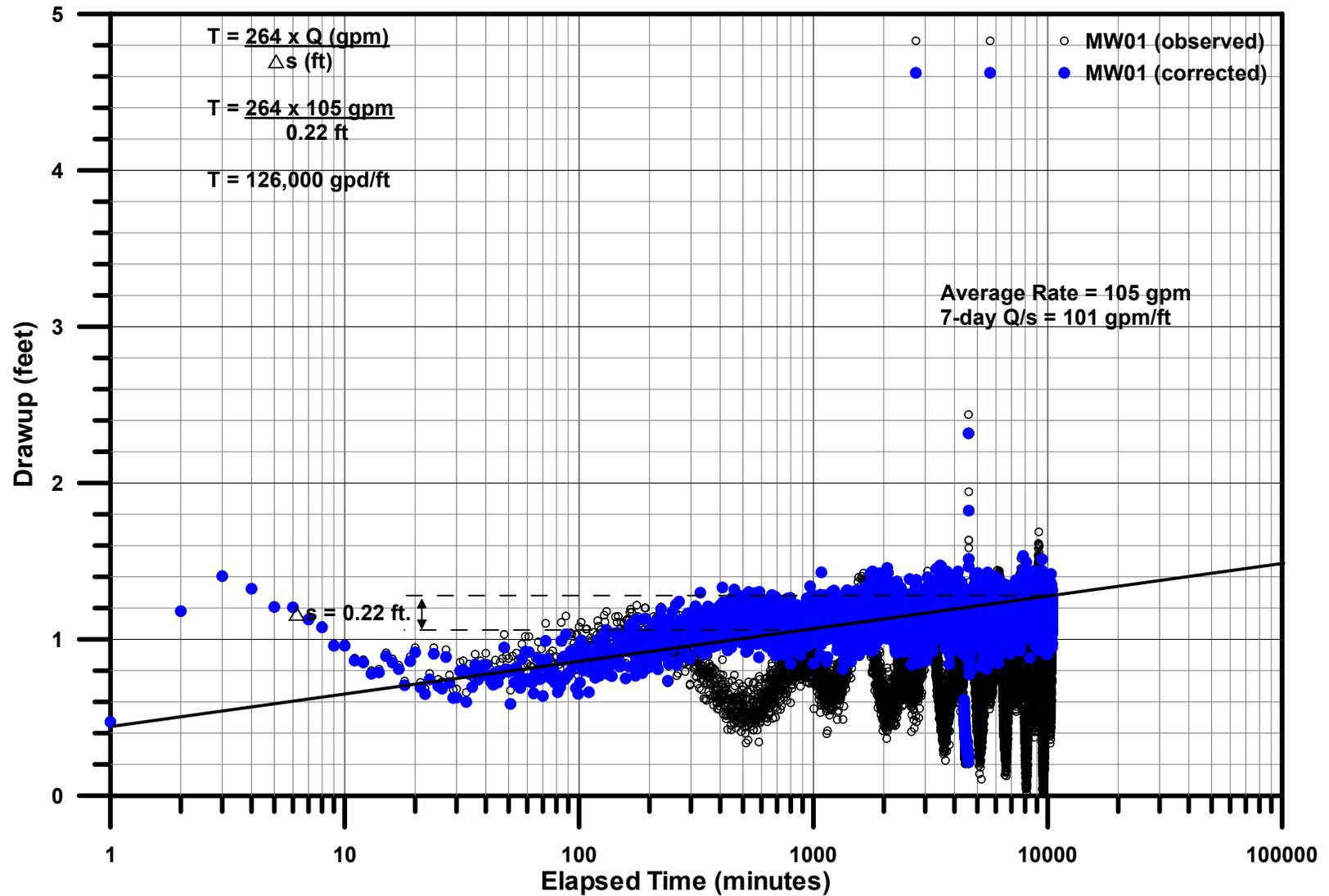


FIGURE B9. MCWP-MW01 7-DAY INJECTION TEST - MW01 DRAWUP DATA
Malibu Groundwater Injection Feasibility Project - Phase 3
RMC Water and Environment / City of Malibu

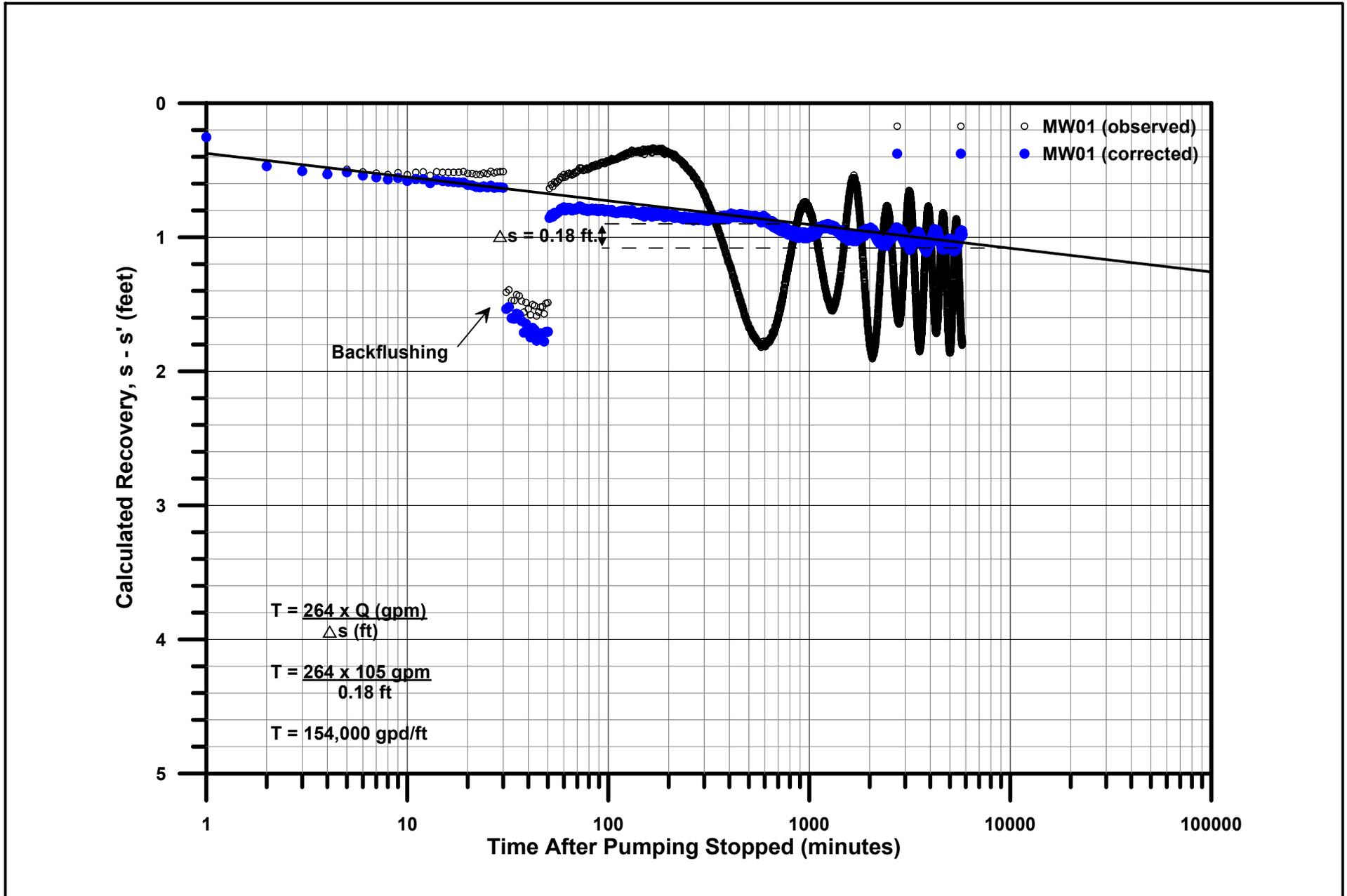


FIGURE B10. MCWP-MW01 7-DAY INJECTION TEST - MW01 RECOVERY DATA
Malibu Groundwater Injection Feasibility Project - Phase 3
RMC Water and Environment / City of Malibu

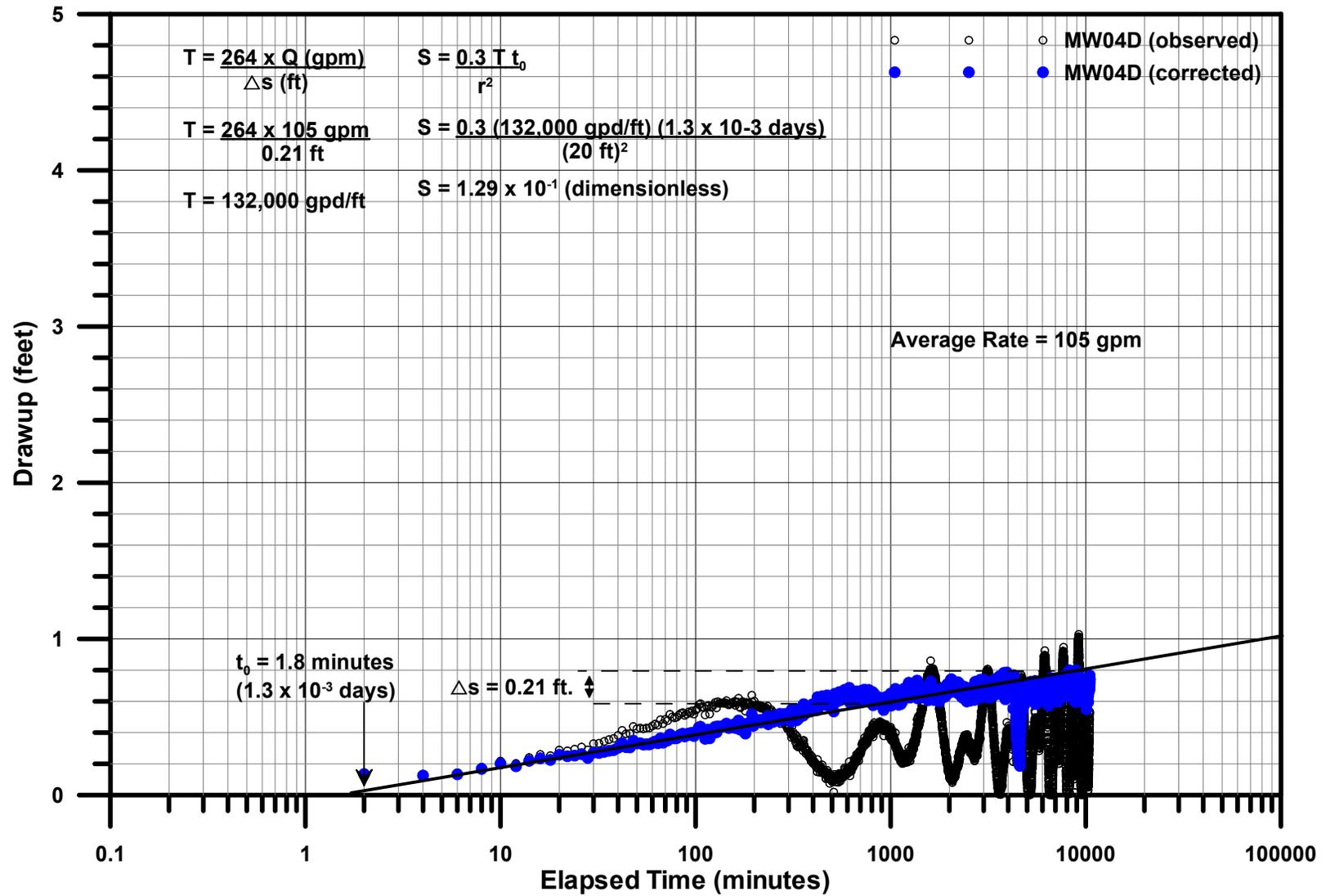


FIGURE B11. MCWP-MW01 7-DAY INJECTION TEST - MW04D DRAWUP DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

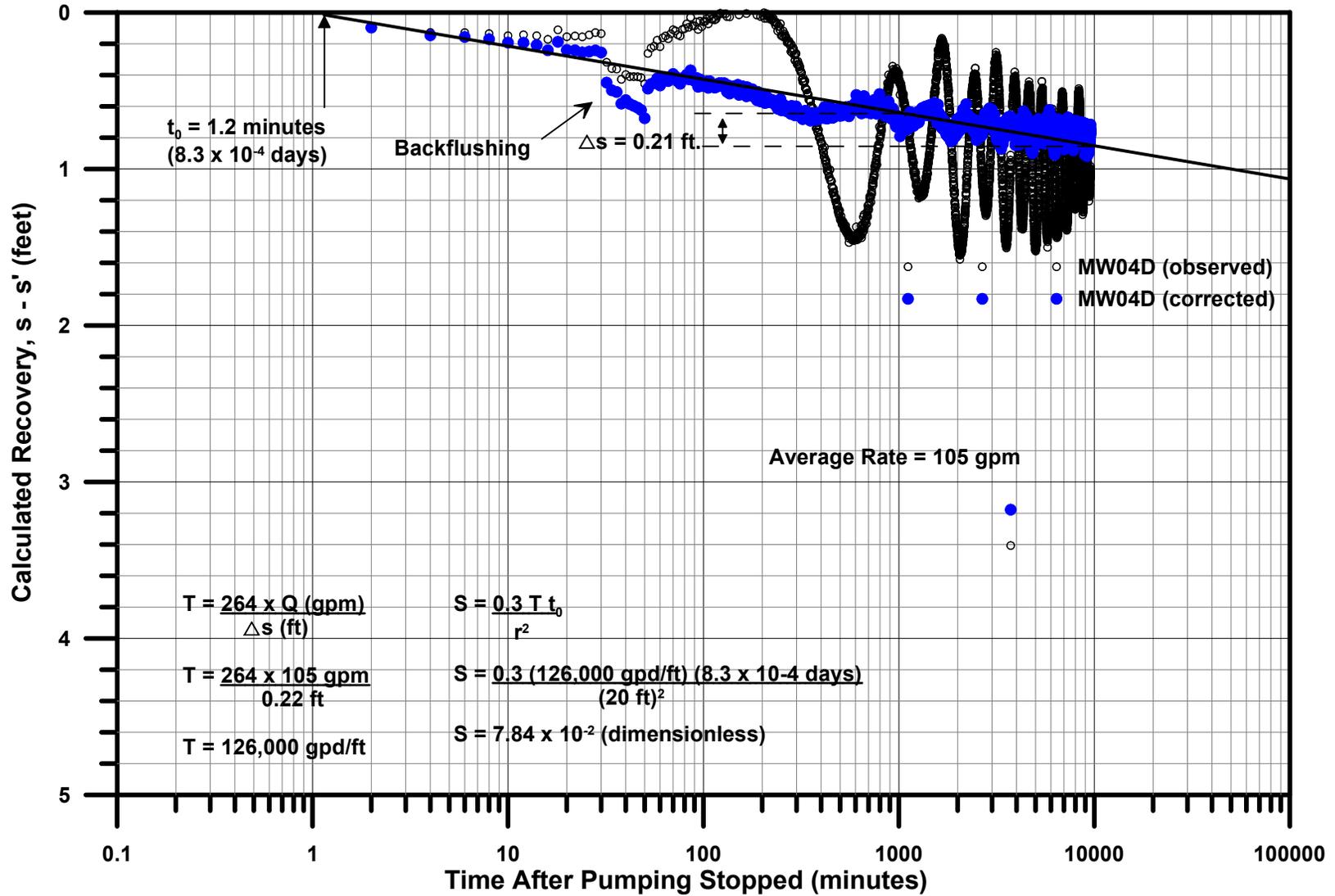
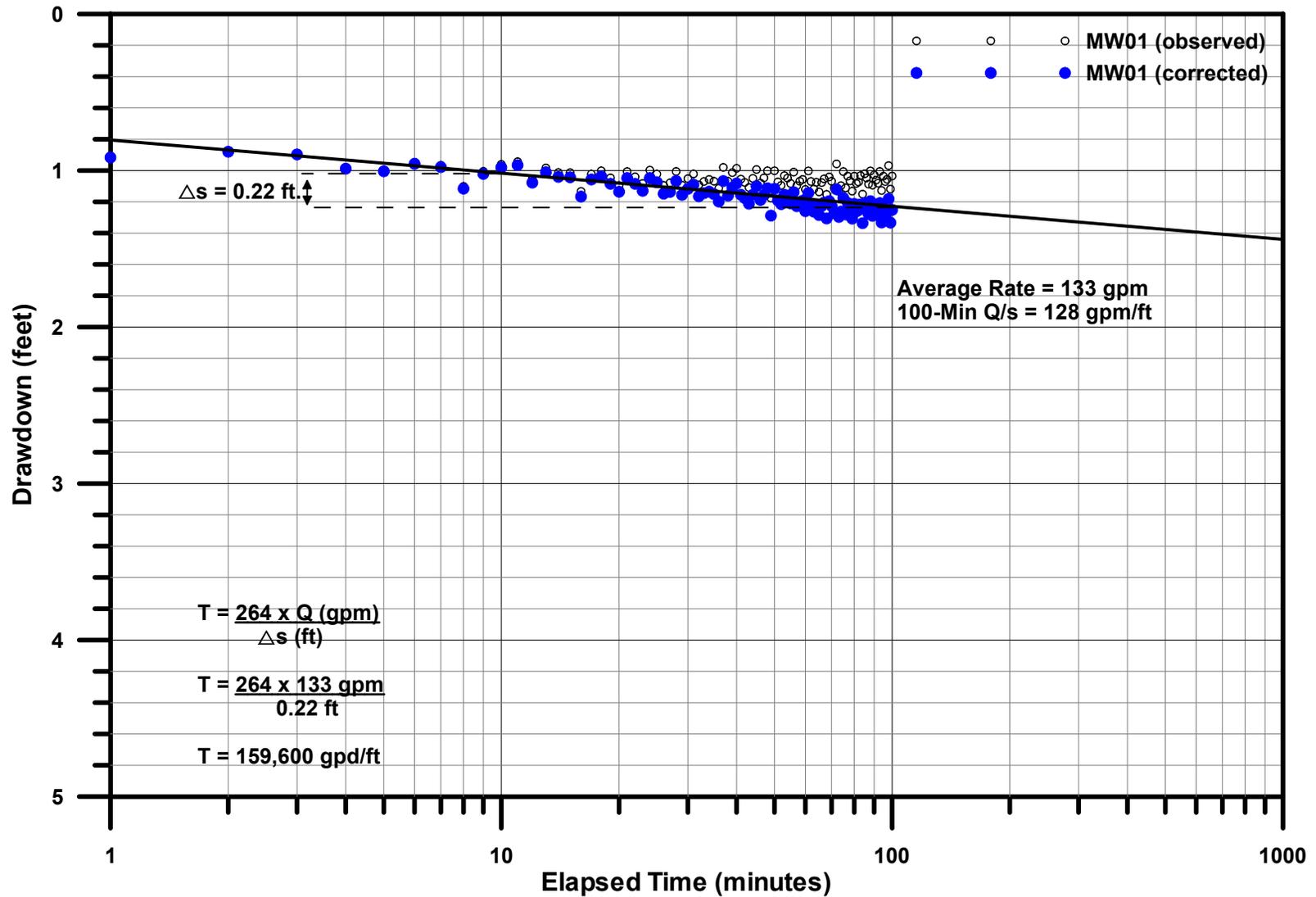


FIGURE B12. MCWP-MW01 7-DAY INJECTION TEST - MW04D RECOVERY DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu



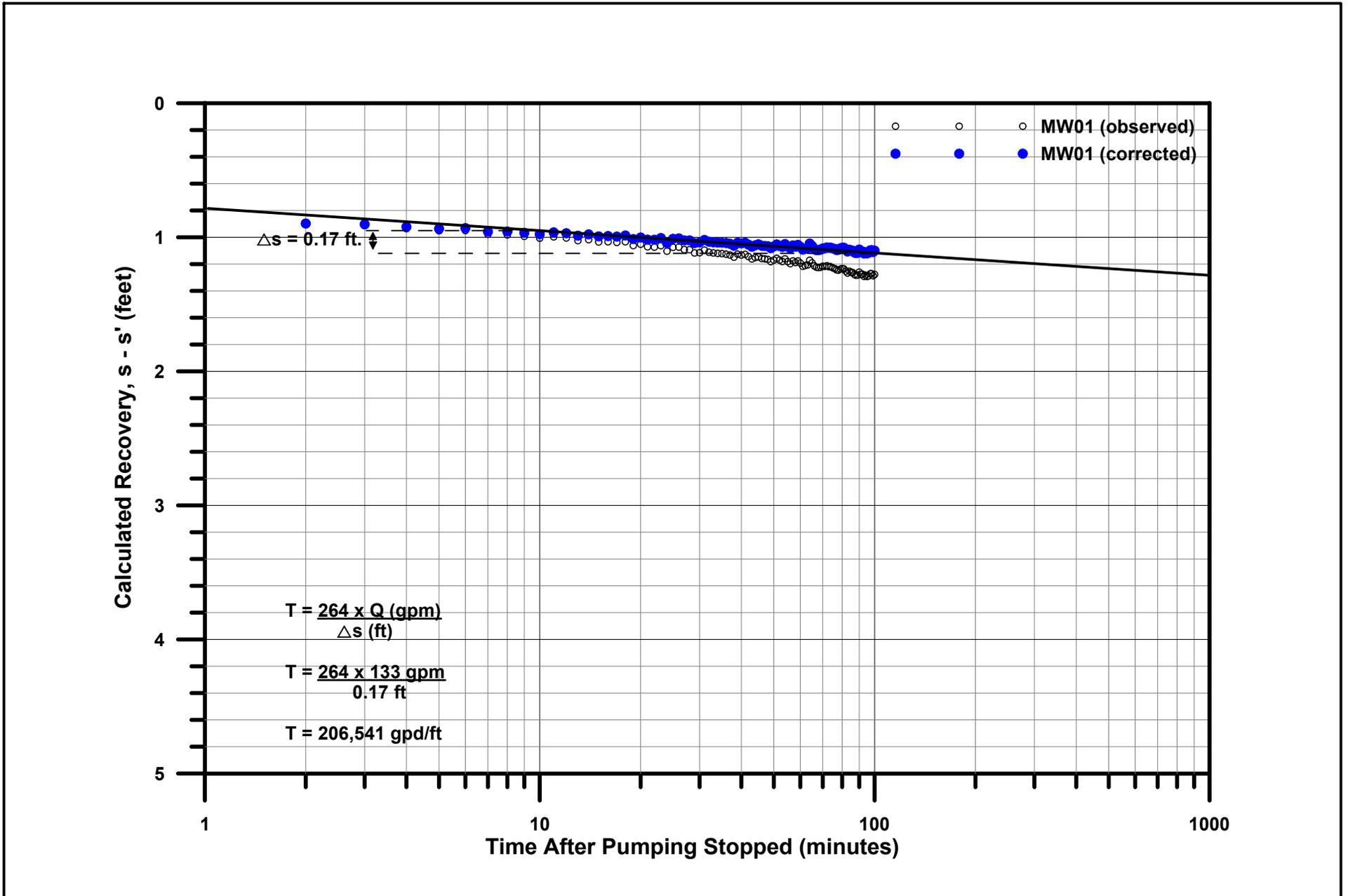


FIGURE B14. MCWP-MW01 POST-INJECTION PUMPING TEST - MW01 RECOVERY DATA
Malibu Groundwater Injection Feasibility Project - Phase 3
RMC Water and Environment / City of Malibu

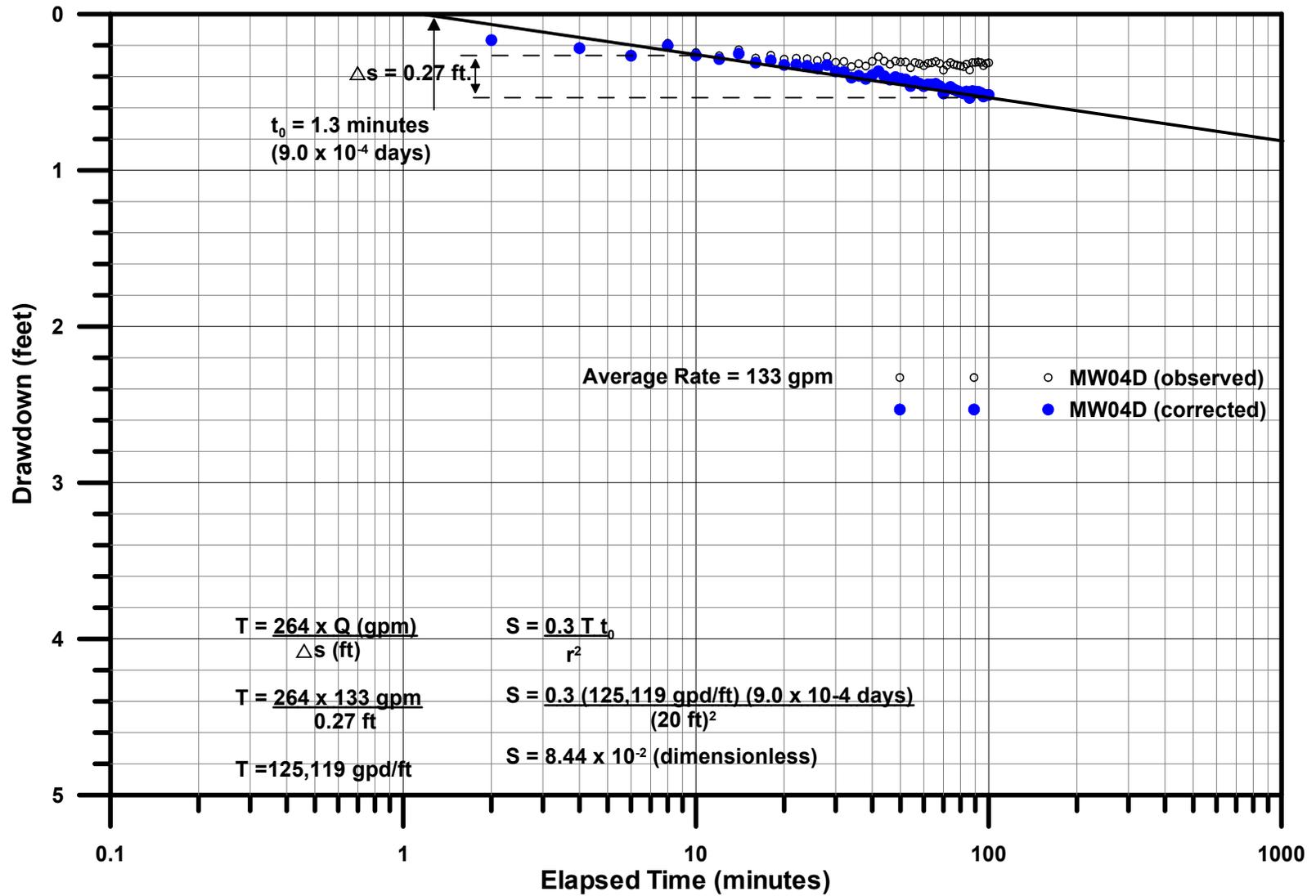


FIGURE B15. MCWP-MW01 POST-INJECTION PUMPING TEST - MW04D DRAWDOWN DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

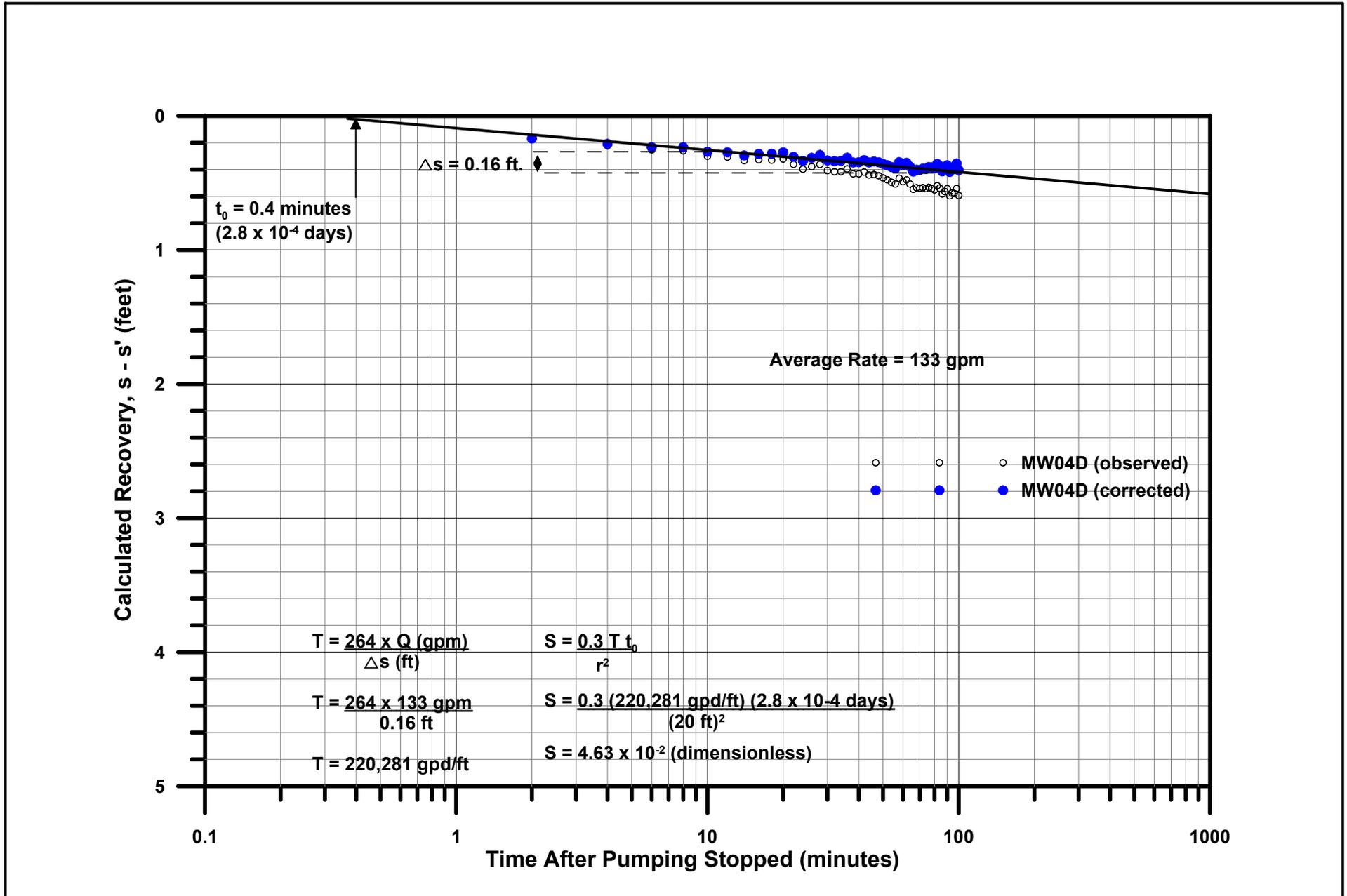


FIGURE B16. MCWP-MW01 POST-INJECTION PUMPING TEST - MW04D RECOVERY DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

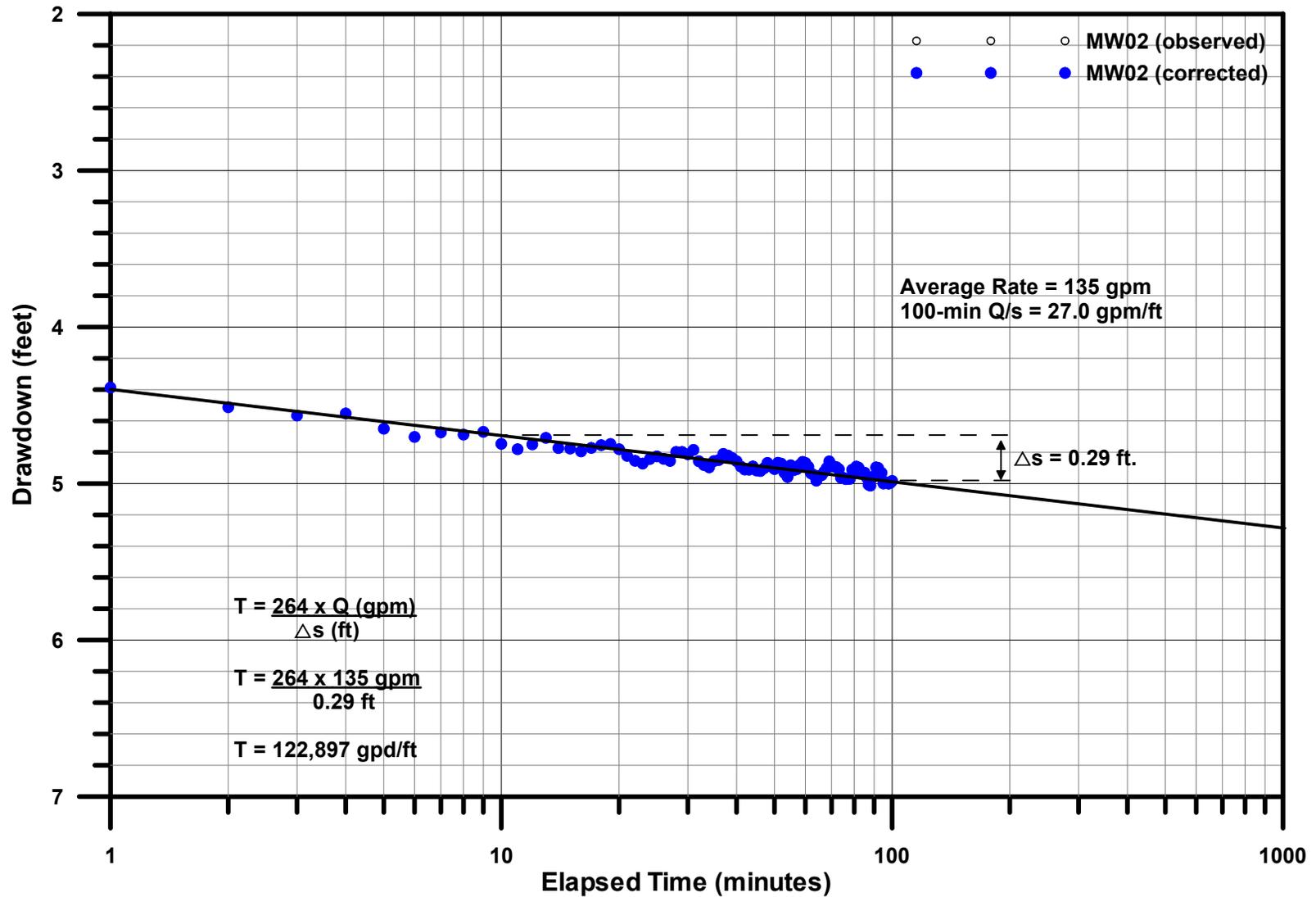


FIGURE B17. MCWP-MW02 PRE-INJECTION PUMPING TEST - MW02 DRAWDOWN DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

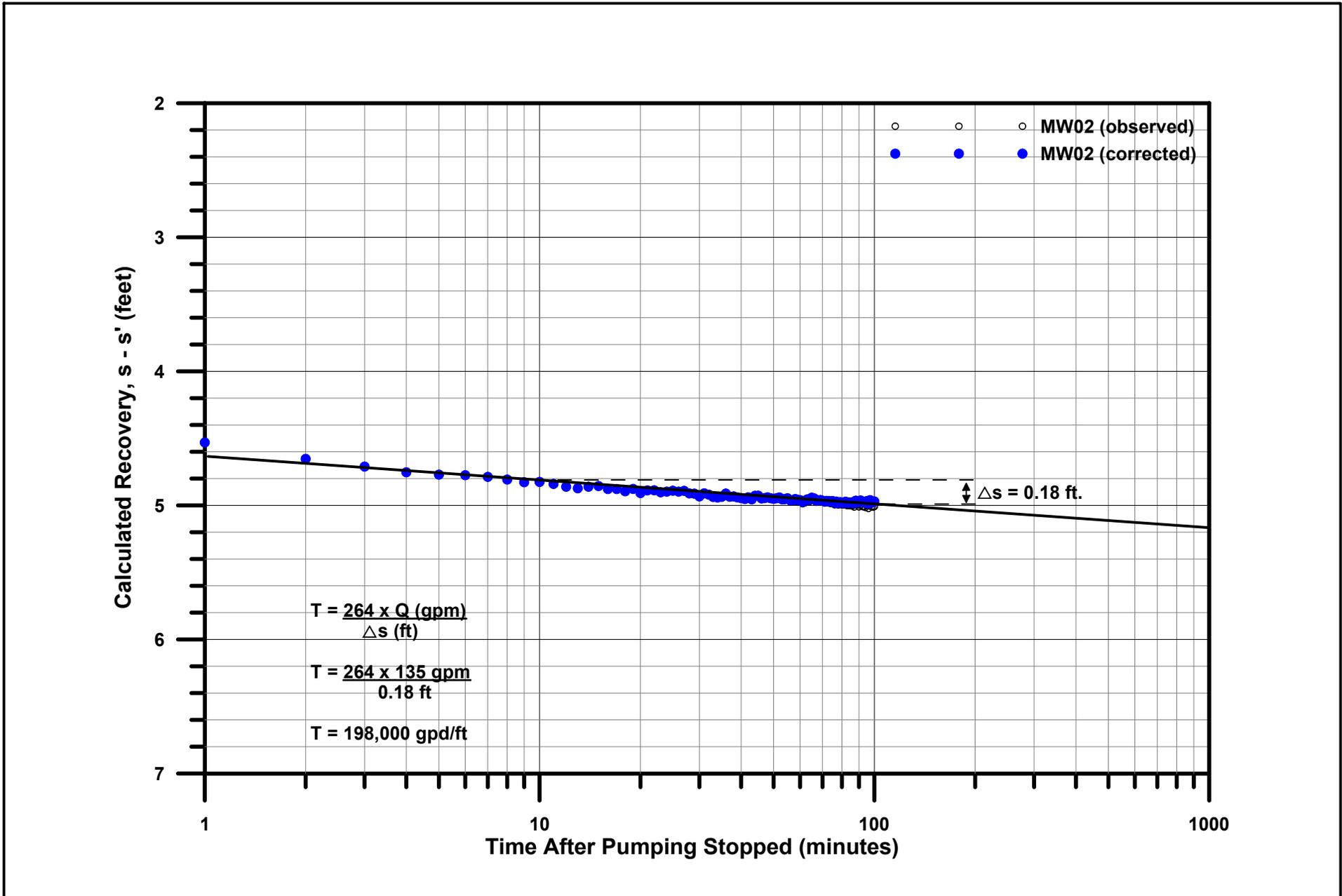


FIGURE B18. MCWP-MW02 PRE-INJECTION PUMPING TEST - MW02 RECOVERY DATA
Malibu Groundwater Injection Feasibility Project - Phase 3
RMC Water and Environment / City of Malibu

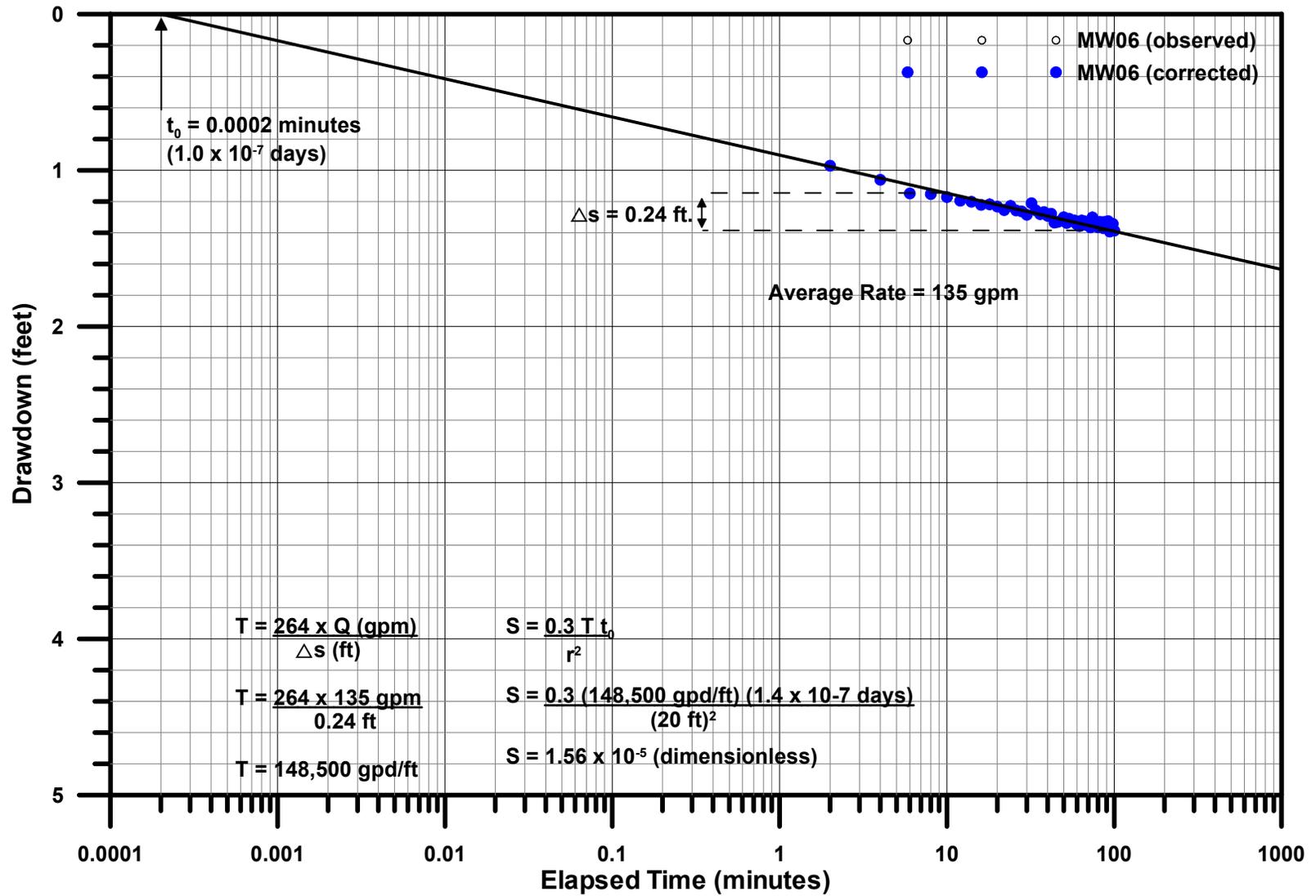


FIGURE B19. MCWP-MW02 PRE-INJECTION PUMPING TEST - MW06 DRAWDOWN DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

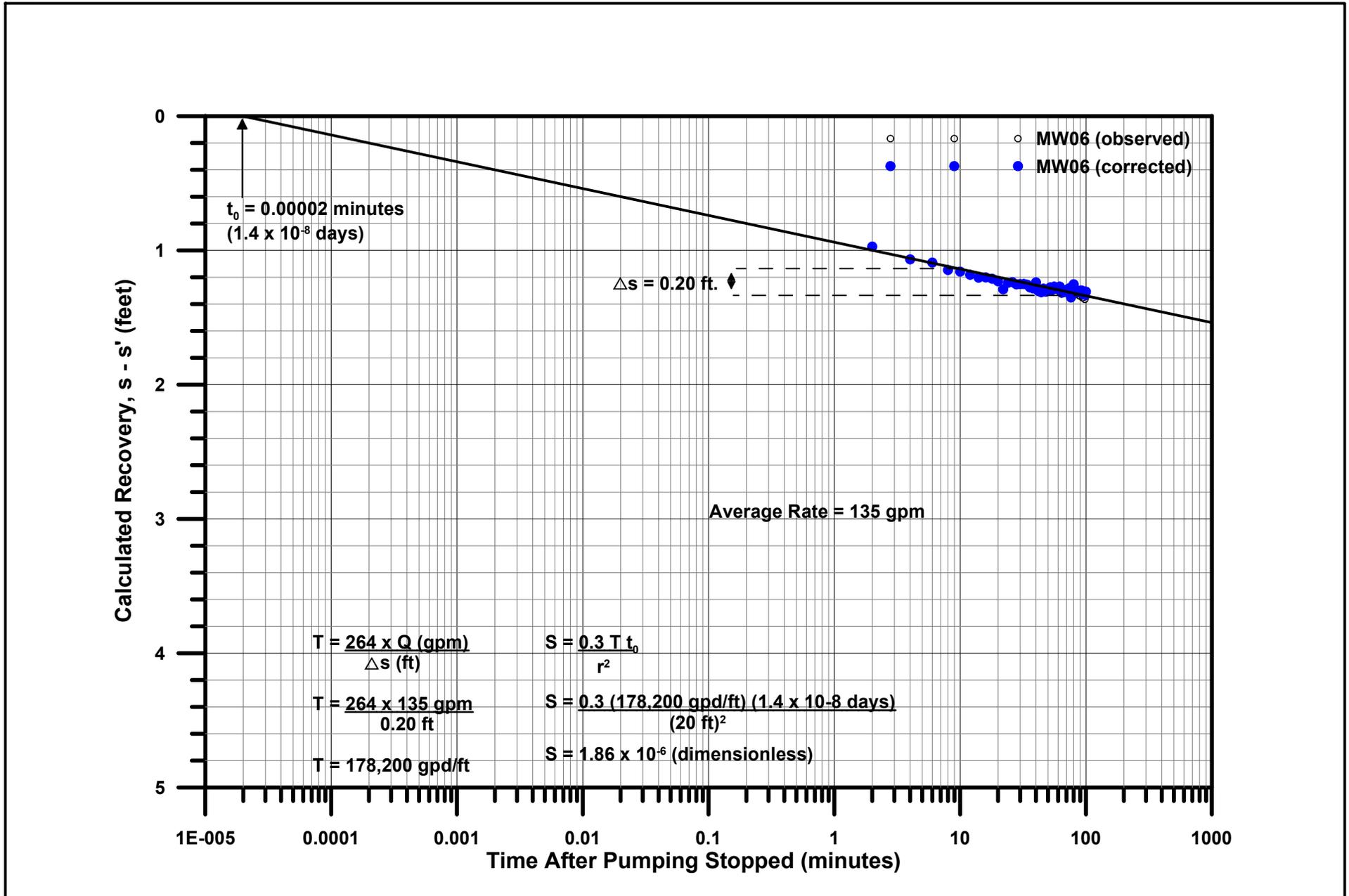


FIGURE B20. MCWP-MW02 PRE-INJECTION PUMPING TEST - MW06 RECOVERY DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

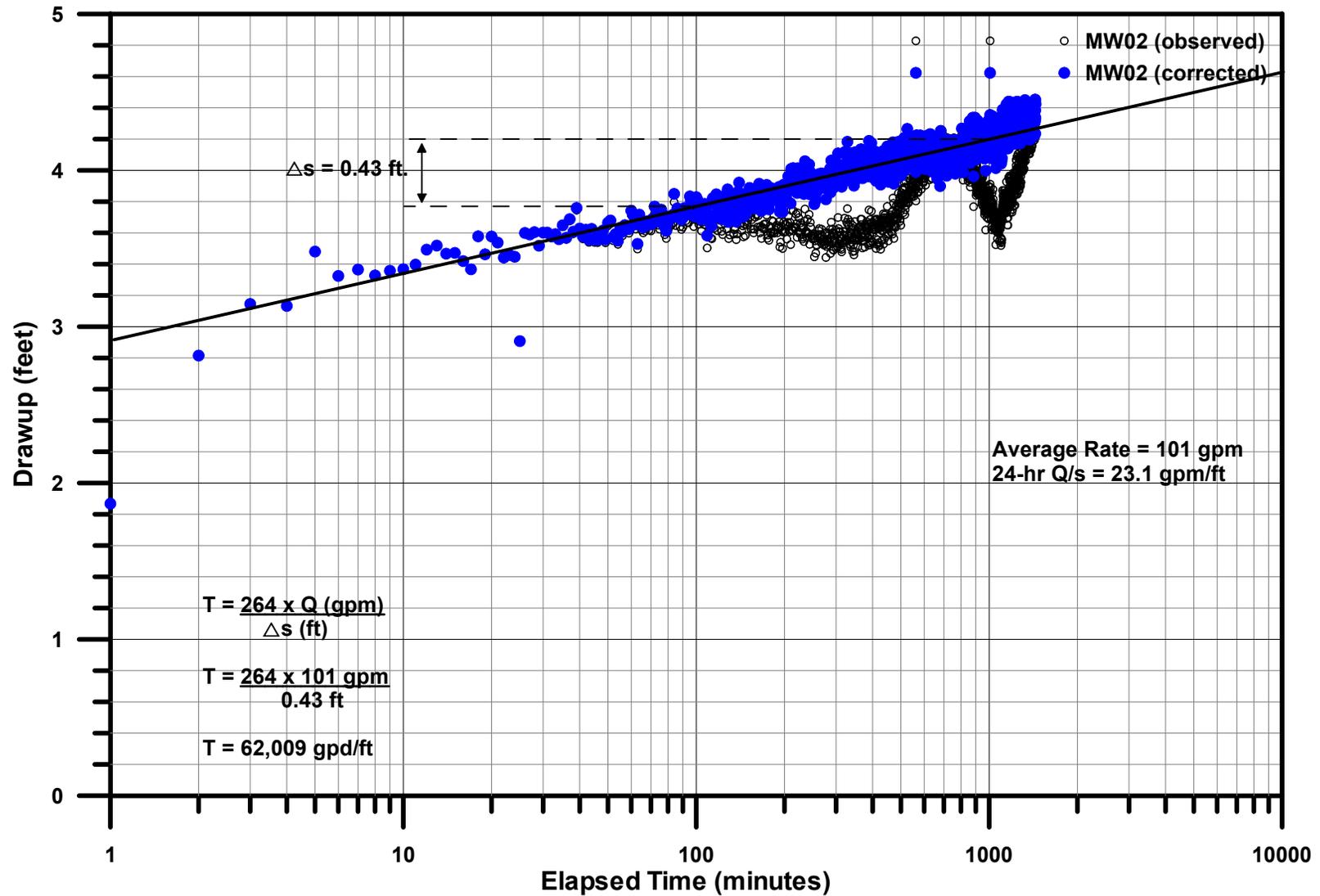


FIGURE B21. MCWP-MW02 24-HR INJECTION TEST - MW02 DRAWUP DATA
Malibu Groundwater Injection Feasibility Project - Phase 3
RMC Water and Environment / City of Malibu

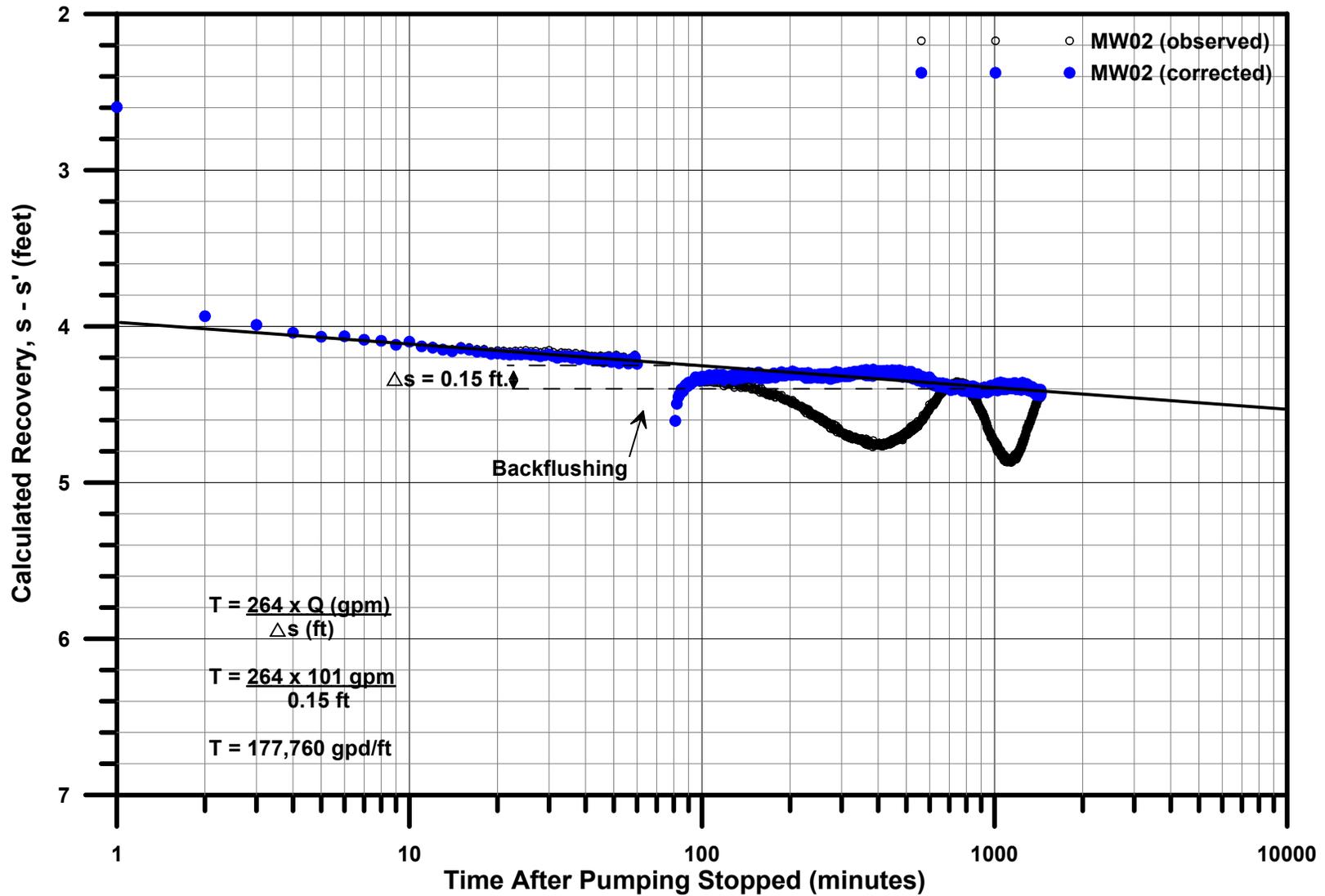


FIGURE B22. MCWP-MW02 24-HR INJECTION TEST - MW02 RECOVERY DATA
Malibu Groundwater Injection Feasibility Project - Phase 3
RMC Water and Environment / City of Malibu

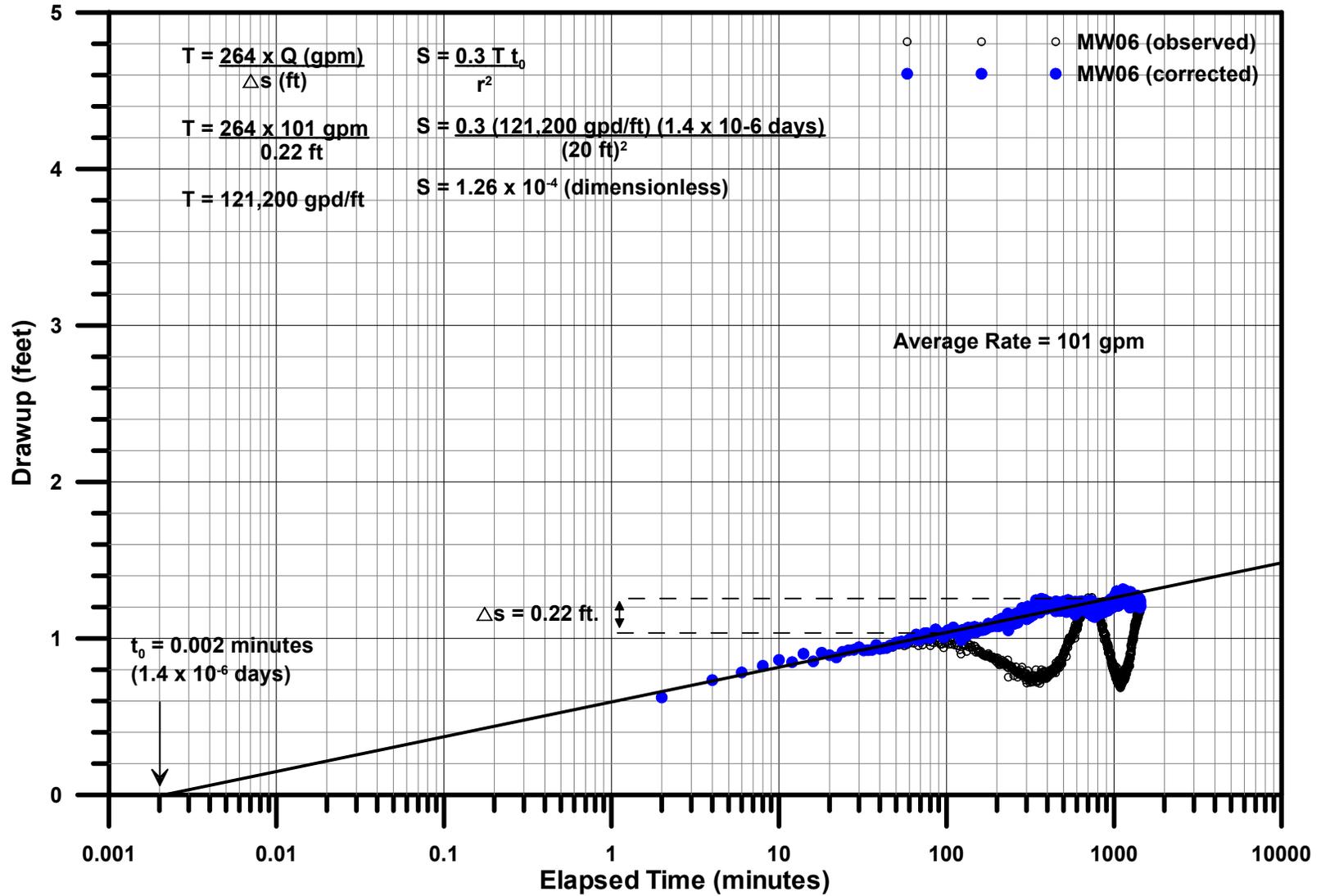


FIGURE B23. MCWP-MW02 24-HR INJECTION TEST - MW06 DRAWUP DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

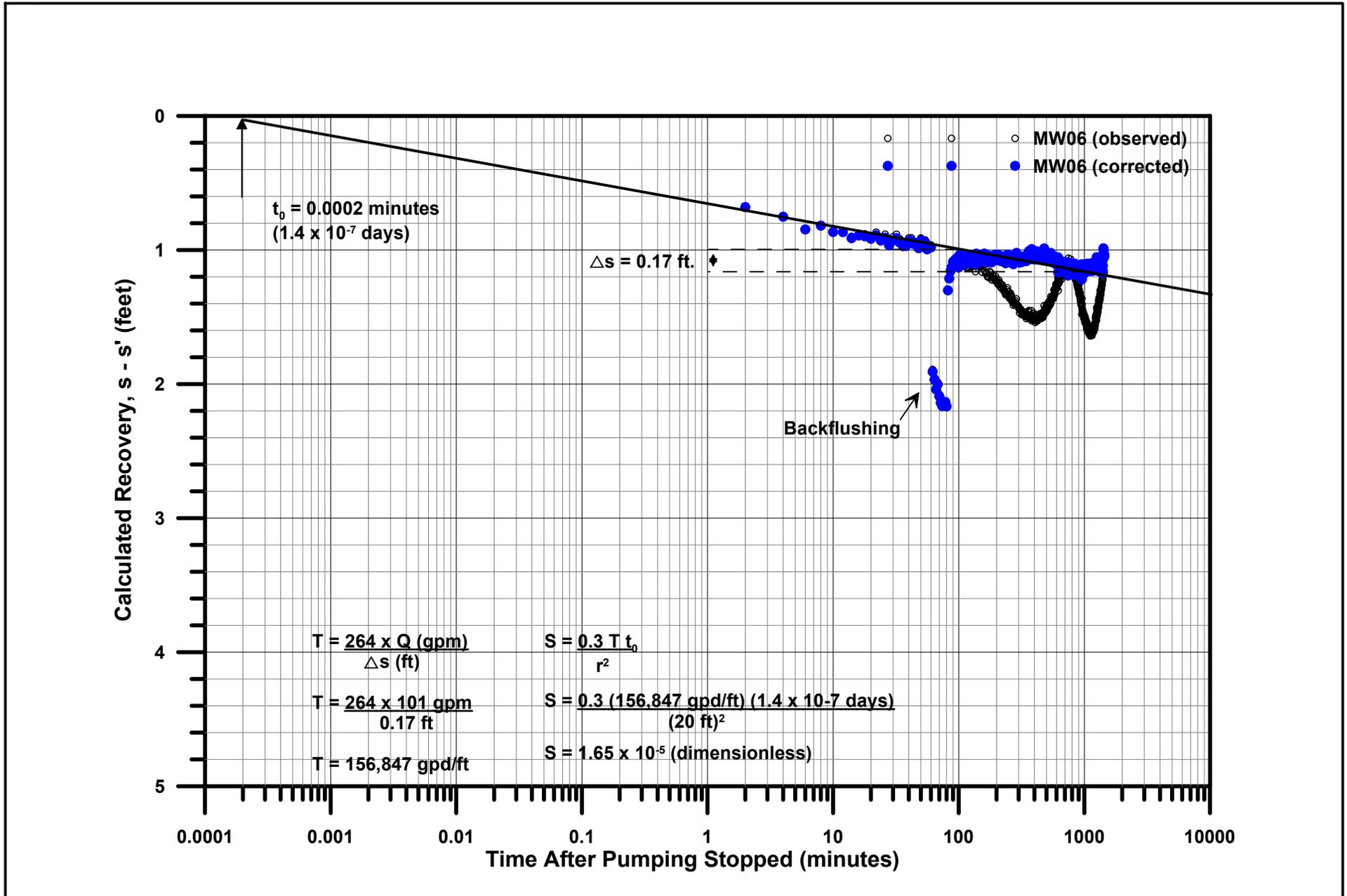


FIGURE B24. MCWP-MW02 24-HR INJECTION TEST - MW06 RECOVERY DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

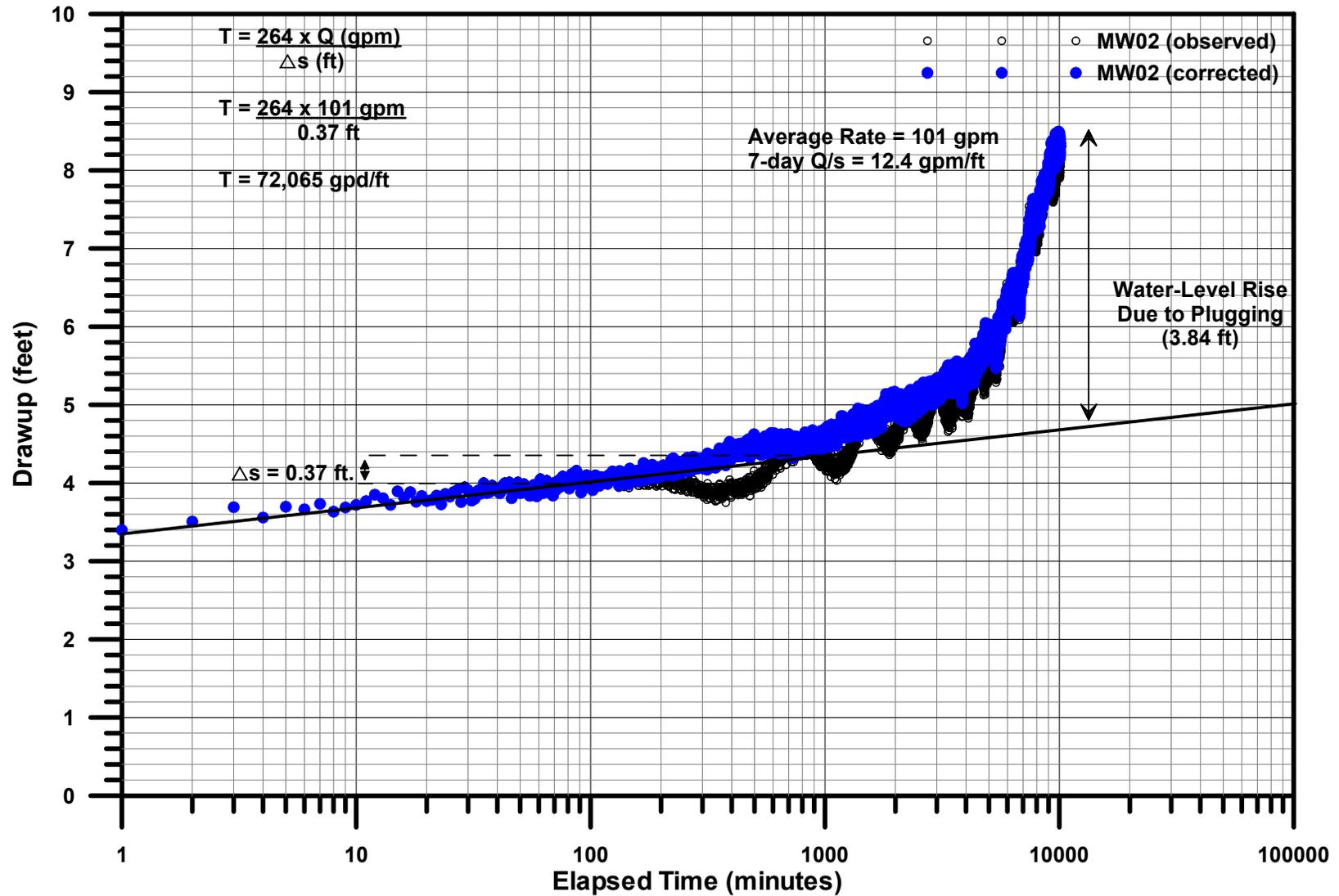


FIGURE B25. MCWP-MW02 7-DAY INJECTION TEST - MW02 DRAWUP DATA
Malibu Groundwater Injection Feasibility Project - Phase 3
RMC Water and Environment / City of Malibu

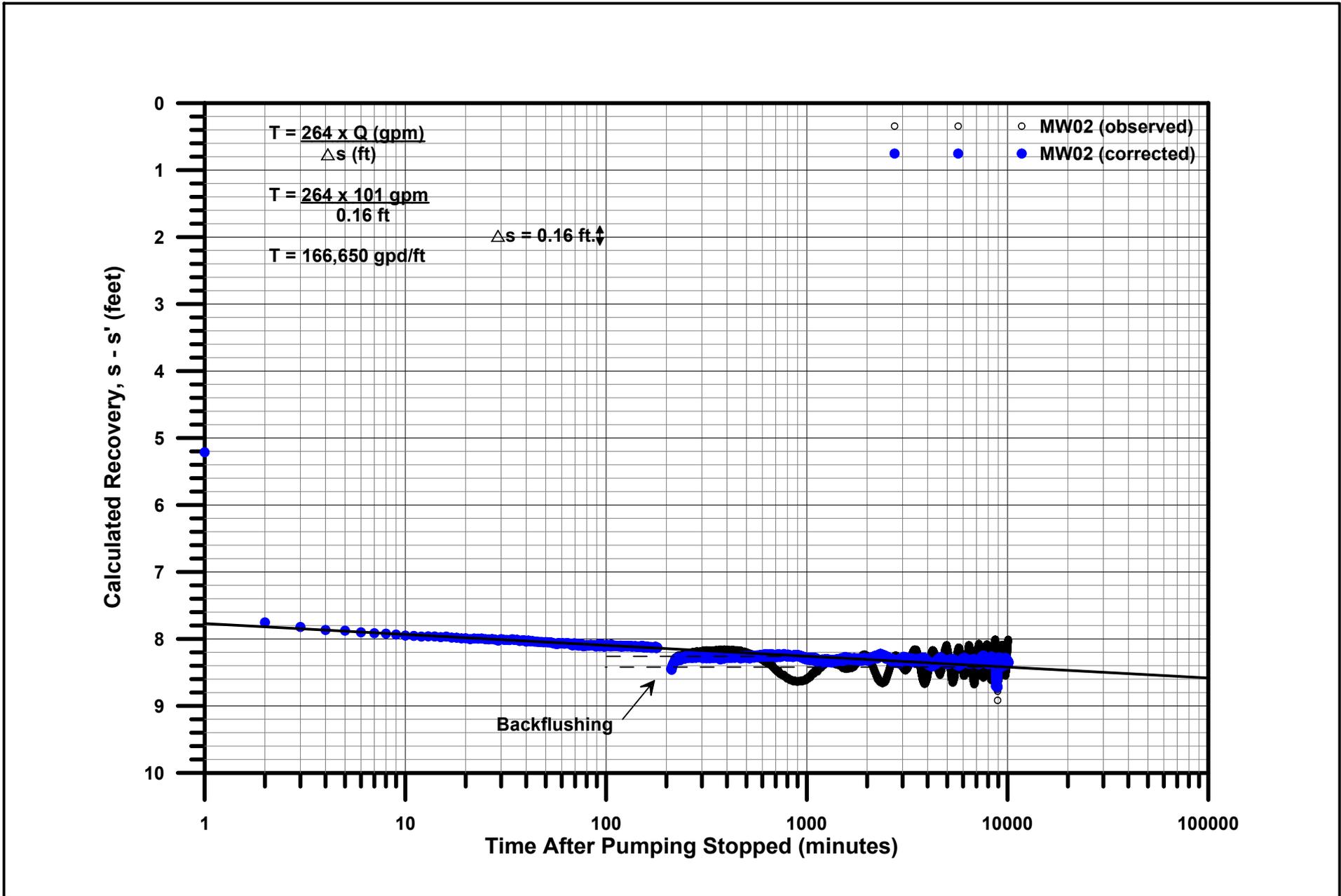


FIGURE B26. MCWP-MW02 7-DAY INJECTION TEST - MW02 RECOVERY DATA
Malibu Groundwater Injection Feasibility Project - Phase 3
RMC Water and Environment / City of Malibu

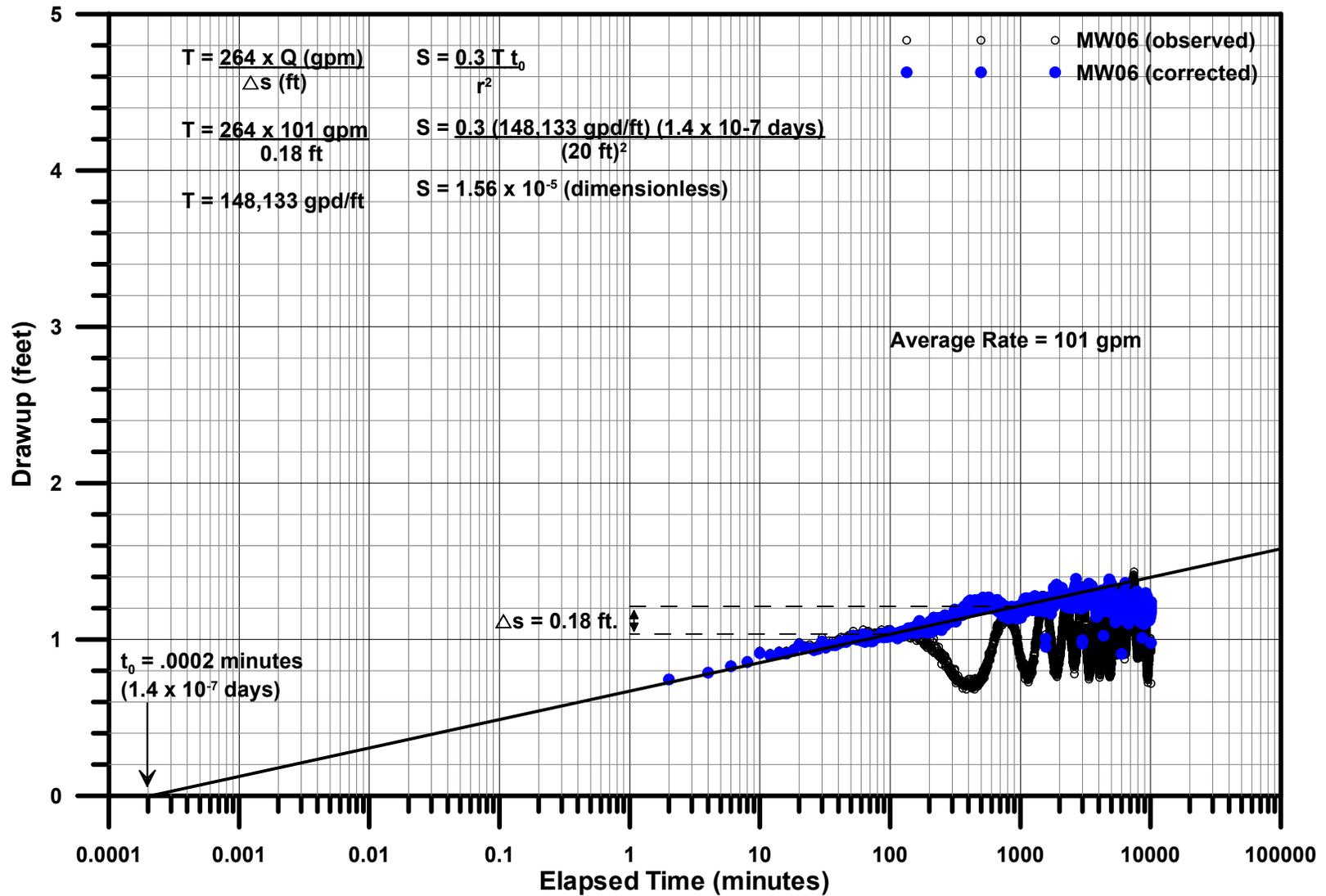


FIGURE B27. MCWP-MW02 7-DAY INJECTION TEST - MW06 DRAWUP DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

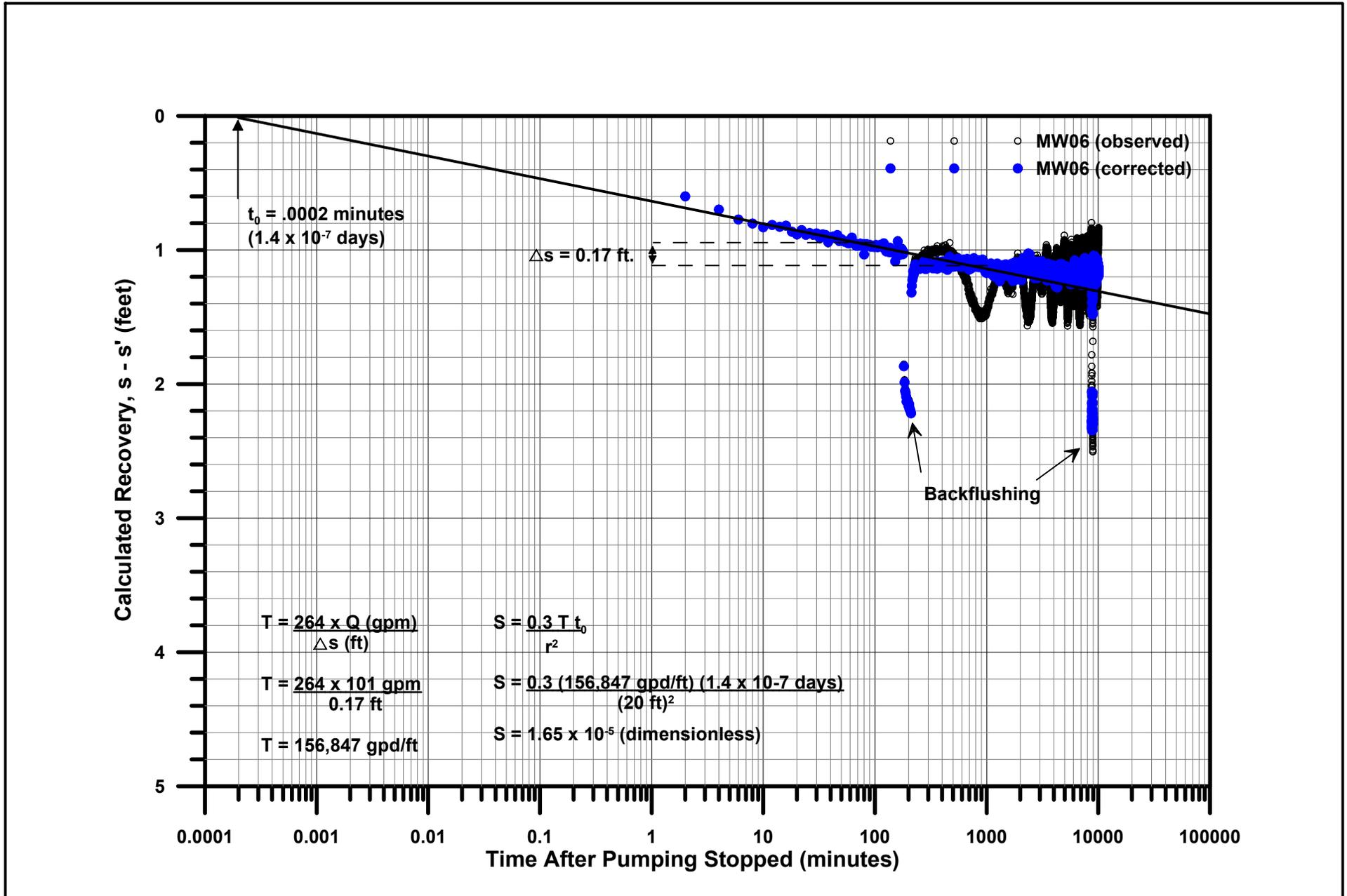


FIGURE B28. MCWP-MW02 7-DAY INJECTION TEST - MW06 RECOVERY DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

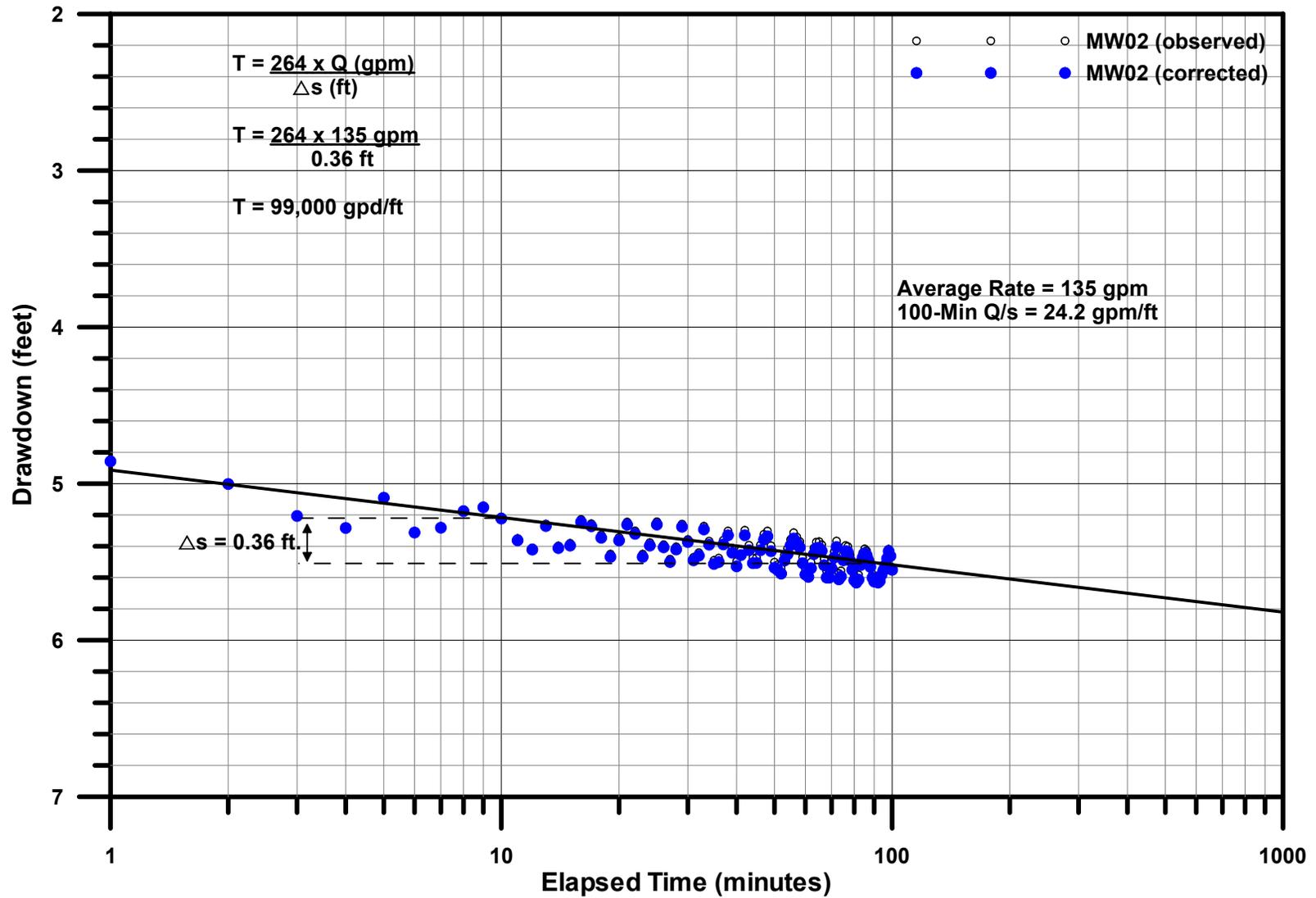


FIGURE B29. MCWP-MW02 POST-INJECTION PUMPING TEST - MW02 DRAWDOWN DATA
Malibu Groundwater Injection Feasibility Project - Phase 3
RMC Water and Environment / City of Malibu

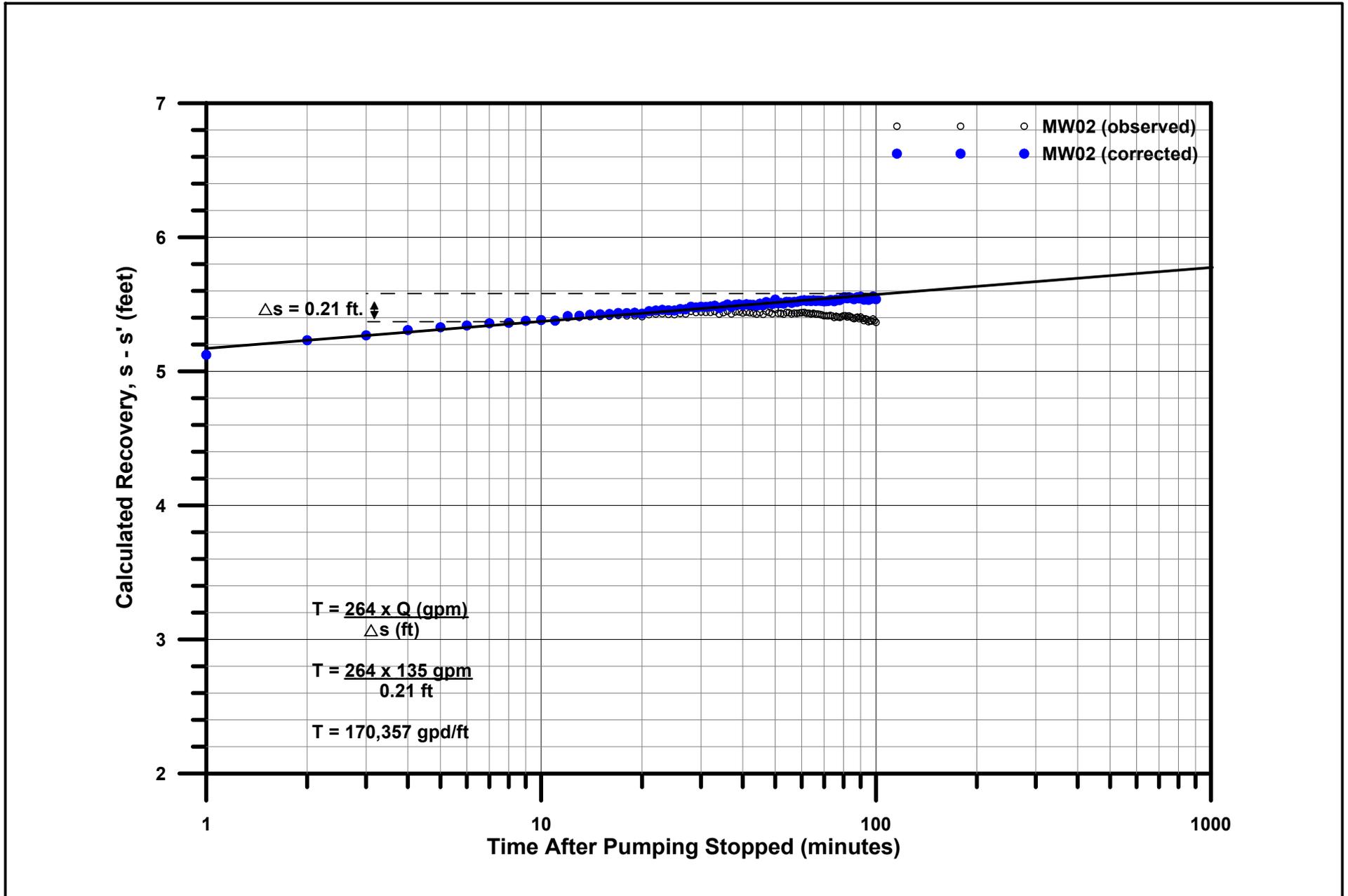


FIGURE B30. MCWP-MW02 POST-INJECTION PUMPING TEST - MW02 RECOVERY DATA
Malibu Groundwater Injection Feasibility Project - Phase 3
RMC Water and Environment / City of Malibu

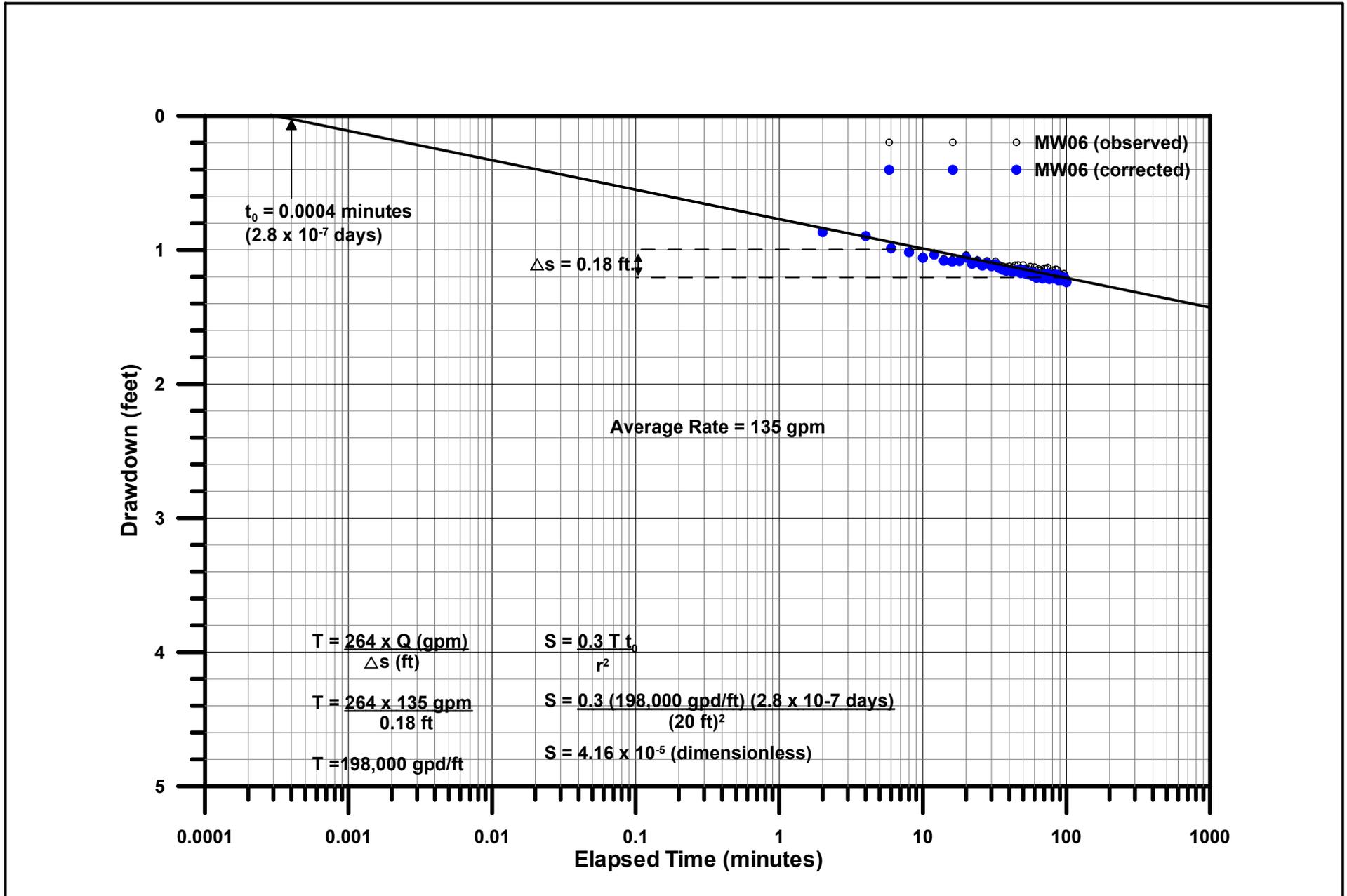


FIGURE B31. MCWP-MW02 POST-INJECTION PUMPING TEST - MW06 DRAWDOWN DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

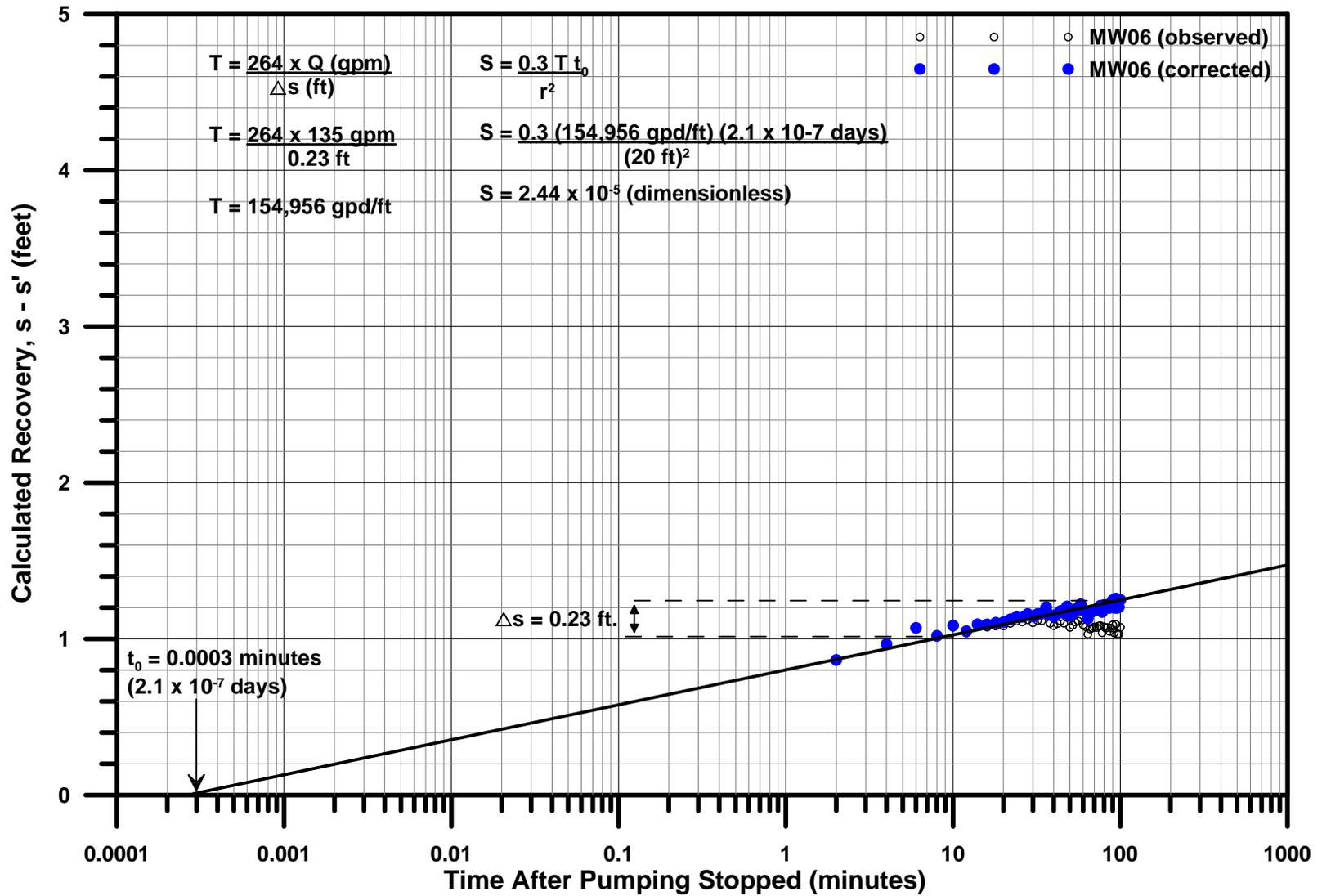


FIGURE B32. MCWP-MW02 POST-INJECTION PUMPING TEST - MW06 RECOVERY DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

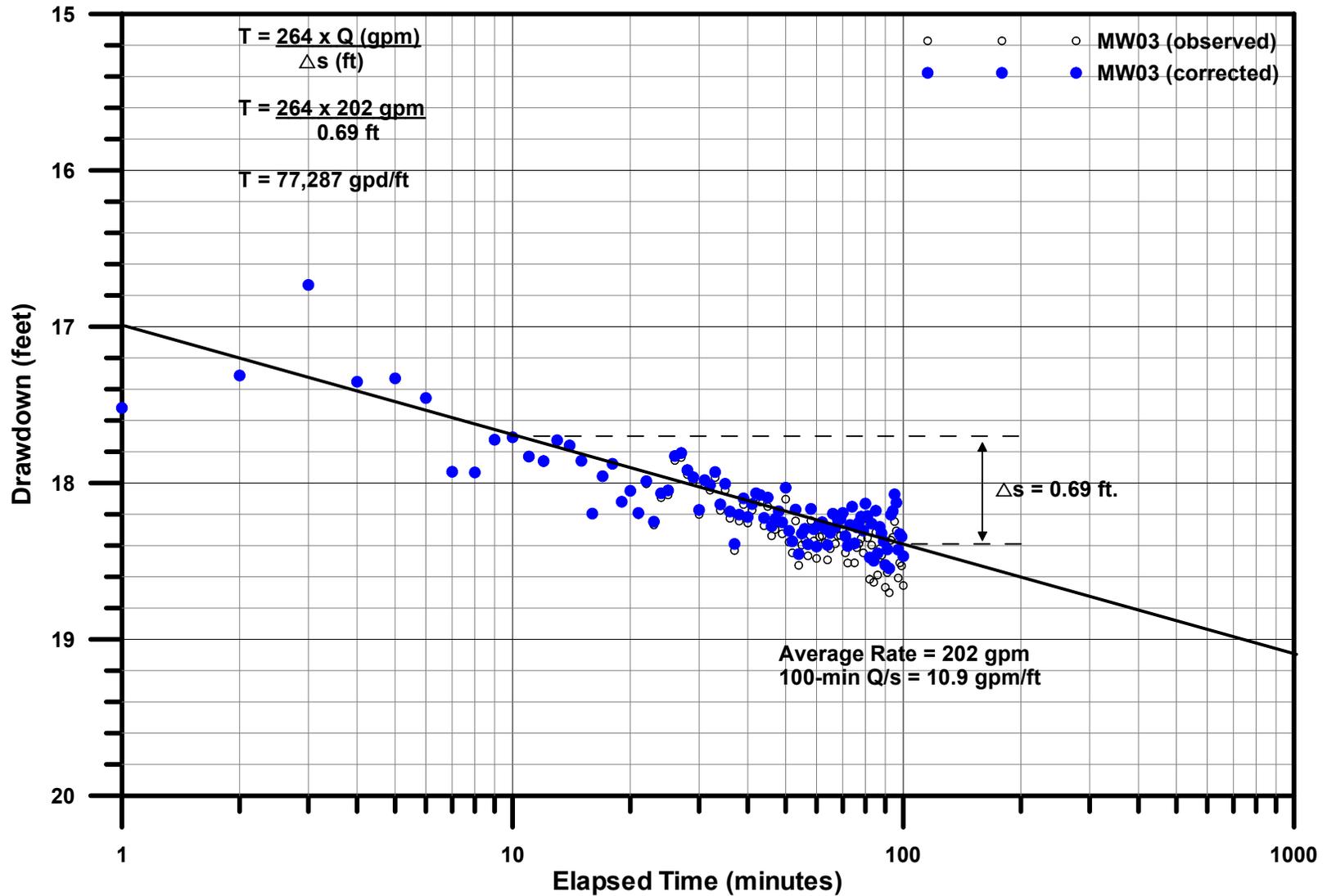


FIGURE B33. MCWP-MW03 PRE-INJECTION PUMPING TEST - MW03 DRAWDOWN DATA
Malibu Groundwater Injection Feasibility Project - Phase 3
RMC Water and Environment / City of Malibu

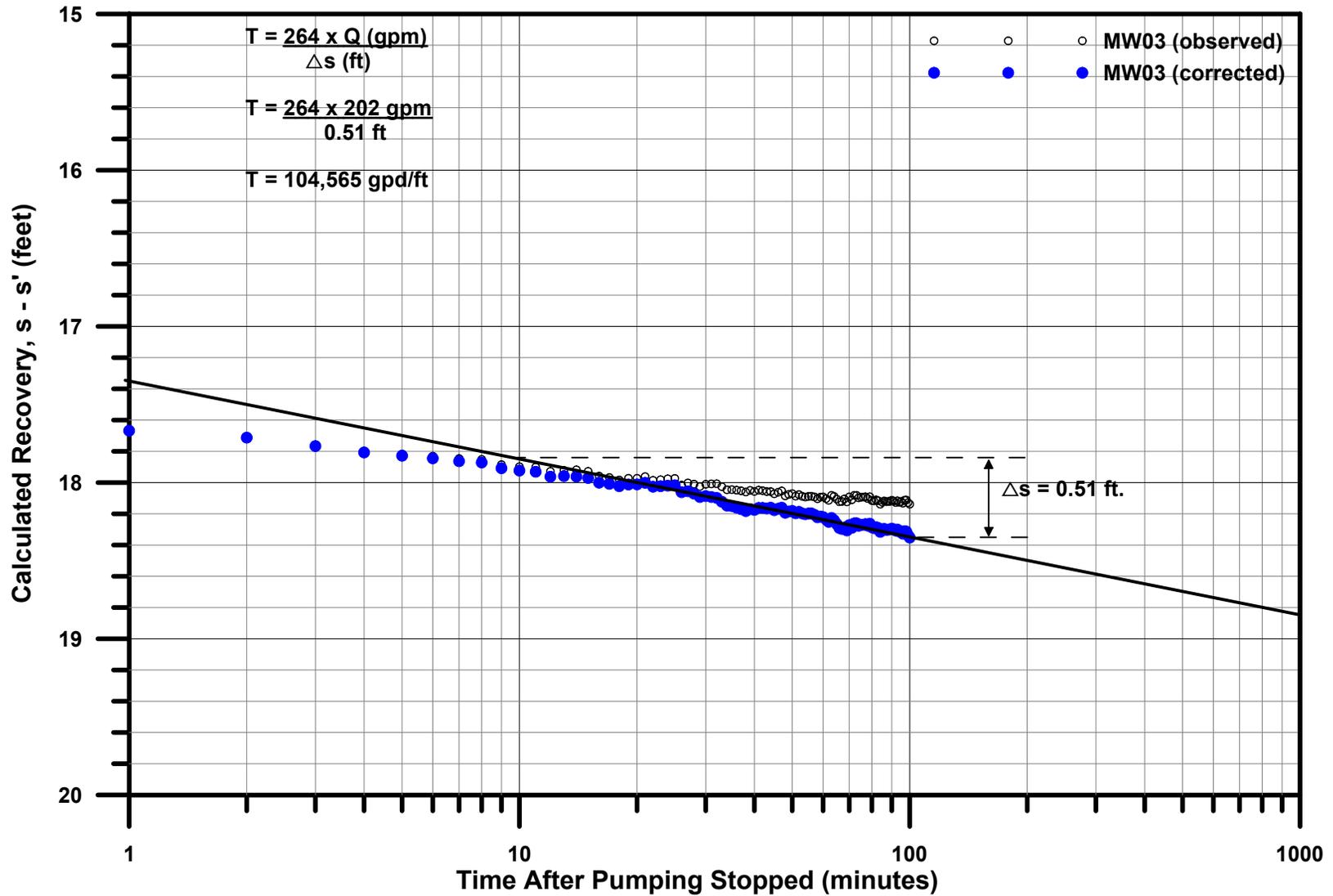


FIGURE B34. MCWP-MW03 PRE-INJECTION PUMPING TEST - MW03 RECOVERY DATA
Malibu Groundwater Injection Feasibility Project - Phase 3
RMC Water and Environment / City of Malibu

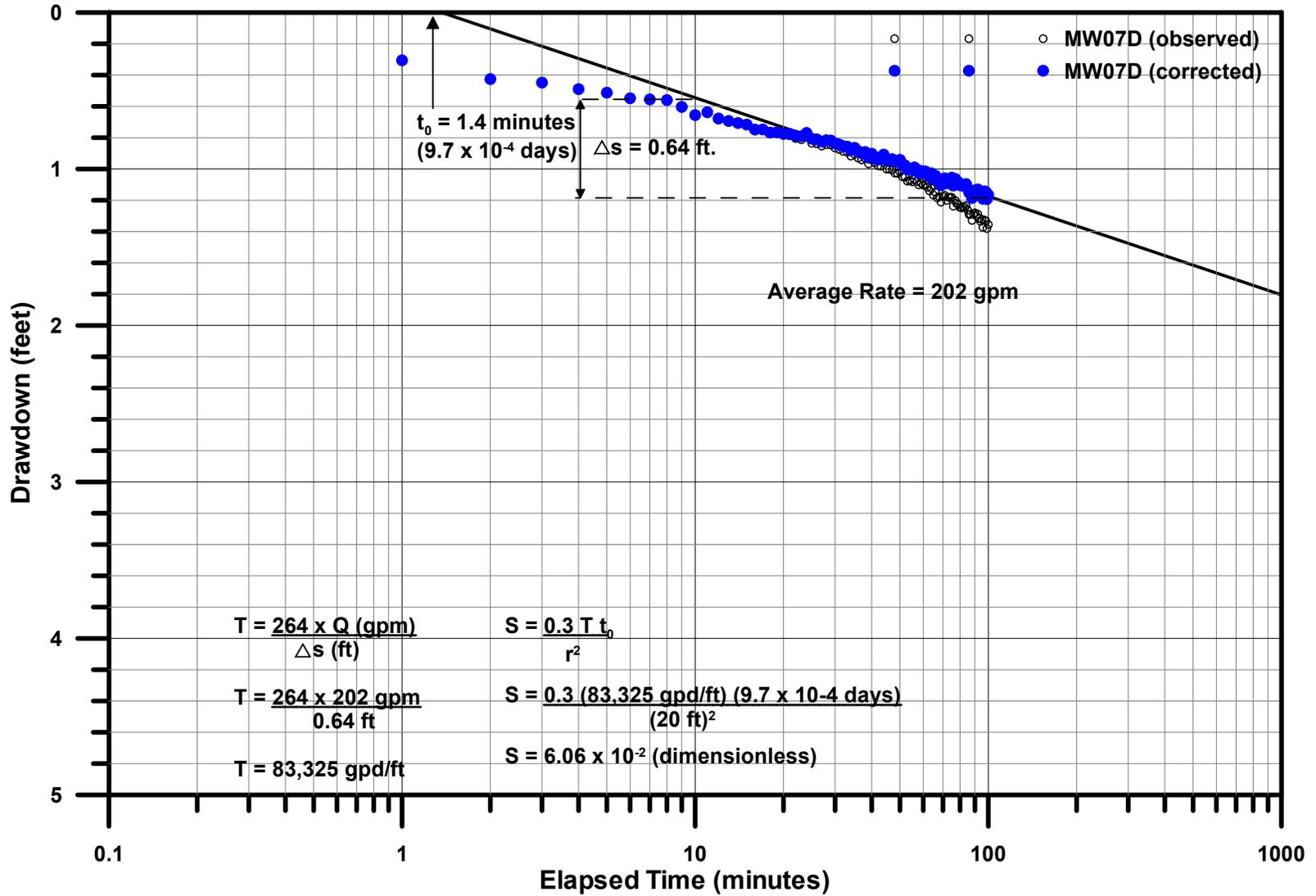


FIGURE B35. MCWP-MW03 PRE-INJECTION PUMPING TEST - MW07D DRAWDOWN DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

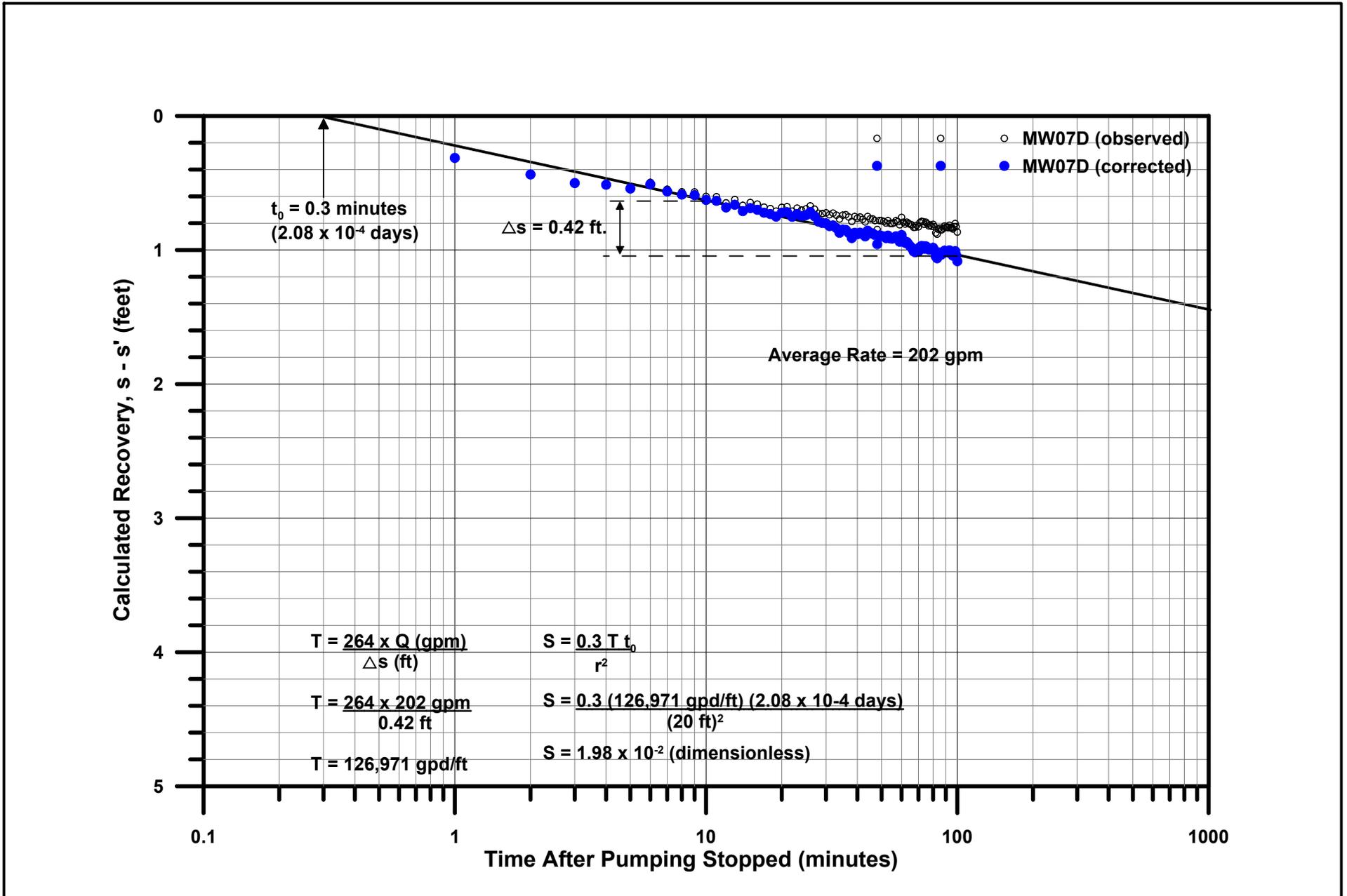


FIGURE B36. MCWP-MW03 PRE-INJECTION PUMPING TEST - MW07D RECOVERY DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

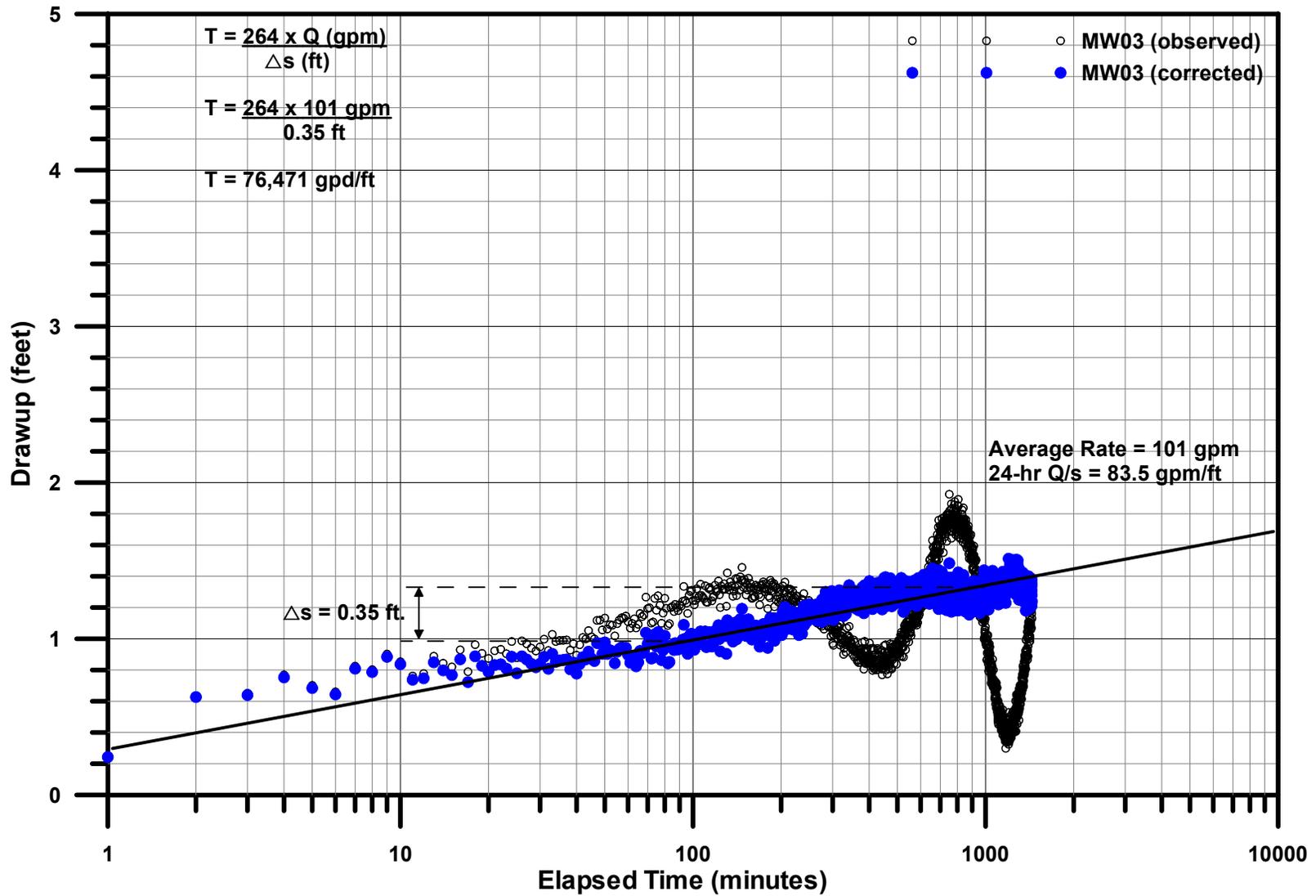


FIGURE B37. MCWP-MW03 24-HR INJECTION TEST - MW03 DRAWUP DATA
Malibu Groundwater Injection Feasibility Project - Phase 3
RMC Water and Environment / City of Malibu

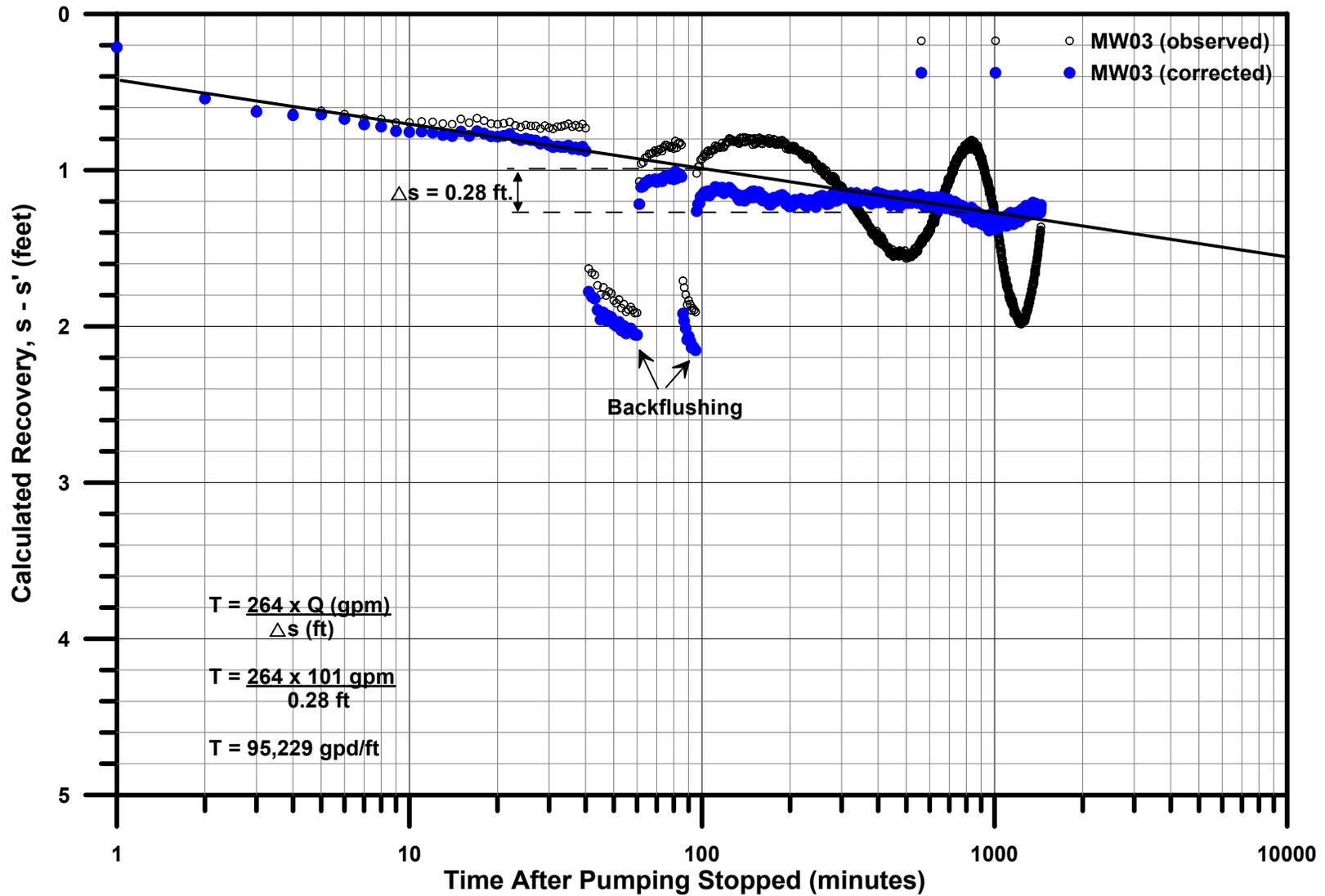


FIGURE B38. MCWP-MW03 24-HR INJECTION TEST - MW03 RECOVERY DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

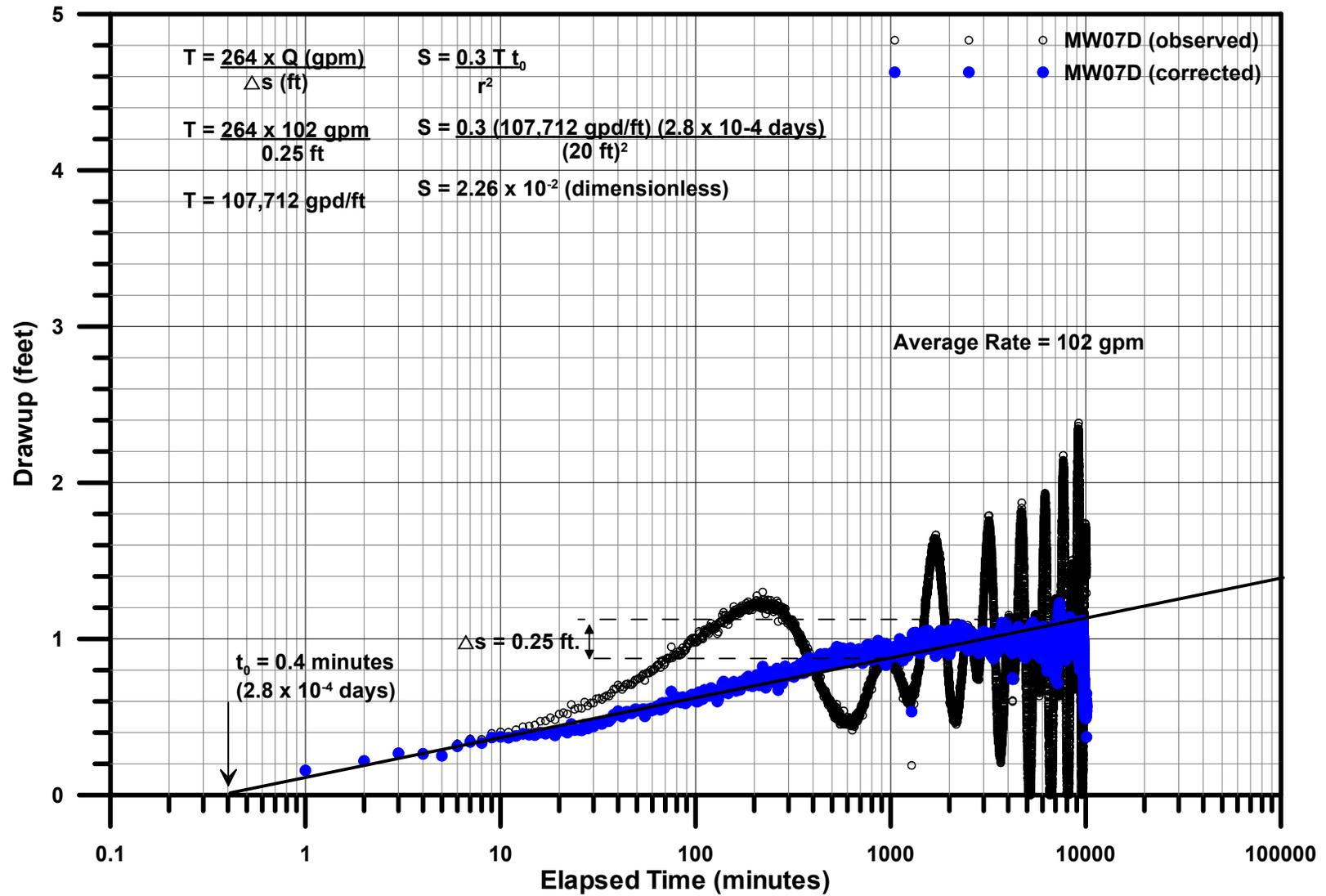


FIGURE B39. MCWP-MW03 24-HR INJECTION TEST - MW07D DRAWUP DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

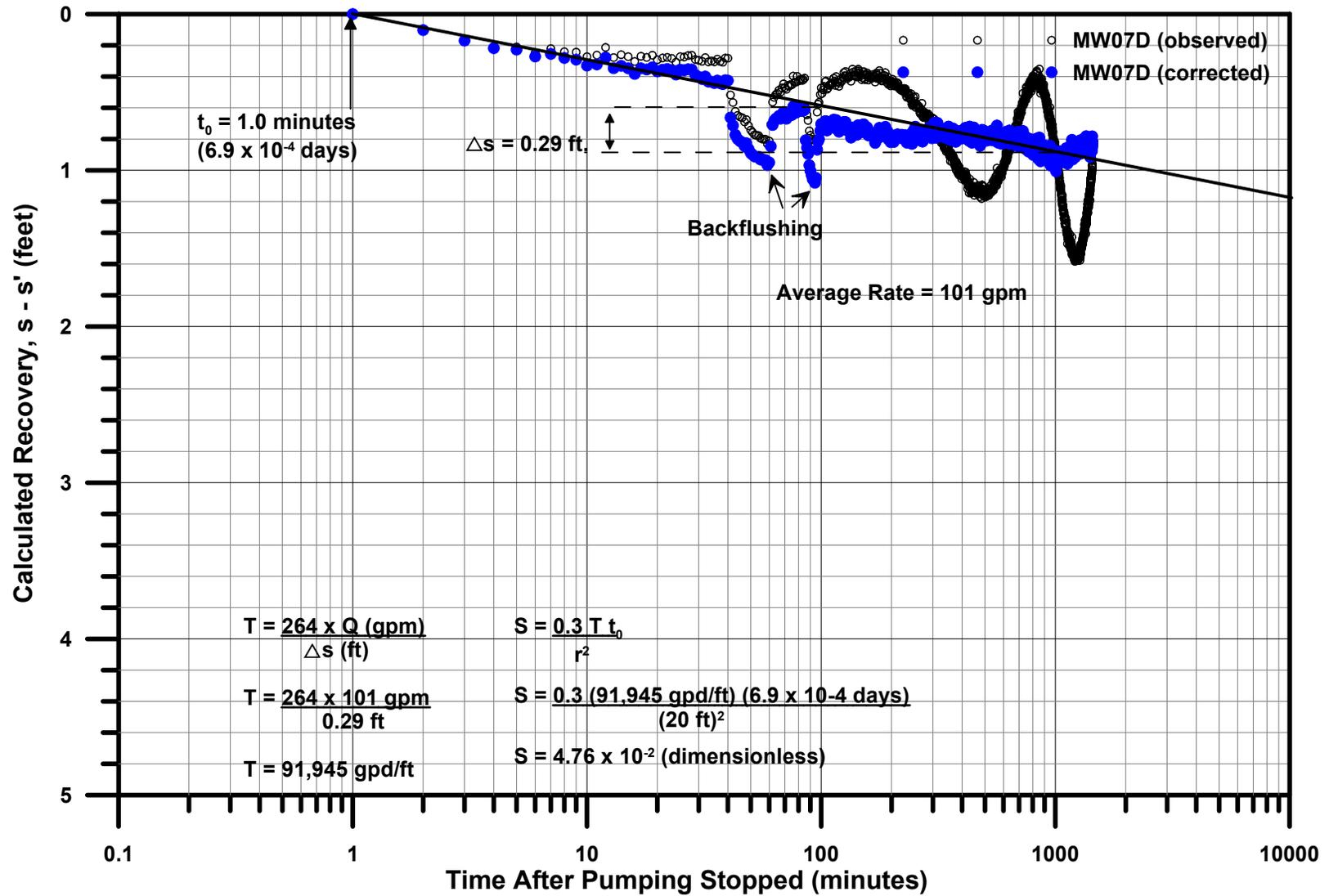


FIGURE B40. MCWP-MW03 24-HR INJECTION TEST - MW07D RECOVERY DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

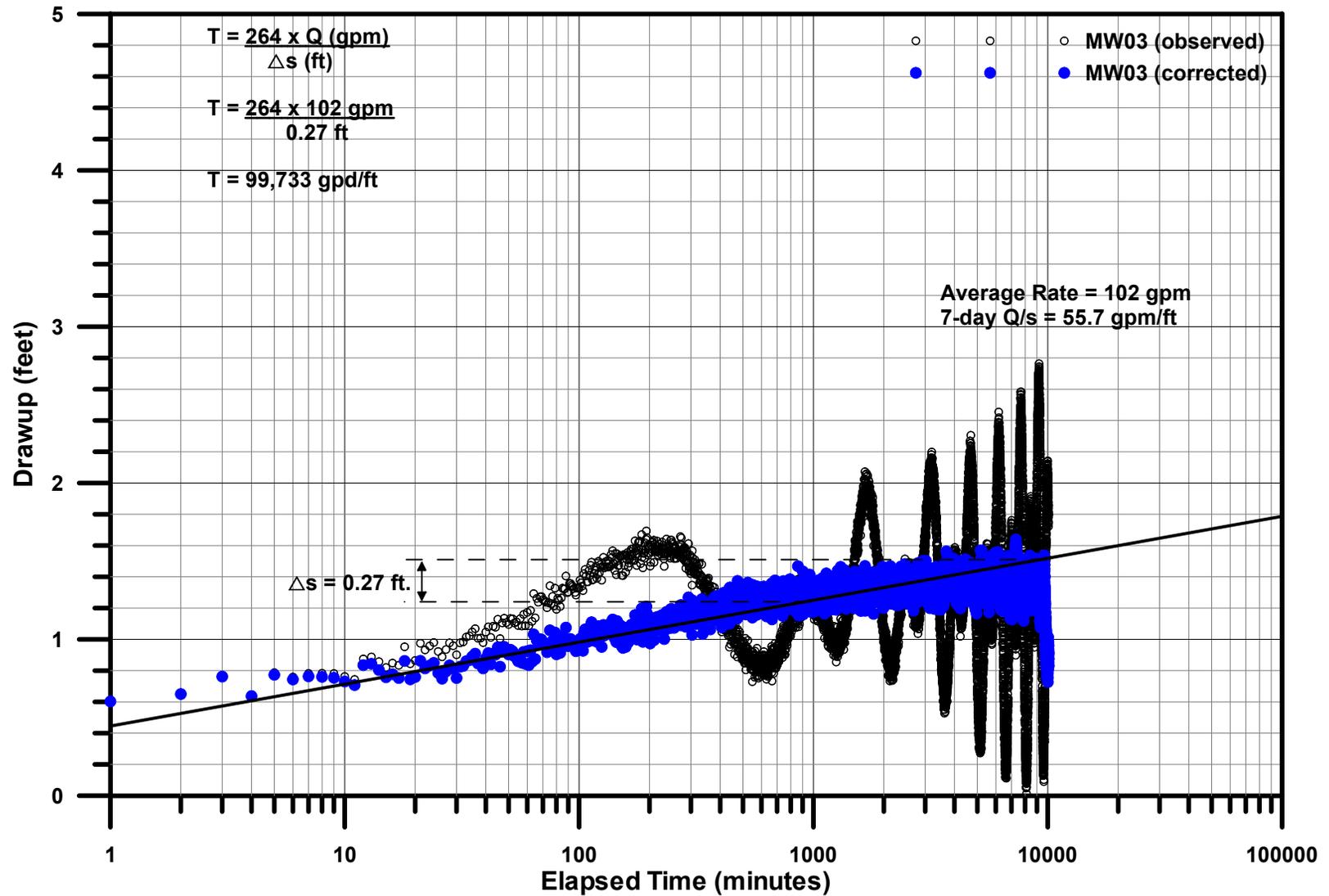


FIGURE B41. MCWP-MW03 7-DAY INJECTION TEST - MW03 DRAWUP DATA
Malibu Groundwater Injection Feasibility Project - Phase 3
RMC Water and Environment / City of Malibu

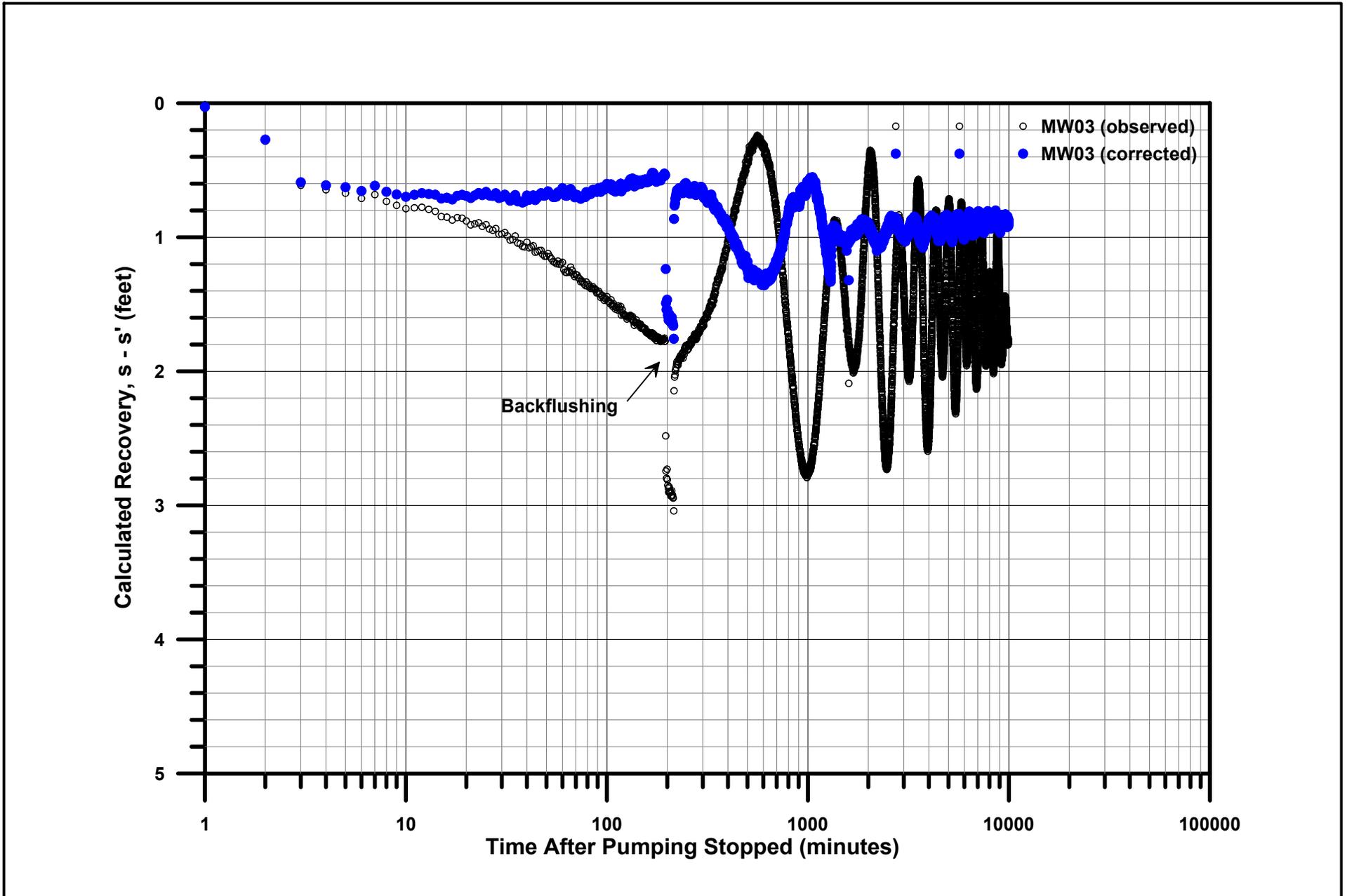


FIGURE B42. MCWP-MW03 7-DAY INJECTION TEST - MW03 RECOVERY DATA
Malibu Groundwater Injection Feasibility Project - Phase 3
RMC Water and Environment / City of Malibu

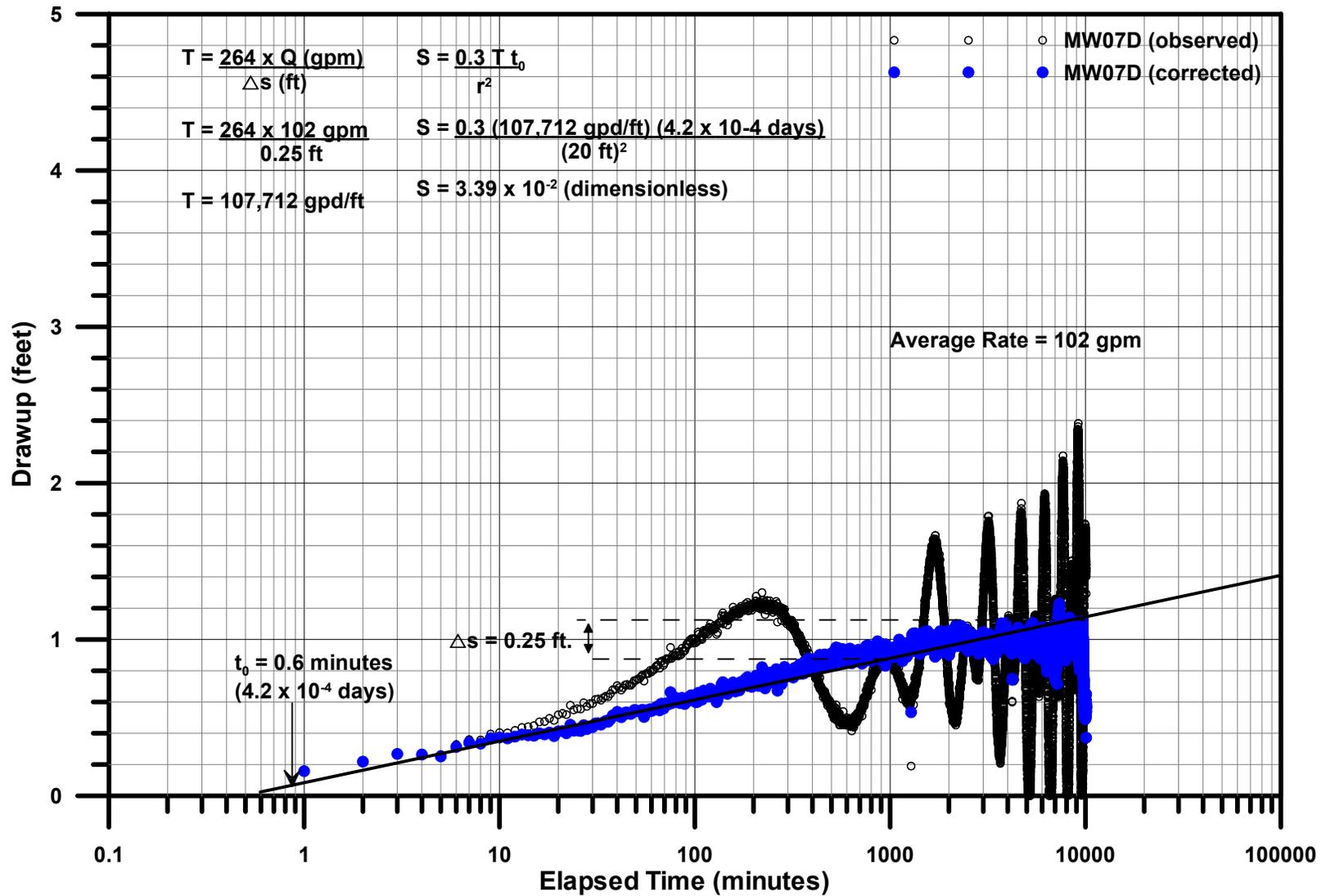


FIGURE B43. MCWP-MW03 7-DAY INJECTION TEST - MW07D DRAWUP DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

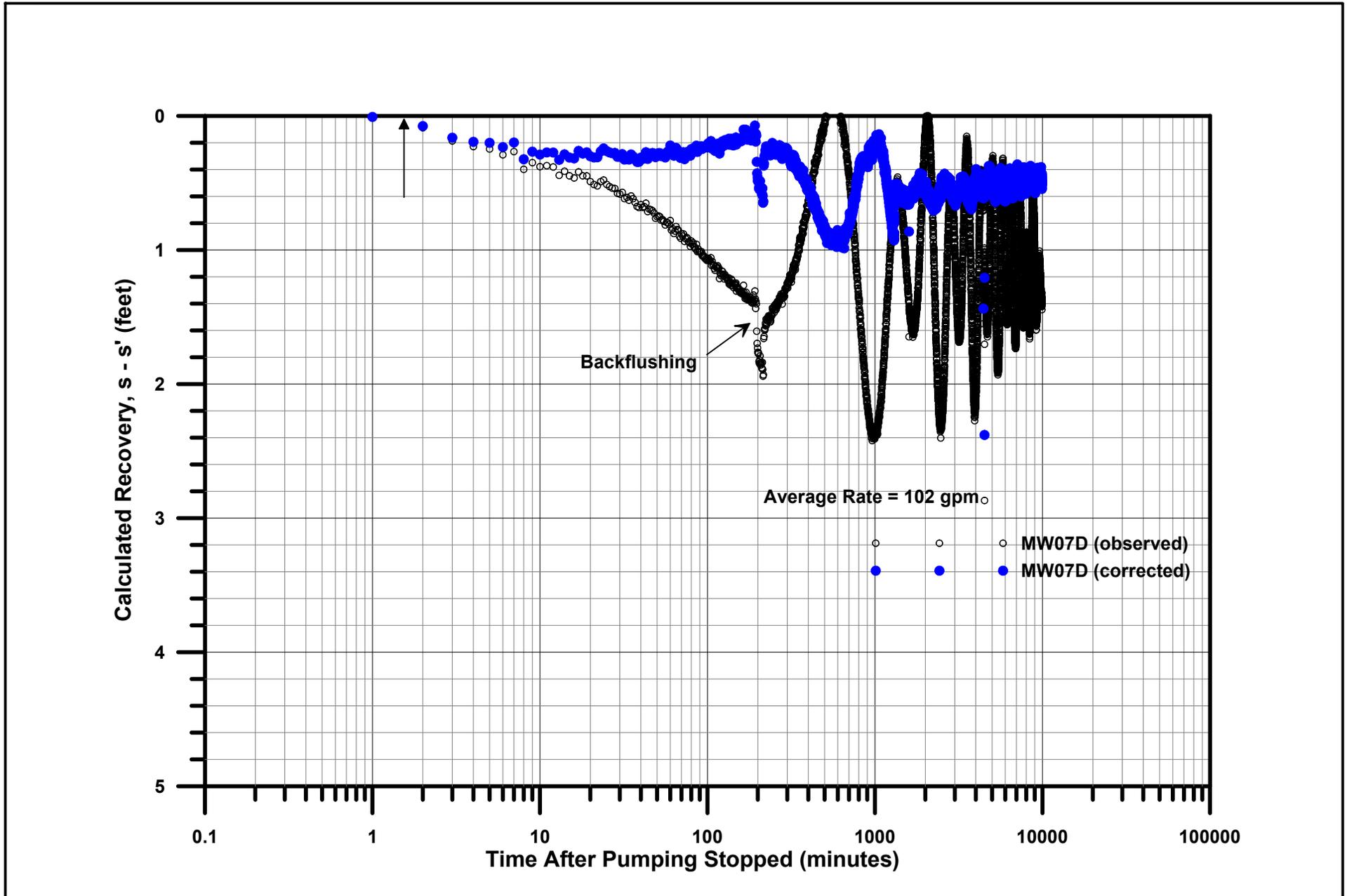


FIGURE B44. MCWP-MW03 7-DAY INJECTION TEST - MW07D RECOVERY DATA
Malibu Groundwater Injection Feasibility Project - Phase 3
RMC Water and Environment / City of Malibu

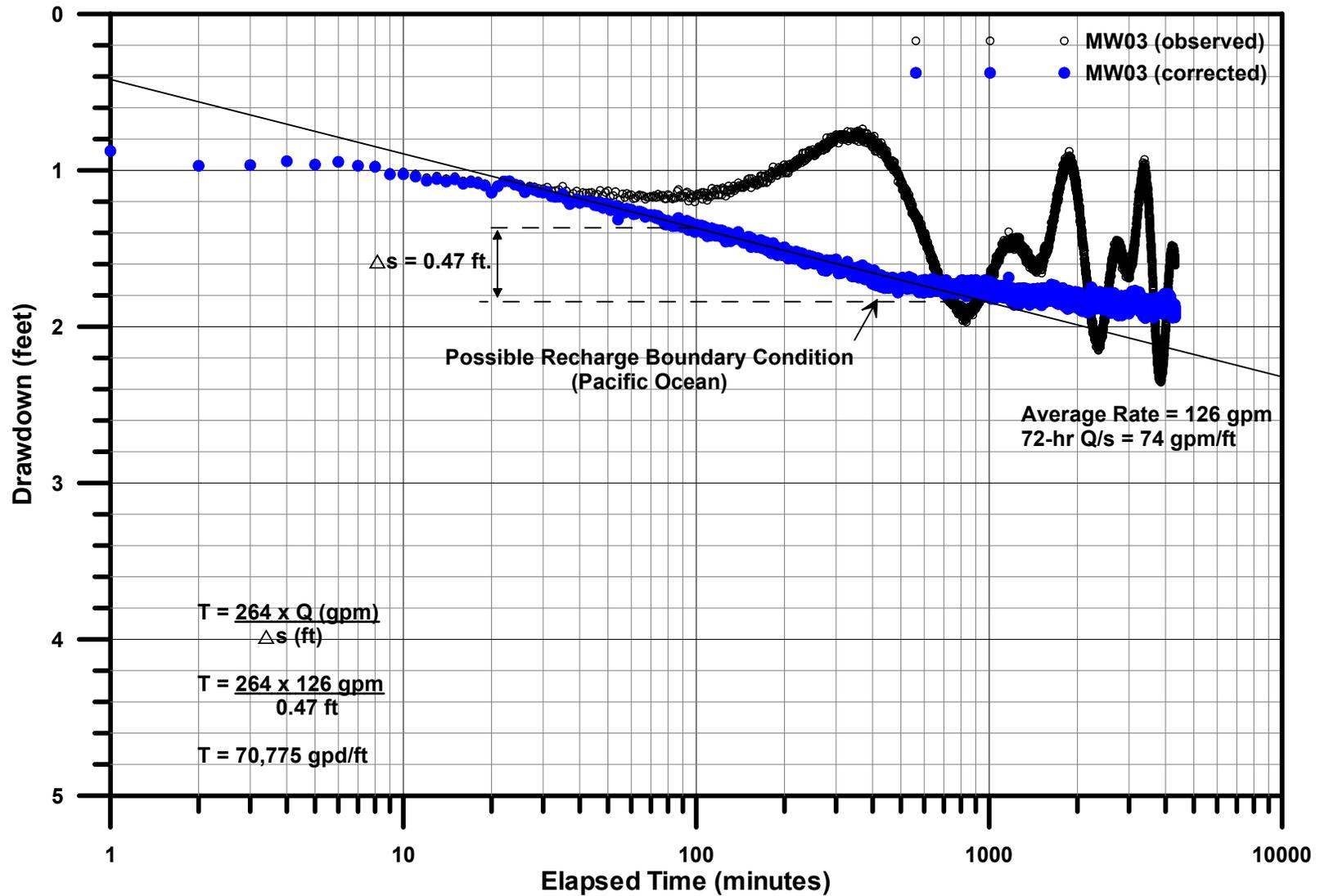


FIGURE B45. MCWP-MW03 72-HR PUMPING TEST - MW03 DRAWDOWN DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

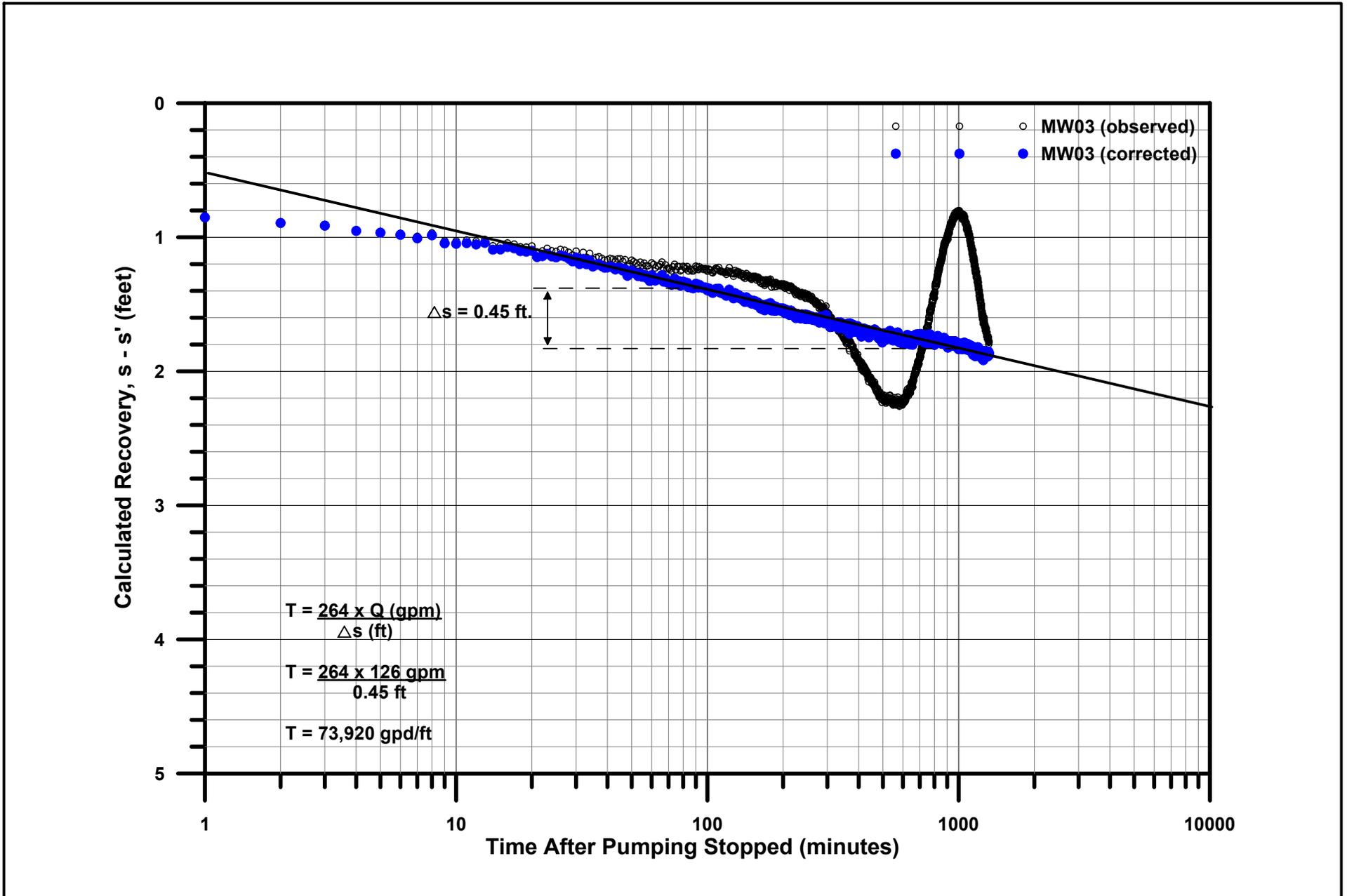


FIGURE B46. MCWP-MW03 72-HR PUMPING TEST - MW03 RECOVERY DATA
Malibu Groundwater Injection Feasibility Project - Phase 3
RMC Water and Environment / City of Malibu

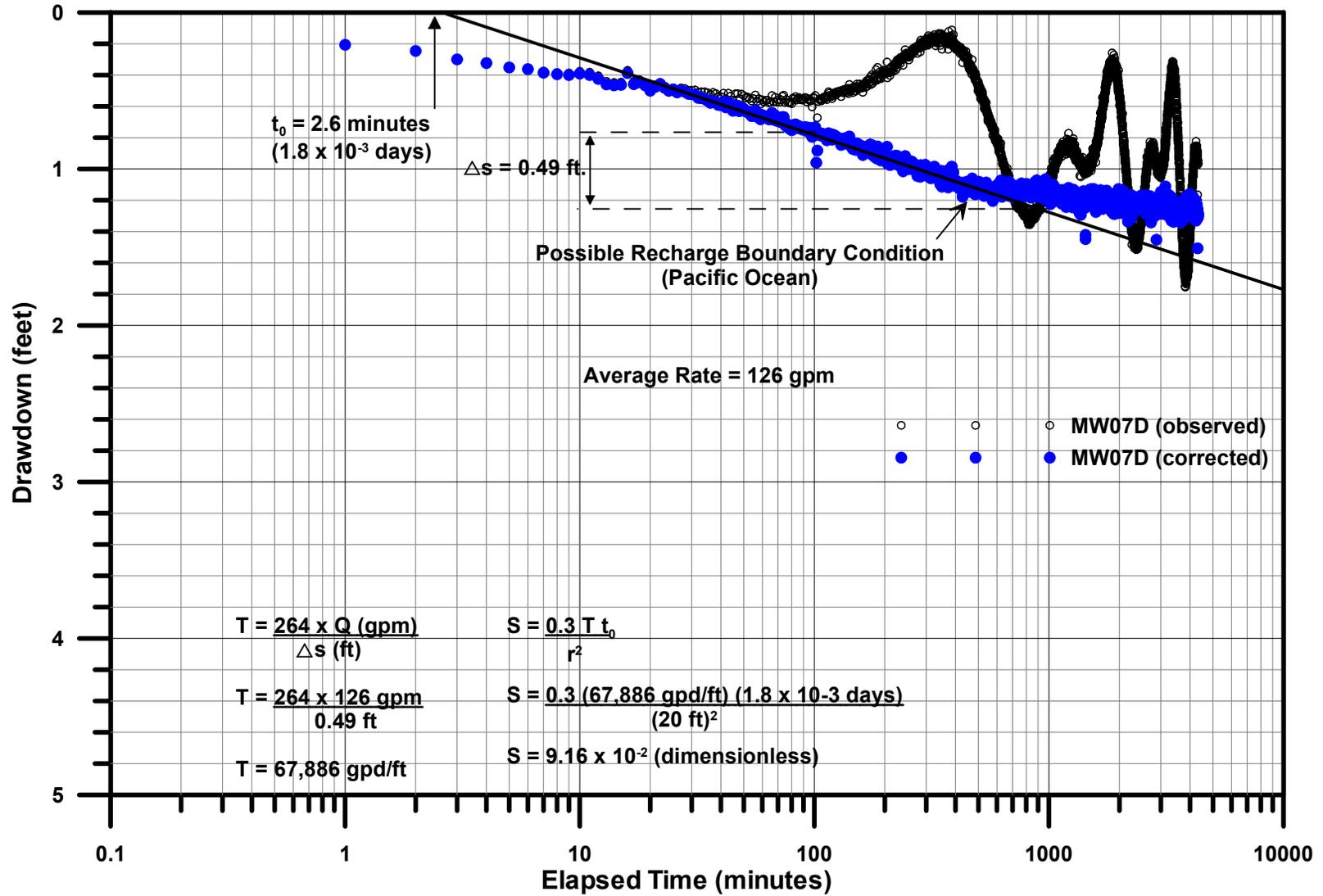


FIGURE B47. MCWP-MW03 72-HR PUMPING TEST - MW07D DRAWDOWN DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

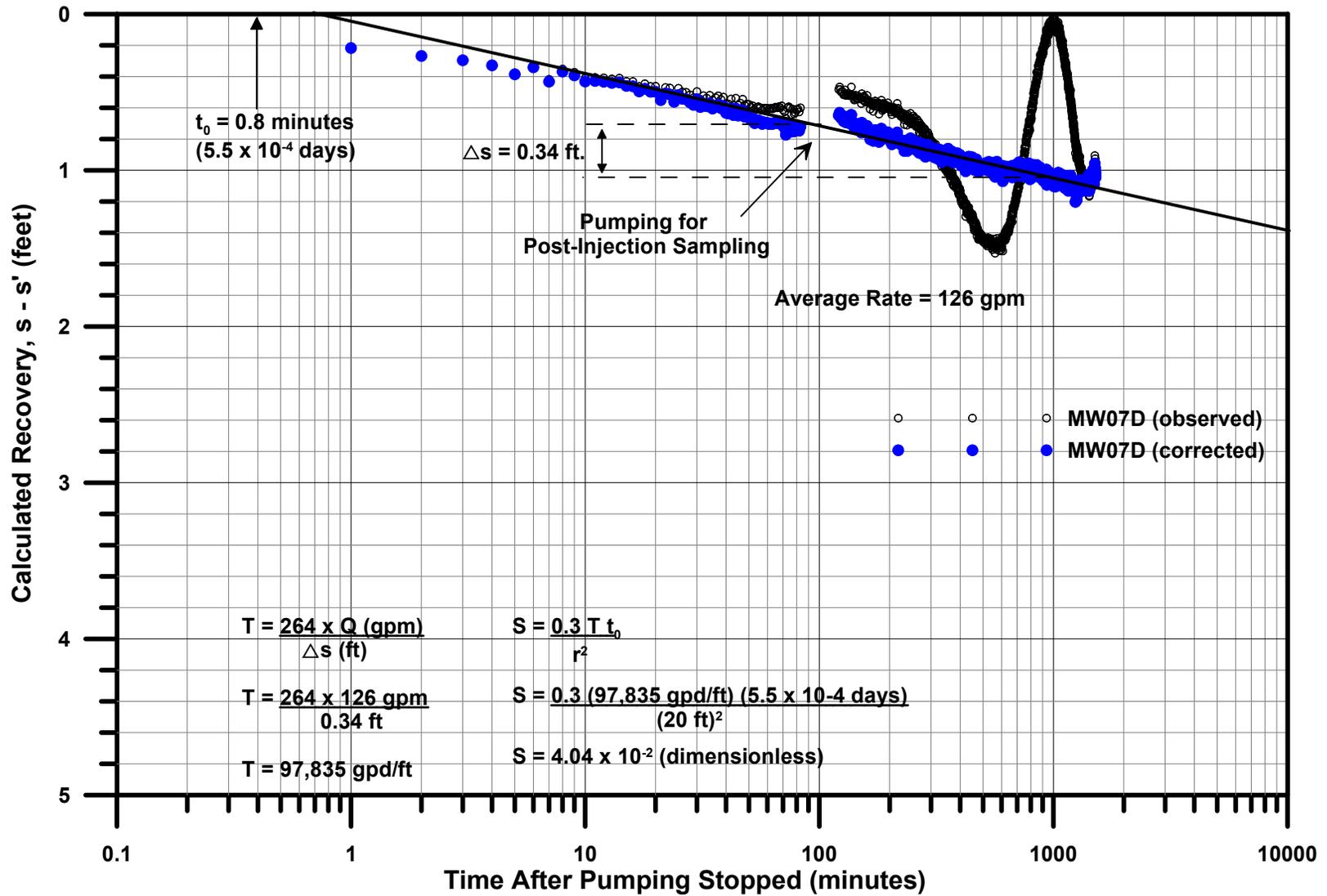


FIGURE B48. MCWP-MW03 72-HR PUMPING TEST - MW07D RECOVERY DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

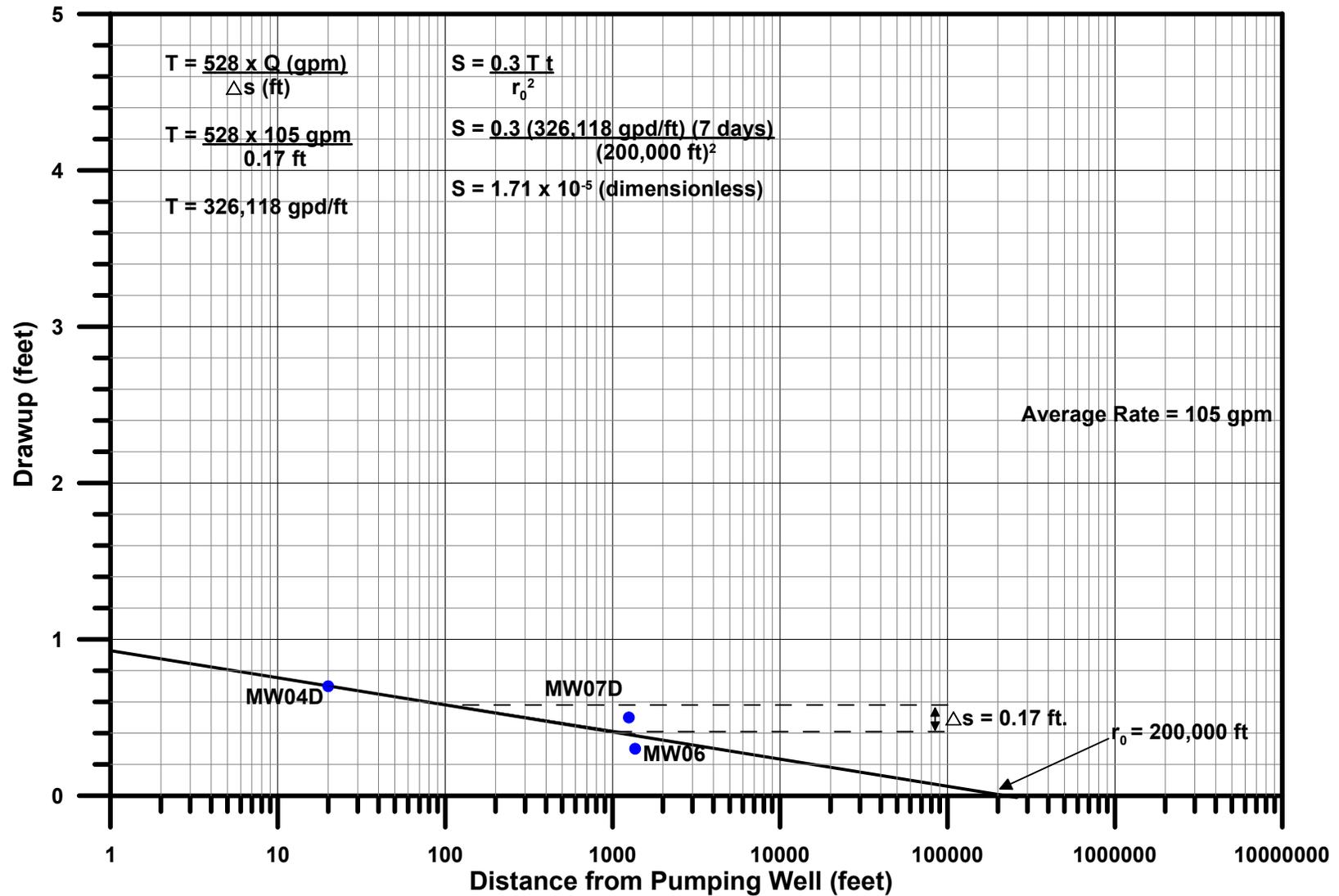


FIGURE B49. MCWP-MW01 7-DAY INJECTION TEST - DISTANCE VS. DRAWUP DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

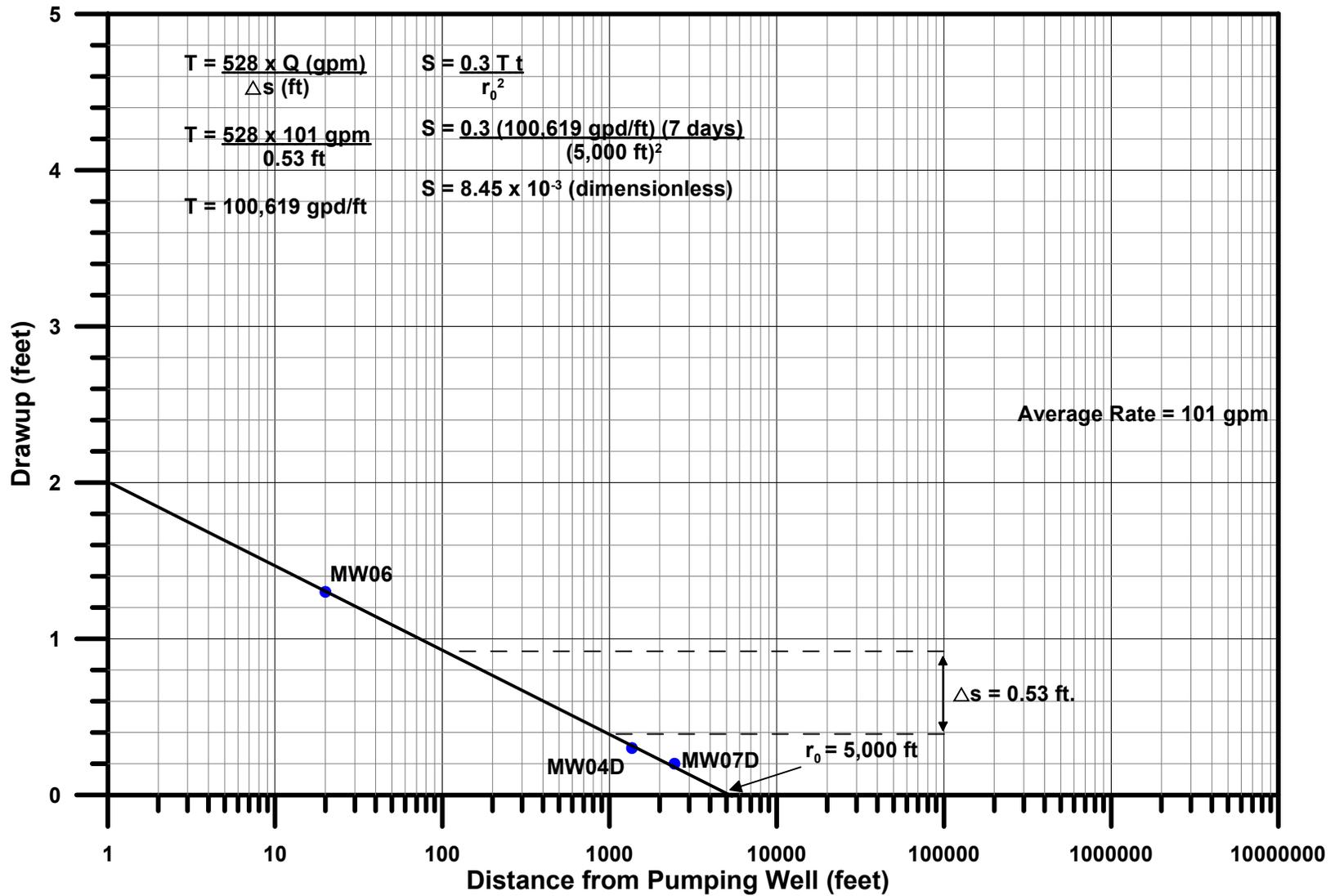


FIGURE B50. MCWP-MW02 7-DAY INJECTION TEST - DISTANCE VS. DRAWUP DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

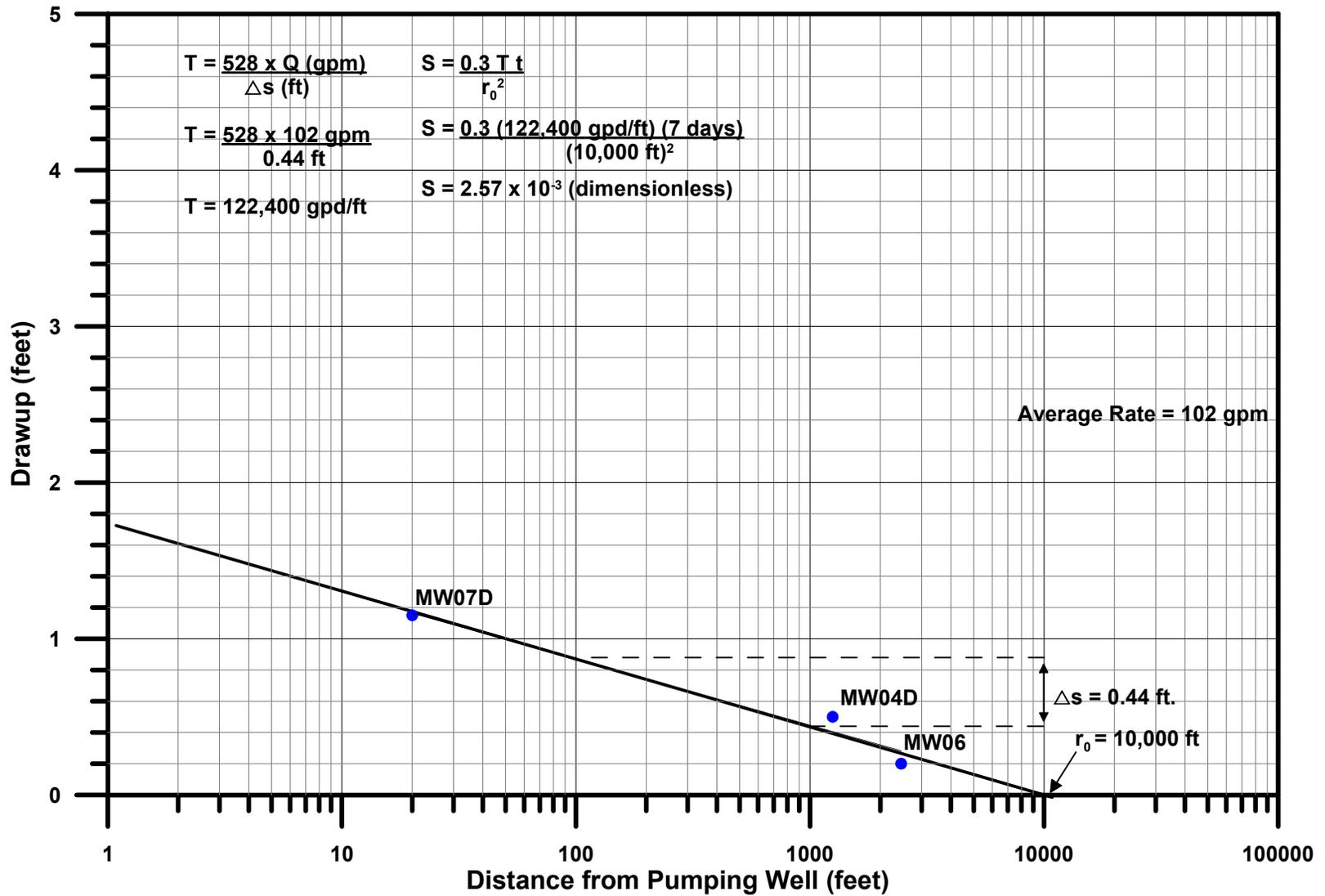


FIGURE B51. MCWP-MW03 7-DAY INJECTION TEST - DISTANCE VS. DRAWUP DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu

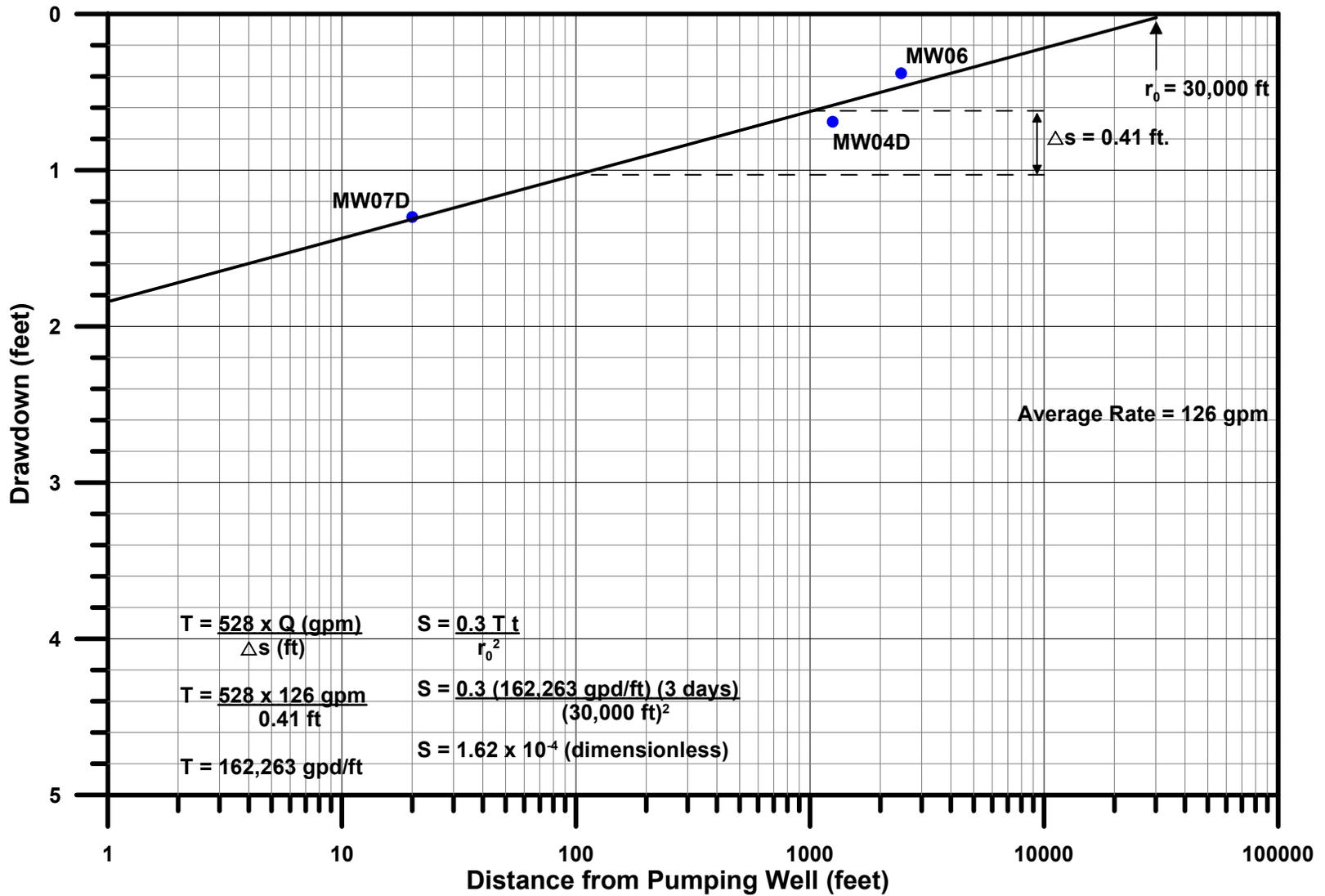


FIGURE B52. MCWP-MW03 72-HR PUMPING TEST - DISTANCE VS. DRAWDOWN DATA
 Malibu Groundwater Injection Feasibility Project - Phase 3
 RMC Water and Environment / City of Malibu



- Water-quality samples collected from the project test wells MCWP-MW01, -MW02, and -MW03 prior to injection testing (to represent the NGW composition);
- Water-quality samples of MBR-treated effluent from a local wastewater treatment plant (known as the Lumber Yard Wastewater Treatment Facility) to represent as a surrogate the future treated effluent from the CCWWFT.

FINDINGS

METHOD OF ANALYSIS

The water and soil analyses were input into USGS's well known and well-documented geochemical equilibrium modeling program PHREEQC (version 2.18) and the Lawrence Livermore National Laboratory equilibrium database (1-10-2010 version). The major steps in the evaluation of the process included the following:

1. Evaluation of the quality and soundness of the analytic data sets to validate the reasonableness and accuracy of the input data to the model.
2. Evaluation of the geochemical character and state of equilibrium of each of the component waters (NGW and surrogate injectate) to determine their natural condition before mixing.
3. Simulation of mixing and displacement of the injection waters upon introduction to the aquifer, and subsequent evaluation of the equilibrium state of the resulting mixes.

PROGRAM RESULTS

1 – Evaluation of Data

The analytic data sets were evaluated in order to validate the reasonableness and accuracy of the input data to the model; anion/cation balances, method detection limits, analysis protocol deviations, and general chemistry conformity were all verified before modeling. The results of our assessment of the data are summarized below:

- In general, the water quality data from the NGW samples were found to be acceptable for use in the modeling work. Minor discrepancies were noted in detection limits and reporting protocols; however, the data were usable without correction or modification.
- The water quality from the surrogate treated effluent sampling (the 'Lumber Yard' effluent) was found to be reasonable with the exception of the analyses for the aqueous nutrient species of nitrogen compounds (TKN, NH₃, T-N, and NO₃) and the phosphorous compounds (T-P and PO₄). These data were not only at odds with typical municipal treated waste effluent results, they were in disagreement with recent plant data collected over a full year of plant operations. Because these laboratory reported data were significantly different than the full year of results from the plant in 2012, it was determined that the 2012 historical dataset would be more appropriate for the modeling work.



- Anion/Cation balances for all water quality samples were reasonable and provided generally acceptable data for model input. There was a very slight outage of balance on MW-03, which is possibly explained by the discussion of MW-03 results below in Step 2 of the evaluation.
- The mineralogical analyses performed on the test boring samples were found to be well documented and conformed well with both typical values and internal QA/QC processes. There were no questionable results in the work.

2 – Evaluation of the Geochemical Character of Individual Components

Evaluation of the NGWs from the three test wells did not show any particularly problematic conditions. Specific highlights of the analyses and evaluation included the following:

- All three wells had redox values indicative of Fe(2+)/Fe(3+) coupled equilibrium, indicating that the ferrous/ferric transitional state was naturally present in the aquifer. This would be a likely result of the presence in excess iron in the geologic matrix. (It is also, however, the redox condition amenable to Iron Related Bacteria, a common and prolific subsurface bacteria that can clog wells with bioslime and accumulated biomass if sufficient nutrients are available to support biometabolism).
- The variability of electrical conductivity (EC) in the MCWP-MW03 samples indicates that water in this well is likely being influenced by tidal action. This finding is in practicality non-sequitur with respect to the modeling simulations, as the precipitation potential of compounds is not significantly influenced; however, it is an indication of hydraulic connectivity between the CCG aquifer and the Pacific Ocean.
- Saturation conditions (i.e. the mineral saturation, under-saturation, or oversaturation of the waters) were evaluated for all components. In general, all of the waters showed near-equilibrium saturation conditions (i.e., Saturation Index (SI) values between -1.0 and +1.0 with the exception of SI's for Gibbsite (Al(OH)₃), an Aluminum oxide compound). Because the model did not include the chelating effects of organic carbon compounds, the results should be considered overly conservative, and with these equilibrium values having been calculated for the native waters themselves, there is likely such a chelating effect taking place, or a slight metastability condition that precludes precipitation of Aluminum hydroxides. This SI condition was taken into account in the Step 3 mixing modeling.
- Other than noted above, there was no indication of scaling potential from iron, calcium, or silica related compounds.

3 – Simulation of Mixing and Displacement of the Injection Waters

Mixing and displacement of the injection waters upon introduction to the aquifer was simulated with the purpose of evaluating the equilibrium state of the resulting mixes. The results of our evaluation are presented below:



- Mixing of the waters was modeled using a variety of NGW/injectate ratios, with the water qualities taken from the lab analyses, and with the minor but realistic assumption that the injected recycled water will have a free Chlorine Residual of 1.0 mg/L and a measurable dissolved oxygen (DO) level (assumed at 0.45 mg/L) accounting for the passage through the proposed CCWTF.
- The NGW/injectate mixing ratios were also subjected to equalization with the mineral matrix of the CCG aquifer lab results.
- The mixing simulations used the baseline SI's of the natural conditions (i.e., those established in Step 2 above) as the practical threshold of oversaturation/precipitation of the mixture. This assumption is both common and realistic based on the unique conditions found in every aquifer that cannot be replicated in a single equilibrium database such as the LLNL compilation.
- The mixing model results show a slight oversaturation and precipitation potential for iron-related and aluminum-related oxides, although the modeled amounts of precipitation are relatively low for MCWP-MW01 and -MW02 (less than 1 mg/L). These values could be metastable and/or chelated by organic carbon enough to have no precipitation potential whatsoever. Field injection trials with representative recycled source water would confirm this potential.
- The precipitation potential for MW-03 is slightly higher than MW-01 and MW-02, however, it is still below 1 mg/L, and not considered problematic.

In summary, the modeling suggests that the potential for precipitation/scaling due to the injection of the proxy-simulated injection water is minimal, and at a theoretical maximum would be at such small levels to be non-problematic for ongoing operations.

BIOFOULING ISSUES

The potential for biofouling in injection wells is always present, as the presence of subsurface aquatic biota is ubiquitous in the environment, and in most cases, the injected water is different in some way from the native ground water. There are some basic elemental building blocks necessary for living organisms; these include the compounds of carbon, oxygen, nitrogen, and phosphorous (C, O, N, and P). The presence of these components, often referred to in environmental geochemistry as "nutrient compounds," provide the ability of subsurface biota to proliferate as long as the ratio of nutrients and the aqueous redox environment is suitable to allow metabolism of the food (nutrient) supply. It is typical in the aqueous subsurface environment for phosphorous to be the most "limiting" compound to unlimited biogrowth, as it is both essential to bioactivity and rare in the environment. The second most limiting compounds in subsurface bioactivity are nitrogen compounds. It is common to refer to these environments as "P-limited" or "N-limited", because the only issue that prevents unlimited biogrowth is the lack of these essential nutrient compounds. Most natural aquifers are P- and/or N-limited.

The evaluation of nutrient supply and supportive metabolism environment were evaluated for the proposed project, and the following findings were noted:



- The proposed injection water likely has adequate levels of N, P, and C to support ongoing biometabolism in the aquifer.
- Because of the method of direct injection via wells, biometabolism would be greatest near the well screens as this is the origin of the nutrient supply.
- The addition of the treated effluent alters the subsurface such that neither N nor P compounds will be limitations on food supply, thus allowing proliferation of an opportunistic biota.
- Based on the composition and ratios of nutrients in the injectate, the only means of controlling biofouling would be if the organic carbon present in the injectate was completely destroyed via oxidation or other means to render it unavailable for biometabolism. (The other method to control bioactivity not mentioned is to limit the P and N levels in the injectate via enhanced treatment processes at the CCWTF.)
- The equilibrium modeling results showing the Fe(2+)/Fe(3+) redox condition indicate that biofouling would likely be comprised of iron-related bacteria (predominantly) which, although non-pathogenic in nature, is a virulent genre of biofoulants characterized by a high biomass, slime-forming nature that is particularly problematic with respect to the plugging of wells.
- The modeling indicates that based on nutrient supply, the most problematic periods of operation would be when the wells are dominated by the injection water, i.e. fouling would be greatest when injection operations were occurring.

We hope the above discussion assists in the understanding of the attached geochemical analysis report. Please give let us know if you have any questions or require additional information.

ATTACHMENT A – GEOCHEMICAL ASSESSMENT REPORT



ecoengineers Pty Ltd

9 Sunninghill Circuit
Mount Ousley NSW
Australia 2519

T: 61 2 4227 4174
F: 61 2 4227 5154
www.ecoengineers.com
ABN 74 078 666 510

25 November 2013

Robert Marks
Principal Hydrogeologist
Pueblo Water Resources Inc.
4478 Market Street, Suite 705
VENTURA CA 93003

Basic Geochemical Review and PHREEQC Modeling to Provide Initial Assessments of Issues Associated with the Proposed Malibu Aquifer Injection Treated Effluent Sub-surface Disposal Scheme (Malibu Centralized Waste Water Project).

Dear Robert

Thank you for engaging Ecoengineers Pty Pty Ltd ('Ecoengineers') to conduct an initial geochemical assessment of the principal issues associated with this proposed sub-surface treated wastewater disposal scheme based on our professional experience and underpinned by PHREEQC model-based assessment of core chemistries, the identification of mineral equilibrium saturation levels and their attendant influence on potential precipitation and scaling effects under a treated wastewater injection/storage scenario as well as some preliminary assessment of the potential for well biofouling during injection.

Background Information

It is important to note that our assessment was made using verbal advices from Pueblo Water Resources ('PWR') and the following data deliverables supplied to us:

1. Field water quality monitoring data for an approximate proxy of the likely Injectate water (being a chlorine-treated effluent), identified as "Lumberyard" and three injection wells designated MW-01, MW-02 and MW-03 being, temperature, pH, Specific Conductance (= Electrical Conductivity; EC; corrected to 25 C), a field Redox Potential denoted 'ORP' being a potential relative to a Ag/AgCl reference electrode with 4.0 M KCl filling solution (electrolyte) at the water temperature, Chlorine Residual (mg/L as Cl₂) and Dissolved Oxygen (DO; mg/L). These data were obtained on 10 September, 6 August, 29 August and 8 July 2013 respectively (only).
2. Detailed, individual laboratory analysis reports on the Lumber Yard waste water treatment plant water and the groundwaters sampled from the three wells MW-01, MW-02 and MW-03 on the above dates (only) issued by the Eurofins Eaton Analytical (Monrovia, CA) laboratory. It is noted that a wide suite of parameters were reported-on by this laboratory, including both filterable and total (unfiltered) values for numerous parameters as well as Disinfection By-Products (DBPs).
3. A copy of a master spreadsheet from the Lumber Yard Plant containing the records of chemical monitoring of the Plant Effluent during 2012.
4. A copy of the report: RMC Water and Environment (2012) Technical Memorandum: Conceptual Groundwater Injection Plan. June 2012 (prepared by: Steve Clary, RMC

Water and Environment, Dan Wendell, Groundwater Dynamics, Richard Laton, Earth Forensics and Daniel J. Morrisey, McDonald Morissey Associates, Inc.)

5. Two bacterial assessment reports #19579 and #19615 by Water Systems Engineering Inc., of Ottawa, Kansas, being respectively one for a sample from proposed injection well MW-01 sampled on 6 August 2013 and one for a sample of the Lumber Yard Plant Effluent taken on 10 September
6. Detailed mineralogical analysis reports for grab sample aquifer lithological material recovered previously during the drilling of each of these three wells in February 2012 issued by Mineralogy, Inc. of Tulsa, Oklahoma. It is noted these reports included XRD, XRF, and Cation Exchange Capacity data and also detailed lithological descriptions and classification information. The latter described the aquifer materials as unconsolidated and disaggregated feldspathic, litharenitic sands. They also included references to the common presence of ironstone and Fe oxides possibly representing altered and recrystallized volcanic rock fragments at all three locations. It is notable from the descriptions of all three samples of lithic material recovered during drilling that they were all devoid of authigenic carbonate or sulfate overgrowths, intergranular cements or fracture infill materials, nor were there visible signs of siliceous e.g. chalcedony overgrowth or infill. Useful estimates of the ranges of void porosity were also given, albeit qualified by a potential for clay migration and/or swelling effects associated with the dominant montmorillonite clay – which XRD showed was typically present at around 13 – 17% by weight.

Assessment

In making our assessment we first critically reviewed all field and laboratory data in accord with best practice, especially in respect of data quality.

Laboratory Data Review

We conducted a comprehensive review of the 7 water quality reports from the Eurofins Eaton Analytical Monrovia laboratory. We found these reports to be of a generally adequate quality but there were some significant issues we identified for which an explanation could not be found, as follows:

1. The laboratory reports for the Lumber Yard effluent and for wells MW-02 and MW-03 were split into two sets, being one for the filtered samples indicating essentially the true solution concentrations and one for the unfiltered samples indicating the included colloidal material. However in the case of well MW-01 there was only one report which included the reporting of both filtered and unfiltered data, often on the same page. Consecutive pages in that report contained mixtures of filtered and unfiltered data which could lead to confusion unless very carefully read.
2. There were inexplicable shifts in Method Detection Limits (MDL) and Method Resolution Limits (MRL), particularly in the MW-01 report. For example, the Total Filtered Aluminum MDL and MRL (by ICP method) were quoted as 0.23 and 0.50 mg/L respectively versus ranges of 0.046 - 0.12 and 0.10 – 0.25 (also by ICP) in all other reports. The explanation given was coded D1 - Sample required dilution due to matrix. Such an explanation is at odds with the fact that all other waters sampled had comparable or sometimes significantly higher salinity e.g. the MW-03 sample. In addition, the NO₃-N (by EPA 300.0 method) MRL was quoted as 0.5 mg/L for the MW-01 water report whereas it was given as 0.25 for NO₂-N in the same report and also typically given as lying in the range 0.12 - 0.13 mg/L for all the other samples (for the same method).
3. Most importantly, the single laboratory report for the Lumber Yard Effluent reported, for the nutrients; (nitrate nitrogen) NO₃-N = 0 mg/L, (nitrite nitrogen) NO₂-N = 0 mg/L, (Total Kjeldahl Nitrogen) TKN = 0.66 mg/L, (ammonia nitrogen) NH₃-N = 0.019 mg/L, (total nitrogen) TN = 0.68 mg/L, (phosphate phosphorus) PO₄-P = 1.0

mg/L and (total phosphorus) TP = 0.98 mg/L. These data compare most unfavourably with the data found in the internal Plant master spread sheet for the entire year of 2012 supplied by PWR which shows the following mean values for these parameters \pm one standard deviation with the total number of measurements (n) which led to those values; NO₃-N = 0.64 \pm 0.07 (n = 52), NO₂-N = 0 (n = 52), TKN = 0.35 \pm 0.05 (n = 52), NH₃-N = 0.33 \pm 0.05 mg/L (n = 52), TN = 0.99 \pm 0.08 mg/L and TP = 0.51 \pm 0.16 mg/L (n = 12). The comparison suggests that *either* the Eurofins laboratory has analytical problems for the NO₃-N and TKN methods or, *alternatively* there were plant operations or sampling issues applying with the sample taken on 10 September 2013.

We also conducted a comprehensive review of the extensive mineralogical report by Mineralogy Inc., of Tulsa. We found that report to be a model of clarity and careful presentation and we could find no significant quality issues with it.

We also reviewed the two small reports bacterial assessment reports by Water Systems Engineering ('WSE') and could find no significant quality issues with them.

It is noted that basic chemical parameters (pH, TDS, Electrical Conductivity, Oxidation Reduction Potential (ORP) chlorine (unusually expressed as Cl not Cl₂, and Iron (resuspended) were also reported by WSE.

Interestingly, these (WSE) chemical parameters seem to have been measured upon receipt at the Water Systems Engineering laboratory as they differ significantly from e.g. the field data reported by PWR (see below). We have not been briefed on whether best practice protocols such as chilling, collection with zero headspace etc., transportation chilled etc., applied to these samples.

Field Data Review

We tabulate below in **Table 1** the field data as supplied by yourself but correcting the observed field redox potentials to an Eh (true ORP) relative to the standard hydrogen electrode (SHE) at the observed temperature. The ECs are reported normalized to 25 C as is usual. NA = data Not Available and ND = Not Detected.

Table 1: Field Water Quality Parameters

Site ID	Date	pH	EC (μ S/cm) (25 C)	Temp. C	Eh (mV)	Cl ₂ (mg/L)	DO (mg/L)
Lumber Yard Effluent	9/10/13	7.6	1373	28.4	+144 (WSE +186)	0.02 (WSE 0.015)	4.9
MW-01	8/6/13	7.3	2070	20.5	+119 (WSE +213)	0.00 (WSE ND)	0.0
MW-02	8/29/13	7.6	2100	21.2	+18	0.00	0.1
MW-03	7/8/13	7.3	2560	22.3	+231	NA	NA

Initially, we modeled the geochemistry of these four waters using USGS PHREEQC version 2.18 and the USGS default database (phreeqc.dat) dated 1 October 2010 and subsequently where required the Lawrence Livermore National Laboratory database (llnl.dat) dated 9 February 2010 version recently distributed with PHREEQC version 3 which is the most recent, most comprehensive and up to date database.

The following **Table 2** compares our model-predicted ECs (@ 25 C) with the PWR field measured values and the WSE laboratory values.

Table 2: Model-estimated ECs versus Field ECs

Site ID	Date	PWR Field EC (µS/cm) (25 C)	WSE Lab EC (µS/cm) (25 C)	PHREEQC model-estimated EC (µS/cm) (25 C)
Lumber Yard Effluent	9/10/13	1373	1425	1402
MW-01	8/6/13	2070	1860	2225
MW-02	8/29/13	2100	NA	2221
MW-03	7/8/13	2560	NA	3343

All field measured EC values agreed well with the PHREEQC estimated values with the exception of well MW-03. Matching of the PHREEQC estimated EC with the observed EC would have required a reduction in NaCl concentration of at least 60 percent (from 650 mg/L to at least 260 mg/L).

Upon discussions with yourself you advised that a previous 14-hr pumping test performed on well MW-03 in 2011 had indicated EC values during that test ranging between 3040 and 3760 uS/cm, averaging 3650 uS/cm – a value very similar to what our PHREEQC model suggests. Interestingly, the EC during that pump test had started out at the low end of the range and steadily increased for about 6 hours, after which it stabilized at around 3700 uS for about 7 hours, but then began to decline again during the last hour before the test was shut down.

This suggested a possible tidal influence on the salinity in well MW-03 (i.e., the seawater/freshwater interface could be rising and falling as the tide rises and falls twice per day). Unfortunately, what was planned to be a 72-hour test was shut down after only 14 hours due to logistical and/or budgetary constraints.

Nevertheless, these observations provides a plausible explanation for why there is a discrepancy between the field EC measured (at 12:30 hours on 7/8/13) and that predicted by PHREEQC for the actually water chemistry as reported by the Eurofins Eaton Analytical Monrovia laboratory (for all significant cations and anions).

These observations (in July 2013 and in 2011) do suggest that the well perforated intervals of at least well MW-03 falls somewhat within the sphere of influence of the local saline/freshwater interface and this then also raises the relevant question as to whether this phenomenon would also affect wells MW-01 and MW-02 (or indeed any others which may be installed for this Project).

As Eh is so important to geochemistry, particularly when mixing waters of different type containing redox sensitive elements such as iron (Fe), manganese (Mn), ammonia nitrogen (NH₃-N), nitrite/nitrate nitrogen NO_x-N), dissolved organic nitrogen (Org-N), arsenic (As), selenium (Se), uranium (U) etc., as in this Project, we also established PHREEQC model redox potentials for the most common redox couples which may apply in these waters especially if bacterial action is occurring, and/or reduced carbon such as methane etc., DO and/or Cl₂ are present. These are the:

- ferrous/ferric couple i.e. Fe(+2)/Fe(+3);
- ammonia/nitrate couple i.e. N(-3)/N(+5); :
- dissolved oxygen/water couple i.e. O(-2)/O(0) in the case of the Lumber Yard effluent;
- chloride/hypochlorite (aqueous chlorine) couple i.e. Cl(-1)/Cl(+1)

These model-predicted potentials were compared with the measured Ehs to determine which couple was likely to be dominating the observed Eh (redox status) of the water in reality. In the case of the ferrous/ferric couple i.e. Fe(+2)/Fe(+3) we assumed that the filterable Fe was all Fe(+2) and that the insoluble Fe as indicated by the difference between the filtered and total analyses reported by Eurofins was all colloidal ferric hydroxide Fe(OH)₃ i.e. in the Fe(+3) oxidation state.

Experience shows this is usually a reasonable approximation which allows determination of the dominant redox couple applying. In some cases; if a parameter concentration was quoted in the lab report as less than the Method Detection Limit (MDL) we assumed as usual that the parameter was present at a concentration of half of the MDL.

The following **Table 3** shows the proximity of the redox couple closest to the observed Eh. NA = Not Applicable where the groundwaters have of course not been subject to chlorination.

The outcomes were predictable and plausible for all waters as it is well known that the reduction of sulfate occurs in the Eh region – 200 to +100 mV, the (abiotic or biotic) reduction of Fe occurs in the region +180 to +400 mV, the reduction of Mn occurs in the region +220 to +500 mV and the (biotic) reduction of nitrate/nitrite in the region +300 to +600 mV.

Table 3: Observed Field Eh versus Model-Estimated Redox Couples

Site ID	Observed Field Eh (mV) by PWR	Observed lab. Eh (mV) by WSE lab.	Model-predicted Fe(+2)/Fe(+3) couple potential (mV)	Model-predicted N(-3)/N(+5) couple potential (mV)	Model-predicted O(-2)/O(0) couple potential (mV)	Model-predicted Cl(-1)/Cl(+10) potential (mV)
Lumber Yard Effluent	+144	+186	+124	+316	+740	+1196
MW-01	+119	+213	+256	+370	NA	NA
MW-02	+18	NA	+231	+325	+743	NA
MW-03	+231	NA	+225	+340	NA	NA

More specifically, this exercise showed that; on this occasion the very low Chlorine Residual field measurement for the Lumber Yard water is probably in error and there was in reality no residual chlorine present on the water at the time of monitoring, resulting in the Eh being dictated by the common natural Fe(+2)/Fe(+3) couple.

The Effluent field Eh value of +144 mV was validated by the similar WSE lab value of +186 mV and is just not compatible with the presence of a strong oxidant such as chlorine (or hypochlorite). It is also theoretically well below the redox potential which might be imposed by the relatively high DO value of 4.9 mg/L (which implies a O(-2)/O(0) couple redox potential of around 750 mV) but this latter value might simply be a function of slow oxidation kinetics with a chemically complex dissolved organic carbon (DOC; which was quite high at 6.1 mg/L) and the absence of reactive reduced carbon species such as low MW organic acids etc.

The outcomes were predictable and uniformly the same for all the native groundwaters (NGWs) in that the observed Ehs were probably all largely dictated by the common natural Fe(+2)/Fe(+3) couple and this is their likely usual state in the absence of injection of another water containing strong oxidants or reductants. This finding accords well with the mineralogical examination by Mineralogy, Inc., which indicated the common presence of

ironstone and Fe oxides possibly representing altered and recrystallized volcanic rock fragments at all three locations, indicating an ample supply of oxidized ferric material.

PHREEQC Modeling Outcomes and their Interpretation

Initially we modeled these actual waters individually to better understand their salinities, the analytical quality of their cation/anion balances and the salient features of their overall actual geochemistry. Please note that in the following text we sometimes refer to the waters sampled from wells MW-01, MW-02 and MW-03 at being NGWs (Natural Ground waters) as opposed to the 'Injectate', which refers to the treated Lumber Yard plant effluent or a simulated future proxy Injectate comprised of a treated waste water based on the observed Lumber Yard Effluent chemistry but modified, as advised by you to probably have a Chlorine Residual of 1.0 mg/L (as Cl₂) and a DO of say around 0.45 mg/L as O₂.

The actual PHREEQC geochemical input files (.phrq extension) and output files (.out extension) of the as-sampled Lumber Yard Effluent and of the three NGWs are appended to this report. These output files were obtained by modeling using the lnl.dat database. They may be inspected with any text file viewer such as Notepad or Wordpad. The following **Table 4** lists the calculated cation/anion balances and the Saturation Indices (SIs) of the most common scaling minerals i.e. Barite (barium sulfate), Calcite (calcium carbonate), Chalcedony (Opaline silica), Gibbsite (aluminium hydroxide) and Fe(OH)₃ (hydrous ferric oxide).

Note these outcomes do not take into account the effect of any organic complexation which may be applying to relevant Ba, Ca, Mg, Al or Fe etc., aqueous species so *the SIs should be considered maximal, ie these outcomes are conservative in their estimation of scaling potential.*

In general, a positive SI, particularly greater than about +1.0 indicates a significant potential for scaling/precipitation whereas a lower or negative SI implies negligible or no such potential. In **Table 4** we have also recorded the (base 10) logarithms of the partial pressures of CO₂ which, -via equilibrium with aqueous CO₂ and bicarbonate - is responsible for producing the observed field pHs. The effective partial pressures of CO₂ (pCO₂) in any gas phase in equilibrium with these waters may be easily determined by taking the antilogarithm of the these values e.g. antilog -2.00 gives 0.01 or 1.0% CO₂ (by volume).

Further details of these modeling techniques may be found in Ecoengineers Pty Ltd (2008).

Table 4: Analysis cation/anion Balances and Principal Mineral Saturation Indices

Site ID	Cation/ Anion Balance (%)	Barite SI	Calcite SI	Chalcedony SI	Gibbsite SI	Fe(OH) ₃ SI	Log pCO ₂
Lumber Yard Effluent	+1.27	-1.05	-0.10	+0.03	+1.96	-1.14	-2.25 (i.e. pCO ₂ =0.56%)
MW-01	+2.64	+0.60	+0.32	+0.60	+1.78	-0.63	-1.88 (i.e. pCO ₂ = 1.32%)
MW-02	+0.46	+0.64	+0.66	+0.57	+0.49	+0.58	-2.11 (i.e. pCO ₂ = 0.78%)
MW-03	+5.05	+0.89	+0.78	+0.64	+1.69	-0.30	-1.56 (i.e. pCO ₂ = 2.75%)

Cation/anion balances were acceptable in all instances except for the NGW MW-03 where it was just outside the normal accepted limit of ±5.0%. This indicates the cation inventory contains an erroneous high cation concentration value or the anion inventory an erroneously

low anion concentration value. Noting the issues with reconciliation of the field and theoretical ECs (see **Table 2** above) this discrepancy mostly likely concerns erroneously high Na or erroneously low sulfate, alkalinity or chloride analyses involving separate sample bottles taken at slightly different times.

Nevertheless, these model outcomes for the Lumber Yard Effluent and NGWs suggest that; upon mixing the Lumberyard Effluent with these NGWs there is unlikely to be significant calcareous or siliceous scaling issues arising in the injection wells.

There are however indications of possible aluminous scaling or precipitation and, noting that as a real Injectate chlorinated to a standard chlorine residual of say ~1.0 mg/L would be much more oxidizing (much higher Eh) than the actual sampled Lumber Yard Effluent which had a much lower chlorine residual and hence a much lower Eh, such that there may also be some more Fe(OH)₃ precipitation than indicated by the above SIs.

We therefore next established slightly more complex PHREEQC Effluent/NGW mixing and aquifer storage models in which we assumed that:

1. a fully chlorinated Injectate with a composition equivalent to the Lumber Yard Effluent but with a chlorine (Cl₂) residual of 1.0 mg/L and a DO of 0.45 mg/L as suggested by yourself was injected into each of the MW-01, MW-02 and MW-03 wells; and
2. in each case, mixing at ratios of 25% : 75%, then 50% : 50% and then 75% : 25% of Injectate : NGW respectively was simulated; while at the same time
3. the mixture comes to full cation exchange ('catex') equilibrium with the Ca, Mg, Na and K major cations on the lithology in these aquifers as determined by Mineralogy Inc., and at the same time
4. coming to full CO₂ solubility equilibrium with the partial pressure dictated by the previous modeling applying in that part of the aquifer as shown in the above table; but at the same time
5. not precipitating any minerals *unless their SIs exceeded those which had been previously observed in that particular NGW at that particular partial pressure of CO₂ on the grounds that; the observed NGW mineralogies reported by Mineralogy Inc., clearly showed no precipitation/overgrowth/infill of Ba (sulfate), Sr, Ca, Mg (carbonate) or SiO₂ minerals and only precipitated Fe oxyhydroxides (hydrrous oxides).*

It is noted in condition 3 above that the size of the catex suite of exchangeable cations applying per litre of the various mixtures listed in item 2 is a modeled function of the amount of each exchangeable cation on the solids (meq/100g) as measured by Mineralogy Inc., multiplied by the estimated total mass of those solids in contact with each litre of water.

Thus the calculation of each suite requires taking into account the estimated porosity of the aquifer in each well (as estimated by Mineralogy, Inc., from their thin section analysis) and the particle density of the solids which is assumed as usual to be 2.65. For example; the solids from MW-01 had 8.13 meq/100 g solids upon which calcium (Ca) is occupying catex sites.

For a lithology which has an average porosity of around 37.5% as suggested, this means that every litre of water is exposed-to a total solids volume of $1/0.375 - 1.0 = 1.667$ litres of solids or some $1.667 \times 2.65 = 4.417$ kg of solids for a total of $44.17 \times 8.13 \times 0.001 = 0.3591$ eq/L Ca-occupied catex sites (Ca_{0.5}X) or 0.1796 moles/L CaX₂ catex sites. A useful way of converting from units of meq/100g to units of meq/L is to note that:

- $1 \text{ meq}/100\text{g} = (10 \cdot \rho/n) \text{ meq}/\text{L}$ where $\rho = \text{dry bulk density} (= 0.625 \times 2.65 = 1.656)$ and $n = \text{porosity} (0.375)$ giving a conversion factor of $10 \cdot 1.656/0.375 = 44.17$

The PHREEQC lnl.dat database includes typical clay minerals (especially appropriate to smectites like montmorillonite) exchange constants for Na, K, Ca, etc., Mg exchanging on those sites (including barium Ba and strontium Sr etc.).

The mineral solubilities we assessed in this manner with respect to possible precipitation/scaling (by assuming equilibrated Injectate/NGW mixture SIs would then exceed that previously established in the respective NGW) were:

Barite [BaSO₄]
 Calcite [CaCO₃]
 Disordered Dolomite [CaMg(CO₃)₂]
 Celestite [SrSO₄]
 Chalcedony [opaline SiO₂]
 Dawsonite [NaAlCO₃OH]₂]
 Hydrous Ferric Oxide [Fe(OH)₃]
 Gibbsite [Hydrous Aluminium Oxide; Al(OH)₃]
 Magnesite [MgCO₃]
 Rhodochrosite [MnCO₃]
 Strontianite [SrCO₃] and
 Witherite [BaCO₃].

The following **Table 5** identifies the major minerals which may cause scaling or precipitation during the injection of a proposed Injectate with the chemical composition of the Lumber Yard Effluent but with a chlorine residual of ~1.0 mg/L and a DO of ~0.45 mg/L, but accords NIL potential for scaling/precipitation if the computed SI does not exceed that observed in the respective NGW.

Once again it is noted that the prediction is conservative because the model neglects the effect of any additional organic complexation effects, particularly of Fe and Al due to dissolved organics present in the Injectate.

Table 5: PHREEQC model-predicted precipitation of Minerals upon Mixing of Injectate and NGWs in wells MW-01, MW-02 and MW-03.

Proxy Injectate (vol. %)	NGW (vol. %)	NGW type	Mass of Barite possibly formed (µg per litre of mixture)	Mass of Calcite possibly formed (µg per litre of mixture)	Mass of Chalcedony possibly formed (µg per litre of mixture)	Mass of Fe(OH) ₃ (Hydrous Ferric Oxide) possibly formed (µg per litre of mixture)	Mass of Al(OH) ₃ (Gibbsite) possibly formed (µg per litre of mixture)
25	75	MW-01	NIL	NIL	NIL	7.0	59
50	50	MW-01	NIL	NIL	NIL	7.2	120
75	25	MW-01	NIL	NIL	NIL	6.6	180
25	75	MW-02	NIL	NIL	NIL	8.0	NIL
50	50	MW-02	NIL	NIL	NIL	NIL	31
75	25	MW-02	NIL	NIL	NIL	NIL	104
25	75	MW-03	NIL	NIL	NIL	40	NIL
50	50	MW-03	NIL	NIL	NIL	26	140
75	25	MW-03	NIL	NIL	NIL	10	213

Biofouling

In assessing the likelihood of biofouling deposits, especially during aquifer injection and storage we note that the most important controlling factors for biofouling of injection well screens and within the aquifer adjacent to injection wells are as follows:

1. Are there adequate levels of nitrogen and phosphorus nutrients to sustain the bacterial action? These nutrients allow growth of significant biofilm mass being a mixture of bacteria and exuded extracellular material (largely polysaccharide 'gel'). Very often there is an adequate supply of nitrogen nutrients (nitrate, ammonia, etc.) but insufficient phosphorus in which phosphorus – especially phosphate - becomes the limiting nutrient. In that case the system is described as P-limited. These processes can be modeled with PHREEQC when adequate information is available. That situation does not apply in the present preliminary assessment stage.
2. Are there adequate levels of soluble and/or total organic carbon (DOC or TOC) to support growth of a bacterial biomass?
3. Has a disinfectant technique such as chlorine, hypochlorite, hydrogen peroxide, ozone or UV irradiation capable of destroying (by oxidation), been used in the Injectate?

The single Lumber Yard (proxy) Effluent sample analysis (by Eurofins) did not have TN level significantly higher than was observed in the three NGW (only a Total Kjeldahl Nitrogen (TKN) of 0.66 mg/L, with ostensibly no ammonia (NH₃) or nitrate/nitrite NO_x) but a significantly higher TP level (~1.0 mg/L).

If this was a true proxy for the final treatment plant for the Project this would have meant that the Lumber Yard Effluent could only contribute organic nitrogen to the native groundwater/Injectate mix and hence with an Injectate of that nature the nitrogen supply would be the biofouling-limiting nutrient. This in turn would suggest that phosphorus would not be the limiting nutrient in the Injectate.

However, as discussed above, we found strong evidence that the single Lumber Yard (proxy) Effluent sample analysis (by Eurofins) either had significant errors with respect to nitrogen (N) nutrients or that there were Plant operational or sampling issues on the date of sampling which adversely changed nutrient levels away from the long term means and likely ranges. For this reason, we do not consider this a likely conclusion for a real world Injectate as most secondary and tertiary treated effluents contain significant concentrations of nitrate and ammonia.

The inhouse Plant record for 2012 for the Lumber Yard Plant showed that the TN in the Plant Effluent over 2012 was 0.99±0.08 mg/L (n = 52) and the TP was 0.51±0.16 mg/L. This gives a TN/TP mass ratio of the order of 2. This is a condition of *no phosphorus limitation* as bacterial biomass has a typical stoichiometric N/P mole ratio of around 4 – 6 equivalent to a mass ratio of around 1.8 – 2.7.

It is also noted that the June 2012 RMC Water and Environment technical memorandum suggests a TN (= TKN + NO₃-N) of around 11 + 6.5 = 17.5 and a PO₄-P of 3.0 mg/L. The N/P mass ratio of that effluent would be 2.6, *again a condition of no phosphorus limitation*.

At this preliminary assessment stage it was considered likely the Injectate would be chlorinated, especially if there was any possible intention to subsequently re-extract water from the aquifer and re-use it e.g. for irrigation.

In our PHREEQC modeling of the scaling/precipitation propensity we therefore assumed that:

1. the residual Dissolved Organic Carbon (DOC) in the Injectate has been completely destroyed by oxidation using one the above disinfection techniques i.e. Injectate organic carbon has been completely deactivated or destroyed and cannot support biomass production; and

2. a suggested chlorine residual of ~1.0 mg/L (as Cl₂) invariably applies to the Injectate; and
3. the Injectate contains 0.64 mg/L NO₃-N and 0.33 mg/L NH₃-N as indicated by the Lumber Yard Plant data spreadsheet for 2012; and
4. the NGWs still have, prior to mixing with Injectate, the levels of DOC reported by the Eurofins laboratory.

The following **Table 6** tabulates the Eh potentials of the inground mixtures and the estimated residual levels of C(-4) i.e. reduced, organic carbon (DOC) in the Injectate/NGW mixtures.

Table 6: Effect of Injecting an Injectate with no bioavailable carbon but a 1.0 mg/L Chlorine Residual

Proxy Injectate (vol. %)	NGW (vol. %)	NGW type	Predicted Eh of mixture (mV)	Mixture minimum DOC (mg/L)	Mixture minimum NO _x -N (mg/L)	Mixture minimum NH ₄ -N (mg/L)
25	75	MW-01	-186	0.62	NIL	0.008
50	50	MW-01	-184	0.27	NIL	0.006
75	25	MW-01	+673	NIL	0.017	NIL
25	75	MW-02	+671	NIL	0.032	NIL
50	50	MW-02	+677	NIL	0.056	NIL
75	25	MW-02	+750	NIL	0.061	NIL
25	75	MW-03	+690	NIL	0.020	NIL
50	50	MW-03	+767	NIL	0.042	NIL
75	25	MW-03	+776	NIL	0.054	NIL

As can be seen, as the components required for biomass production are all minimal in the above **Table 6** and rely on the assumption of N-nutrient and DOC contributions by the Injectate, the assumption that the Injectate does not contribute DO, N-nutrients or 'feedstock' DOC into the Injection Zone is a critical one.

The period of highest risk for biofouling would therefore occur when the proportion of stored water in the aquifer is dominated by Injectate i.e. when greatest concentrations of TP and NO_x-N apply.

This can only be controlled by control of the concentration of residual DOC after disinfection and immediately before injection.

Unfortunately, at present we do not have, in the Lumber Yard Effluent, a sufficiently accurate proxy to indicate what the real 'advanced Plant' Injectate DOC, TN and TP composition would be, nor even confirmation as to whether TN levels would be significantly higher in the Injectate than in typical NGWs as the RMC June 2012 technical memorandum strongly suggests.

It is therefore premature to attempt to model the potential biological situation any further.

Summary of Assessment

The major findings of this preliminary assessment of geochemical issues of the Proposed Malibu Aquifer Injection Treated Effluent Sub-surface Disposal Scheme are as follows:

Any Injectate would clearly be aerobic and contain at least some dissolved oxygen if not other oxidants such as chlorine or peroxide etc. There are adequate levels of reactive dissolved organic carbon (DOC) in the aquifer to ensure that the already relatively high partial pressures of CO₂ in the aquifer (0.8 – 2.8%) would only increase upon injection/mixing, increasing the solubility of carbonates still further. The potential for abiotic (i.e. without biological influence) calcareous precipitation/scaling is very low.

The native groundwater geochemistry is just anoxic rather than fully aerobic i.e. reduction of sulfate or organic matter is clearly not occurring naturally as deduced from the absence of dissolved methane and sulfide but a low level of reduction of iron is probably occurring as indicated by chemical analyses and redox potential (Eh) measurements.

Any precipitation in the zone of injection is only likely to involve precipitation of small amounts of aluminum and iron hydrous oxides (oxyhydroxides). Such aluminum and iron hydrous oxide precipitates are usually not problematic unless associated with biofouling as follows.

Due to the relatively high total or dissolved organic carbon (TOC; DOC) level in the NGWs (ranging from 1 – 6 mg/L depending upon location), the relatively high level in the Lumber Yard proxy Effluent (>6 mg/L), as well as the suggested magnitude of supply of DOC in the June 2012 RMC Water and Environment technical memorandum (9.5 mg/L), and the likely lack of phosphorus limitation, we conclude the potential for biofouling of injection wells screens and within the aquifer storage area is relatively high. unless it can be shown that chlorine or some other oxidizing disinfectant has largely destroyed the TOC and/or DOC in the actual treatment plant effluent proposed for an Injectate to the local aquifer.

Unfortunately, on chemical grounds, both the Lumber Yard Effluent field and laboratory analyses and the numbers given in the June 2012 RMC Water and Environment technical memorandum do not tell us anything particularly reliable about these parameters in the Treatment Plant Effluent Injectate created for the Scheme.

The Lumber Yard Effluent analysis did however show significantly high TP levels (~1.0 mg/L), and the June 2012 RMC Water and Environment technical memorandum suggested a likely PO₄-P level of around 3.0 mg/L.

At least we can say with some confidence that such levels both indicate that the zone of injection would not be subject to any phosphorus (P) limitations on biofouling.

But as noted above, at present we do not have a satisfactory proxy to indicate whether TN levels would be significantly higher in the Injectate than in the NGW nor what the likely N-nutrient speciation pattern would actually be. Thus we are unable to conduct model simulations of biofouling potential with any confidence.

It is noted the N-species values quoted in the June 2012 RMC Water and Environment technical memorandum contain a mathematical error in that the predicted ammonia nitrogen (NH₃-N) level of 13.3 mg/L exceeds the predicted Total Kjeldhal Nitrogen (TKN) level of 11.0 mg/L which is strictly impossible as $TKN = NH_3-N + Org-N$.

The PHREEQC predictions of likely low level Fe and Al oxyhydroxide precipitation upon mixing of Injectate and NGWs and the observed mineralogical occurrence of secondary Fe oxides in the aquifer mineralogy (refer Mineralogy Inc. report) suggests that biofouling would most likely be comprised of deposited Fe oxyhydroxides and biomass comprising Fe-reducing bacteria and their associated extracellular slimes.

In our view, at this stage, the fact that the Fe/Mn oxidizing bacteria were not detected by the Water Systems Engineering laboratory bacterial studies in either the Lumber Yard Effluent or in a sample of the MW-01 NGW is not particularly relevant to this conclusion.

The above key findings are obviously important from an injection, performance, capacity, and maintenance perspective (i.e. injection well operation and maintenance issues).

In addition to the potential for Fe- and Al-based precipitation/scaling and/or biofouling, however, another issue particularly important to regulators is the potential for dissolution/mobilization of metals or other elements or chemical of concern. Below is an excerpt from the Findings of a recently adopted ASR general permit in California related to this issue:

Finding 28. Finally, injection of water into any aquifer may induce geochemical reactions, some of which may cause exceedance of a water quality objective. For example, the introduction of water with a higher concentration of dissolved oxygen into an anaerobic aquifer may induce geochemical oxidation-reduction (or “redox”) reactions that increase concentrations of inorganic species in the aquifer and recovered water. The redox reactions may result in higher dissolved concentrations of inorganic constituents in recovered water than in the injected water. Specifically, arsenic, iron, manganese, nitrogen, selenium, and sulfur have been identified as constituents of concern in ASR projects.

If this project does not propose to recover injected water for any possible reuses then it may be concluded that Finding 28 does not really apply. This would appear to be a regulatory issue requiring clarification.

If there were possible reuses contemplated we also do note that the redox-sensitive elements arsenic (As), iron (Fe), manganese (Mn), selenium (Se) and uranium (U) are significantly higher in the native groundwaters (NGWs) studied than in the Lumberyard Effluent used as a proxy for a possible treated effluent for this Scheme. This implies that the Injectate/NGW mixture will possibly exhibit an increase in the concentrations of these elements during storage.

In the absence of a trial with a real effluent which, in particular, has a redox potential and degree of chlorination (if any) which can be assumed to be truly representative of that applying in the real project we are not in a position to assess the degree of pickup into solution any re-extracted water of soluble As, Fe, Mn, Se or U more precisely.

That degree of pickup into solution would be the outcome of a geochemical balance between the amounts leached out of the aquifer lithology and the degree of precipitation of Fe and the degree of adsorption of As, Mn, Se and U both onto the native solids of the aquifer – particularly the pre-existing hydrous oxides of Fe and onto the hydrous oxides Fe and Al oxides predicted to be precipitated by our PHREEQC modeling of the injection scenario. As the elements As, Se and U would be largely present as negatively charged anionic species and the Fe and Al hydrous oxides would most likely be largely positively charged at the observed pHs, the degree of removal from solution by adsorption may be very significant.

It is assumed likely that real Injectate will have a much higher Eh than the Lumber Yard effluent and this suggests levels of dissolved Fe and Mn will be reduced in the stored Injectate over the original native levels (due to oxidation and precipitation).

The potential for DBPs formation/ingrowth in the aquifer is a key concern for the regulators.

Unfortunately we did not see any evidence to conclude that the single Lumber Yard effluent sample is a satisfactory proxy for DBP production given that PWR reported a Cl₂ residual of only 0.02 mg/L and WSE a confirming value of 0.015 mg/L – rather than the 1.0 mg/L or higher considered likely to apply to an actual Injectate. Furthermore, strangely the Lumber Yard Effluent did not contain detectable Haloacetic Acids (HAAs) nor Trihalomethanes (at least at the laboratory Method Resolution Limits; MRLs).

This greatly limits the precision of any statements we can make about the potential for the ingrowth of chlorination-induced DBPs during aquifer storage.

Certainly the high DOC of the Lumber Yard effluent (6.1 mg/L) and the even higher number suggested for the real Effluent by the June 2012 RMC Water and Environment technical memorandum (i.e. 9.5 mg/L) suggests that DBP production could be potentially be higher than was observed for the single grab sample of Lumber Yard effluent.

We also note that if chlorination was employed to disinfect the Injectate, as seems likely, thereby leading to DBP ingrowth (and decay) within the aquifer; this could potentially

mandate re-use by drip, rather than spray irrigation due to the potential risk to the public from inhalation of spray drift containing DBPs.

Drip irrigation systems are more expensive to maintain than spray irrigation systems, particularly in respect of biofouling control and corrosion (due to their proximity to the soil), and are less mobile than spray irrigation systems. This is a factor which should be carefully considered if re-extraction is considered a likely option and wherever chlorination of the Injectate is unavoidable for any reason.

To further investigate the issue of DBPs in re-extracted water intended for some reuse e.g. drip irrigation of municipal parks and gardens it would be necessary to:

1. determine whether chlorination was to be mandatory for the Injectate prior to the injection and if it were; then
2. conduct a separate study to determine the typical degrees of DBP ingrowth and decay during aquifer storage,

in order to identify whether the storage timescale in a particular area of the aquifer could be extended to allow decay of DBPs to acceptable levels (in the specified reuse context).

Some References

Ecoengineers Pty Ltd (2008) Assessment of Geochemical Effects Monterey Peninsula Water Management District Phase 1 Aquifer Storage and Recovery Project August 2008 (for Pueblo Water Resources, Inc.)

McLaughlan, R. G., Knight, M. J., and Stuertz, R. M. (1993) Fouling and Corrosion of Groundwater Wells: A Research Study. National Centre for Groundwater Management. University of Technology Sydney Research Publication 1/93

RMC Water and Environment (2012) Technical Memorandum: Conceptual Groundwater Injection Plan. June 2012 (prepared by: Steve Clary, RMC Water and Environment, Dan Wendell, Groundwater Dynamics, Richard Laton, Earth Forensics and Daniel J. Morrissey, McDonald Morrissey Associates, Inc.)

Sincerely

Dr. Stephen A. Short
Director