#	Test	Purpose	Date	Duration	Result	Comments
1	**BW6 constant-rate pumping test;** Target rate= 5 pgm	1) Estimate large scale equivalent T and S integrated over the open interval of BW6; 2) Start a series of sequential cross-hole pumping tests for a "2D" hydraulic tomography among BW 1, 6, 7, 8, and 9.	7/31	Target duration: 48 hours *The target duration is 48 hours, or shorter (if WL in pumping hole falls below the in-well transducer before 48 hours), or longer (if WL drop in pumping hole is slower than expected).	Test was abandoned as the 4-inch submersible pump (rated for 5 gpm) was clogged right after the pump was turned on. After the pump was pulled, we observed sticky clay-like material on and inside the pump.	 After another borehole camera log, we excluded the possibility of leaking bentonite outside the surface casing. Both red and gray clays were produced during the drilling of BW6 in winter, 2016. The clays are determined to be naturally sourced. One possibility of a source is the clay bed in the adjacent Blair Creek that is connected to the fractures and the clay may have been filling into the fractures over time. The fact that the clay was observed to be accumulated at the bottom of BW6 over a 15 ft interval suggests that clay may be *migrating* into the open borehole following ambient groundwater flow. Note that BW6 was air-lifted following its drilling in Oct, 2016, and the borehole was well developed with little debris in the bottom. See the Well Test summary table for 2016. Another possibility, as pointed out by Prof. Carrick Eggleston: "*From the picture, I see a lot of light-colored stuff that is not like Sherman granite, and some larger nearly black pieces as well. This makes me think of more mafic xenoliths that occur in the granite - there is a major example of this just past Virginia Dale as you go toward Fort Collins on 287, but walking around the Blair area you can find a few of these outcropping. It is not just Sherman and Lincoln granite, but also occasional xenoliths.*"

2	**BW7 constant-rate pumping test;** Target rate= 8 gpm After the test, the 4-inch pump propellers were destroyed by large granite debris.	Estimate large scale equivalent T and S integrated over the open interval of BW7; The first of a series of sequential cross-hole pumping tests for a "2D" hydraulic tomography among BW 1, 6, 7, 8, and 9. **Chemistry:** On 8-22, the pH of water produced from BW7 was 7.36 and on 8-23 it was 7.54. On 8-22, shortly after the start of the test, a bottle of water was sampled. Later, it was taken to Analytical Services Laboratory, of Wyoming Department of Agriculture, which gave: pH=7.5 TDS=100 mg/L TSS=51 mg/L In the first 24 hours of pumping, we pumped about 5800 gallons. In the remaining 20.75 hours we pumped about 4000 additional gallons. In total, we pumped about 9800 gallons in 44.75 hours.	8/22/2017 ~8/24/2017	44 hours A constant pumping rate was not maintained throughout the test duration, however during the first 2 hours it can be regarded as a constant rate pumping test. Inline flowmeter was not working at the start of the test. Water from the pumping test was discharged to the "above Blair" wetland west of the well field. On 9/1, received note from Prof. Scott Miller: "The "Below Blair" stream has run dry for the first time since we've been out here recently." The "Below Blair" creek is Blair Creek east of the well field.	Final WL of BW7 is 26m, and the total drawdown is 13.71m. WL drawdown was found in BW6, 8 and 9 within half an hour of pumping BW7. Total drawdown for BW6, 8 and 9 is 14.4 cm, 44.3 cm and 69.8 cm respectively. For BW1, during the first 5 hours, no response was found in WL, while there was small and slow change in WL after 5 hours, and the final drawdown of BW1 is 4.2 cm.	We taped the transducer just above the pump (the bottom of the transducer is 20cm above the top of the pump), and the distance between TOC and the bottom of the transducer is 57.27m. The pumping test was exactly started at 1 pm on 22th August and ended at 9:43 on the 24th of August. After starting the test, we made manual measure of DTW for BW7 with e-tape and we tested the flow rate with a bucket test. After 30 minutes we measured the DTW of the 4 observation wells (i.e., BW1, 6, 8 and 9). Crosshole response was found significantly in these wells except BW1. The WL of the pumping well is declining at the first 105 minutes, but it went up for 25 cm after that, from 4pm to 4:30pm on 8/22 the WL declined more than 1m, and from 4:30 to 5pm the WL declined nearly 6m. From 5:30 to 9 pm the WL was going up for nearly 3.5 m, and then it declined. From 0 to 3am on 8/23, the WL declined for 2.36 m, and then it declined slowly until the end of the test. For BW6, 8 and 9, significant drawdown was found within 30 min and their WL were *continuously going down* until the end of the pumping test. Drawdown wasn't visible in BW1 until about 5 hours after pumping started. It had a final drawdown of about 4.2 cm.

Flow rate recording: bucket test

	time	flow rate (gpm)
8/22	1pm	7.89
	2:15pm	7.50
	3:15pm	6.86
	4:10pm	6.59
	5:20pm	3.49
	6:26pm	3.30
	7:35pm	3.31
	9:10pm	3.43
	10:10pm	3.58
8/23	0:05am	3.47
	3:05am	3.39
	7:35am	3.48
	8:35am	3.48
	10:35am	3.39
	12:20pm	3.46
	15:10pm	3.37

						17:05pm	3.32
						11:05pm	3.03
					8/24	3:05 am	3.17
						7:05am	2.97

The water from BW7 became cloudy at 5:20pm, 8/22; and the water then became clean 1 hour later and remained clean until the end of the test.

Light rain started at 1:45pm, 8/23 and it lasted for all the afternoon (until about 8pm).

#	Test	Purpose	Date	Duration	Results	Comments
3	**BW8 surge test**	1. Development in the vicinity of BW8 (clearing off debris and fracture fillings) 2. Using the recovery phase to determine the average flow rate during recovering, and therefore provide an approximate constant pumping rate for the next pumping test. A new pump rated at **10 gpm** with 1.5 hp, was used because of its relatively durability to granite debris.	9/21/2017~ 9/22/2017	(1) An initial test with 12~4 gpm; producing **debris**, pump could not maintain a low rate at 5 gpm; BW8 was drawn down to near well bottom within 40 min; (2) 4 surge tests: In each surge test, pumping duration is around 14 minutes, while recovering duration is ~6 hours. Flow rate is kept at ~15gpm (gate valve is wide open and pump is operating at full capacity). During the surge tests, we observed very clean water produced from BW8, with very limited debris.	The average flow rate during the **recovery** phases of the 4 surge tests are 0.72gpm, 0.63gpm, 0.24gpm, and 0.48gpm respectively. The waiting time for each test are 168 minutes (5 m to full recovery), 215 minutes (2 m to full recovery), 603 minutes over night (0.2 m to full recovery), and 299 minutes (0.5 m to full recovery), respectively. Because the waiting time for each test are different, so the above computed average flow rates are different. It will take a lot more time for the WL to recover the last few meters. During the early stage of recovery, the average flow rate is 0.83gpm, because WL rise is more rapid. For the observation well, the WL changes at each well is: Well time DTW(m) BW7 9:04(21th) 12.498 BW7 14:21 12.515 BW7 17:47 12.527 BW7 21:35 12.533 BW7 7:51(22th) 12.530 BW7 13:05 **12.539*** BW1 9:15(21th) 13.448 BW1 14:23 13.443	The distance between the top of PVC casing and the top of pump is ~57.45m. The pumping test was started at **13:42** on 9/21/2017. We want to make it at a constant rate of 5gpm, but the pumping rate changed a lot. Moreover, the water level drawdown in the well was very fast, and at 14:19 the WL was 56.157m, and we stopped it then. The pumped water was dirty, which indicates debris in the open fractures. By the end of the **initial** test, the TDS is 94ppm, and pH is 7.42. We waited for the WL to be recovered until 17:23, and started the **first of the surge tests**, and we stopped at 17:37, at which time the WL was 56.412m. The pumping rate was quite stable at 15gpm --- the water was very clear. Then, we wait until 21:14, and stated the 2nd surge test, and ended at 21:27, at which time the water level was 56.450m. The pumping rate was a little bit over 15gpm. TDS was 82ppm, water temp is 7.0 C°, and PH was 7.51. Then we waited a full night until 7:34 on 9/22/2017, and we started the third surge test. We ended at 7:48, at which time the WL was 56.413m. The pumping rate was a little bit more than 15gpm. TDS, temp, and PH were 82ppm, 7.0 C° and

BW1	17:48	13.444
BW1	21:36	13.453
BW1	7:52(22th)	13.452
BW1	13:06	13.450

7.57, respectively. At 12:50 we started the 4th surge test, and ended at 13:04, at which time the WL was 56.339m. TDS, temp and PH were 82ppm, 7.9 C° and 7.46, respectively.

BW6	9:06(21th)	13.919
BW6	14:24	13.920
BW6	17:49	13.929
BW6	21:37	13.928
BW6	7:53(22th)	13.926
BW6	13:07	**13.931**

BW9	8:59(21th)	13.324
BW9	14:25	13.326
BW9	17:51	13.344
BW9	21:38	13.353
BW9	7:54(22th)	13.341
BW9	13:08	13.346

- Will check against background WL change in BW7, which was often naturally declining in the dry season.

#	Test	Purpose	Date	Duration	Results	Comments
4	**BW8 constant rate pumping test** Target rate= 3 gpm	Estimate large scale equivalent T and S integrated over the open borehole of BW8; The third of a series of sequential cross-hole pumping tests for a "2D" hydraulic tomography among BW 1, 6, 7, 8, and 9. **Chemistry:** The pH of water produced from BW8 was 7.65, and TDS is 85ppm. During the 95 minutes pumping, we totally pumped about 268 gallons.	10/04/2017	95minutes, from 11:40 am to 1:15pm. Pumping rate was very hard to control using the inline gate valve, and it changed between 2gpm to 4gpm all the time.	Final DTW of BW8 is 56.5m, and the total drawdown is 42.115m. No significant drawdown are found at BW1, BW6, BW7, and BW9. The total (maximum) drawdown during the test for each well are 0.002m, 0.013m, 0.029m, and 0.010m for BW1, BW6, BW7, and BW9, respectively.	The distance between the top of PVC casing and the top of pump is ~57.45m. The pumping test was started at 11:40am on 10/04/2017. We wanted to make it at a constant rate of 3gpm, but the pumping rate changed between 2gpm to 4gpm during the whole test. The water level drawdown all the way, and we stopped the test at 1:15pm, at which the DTW of BW8 was 56.500m. The pumped water is clean, just as it was the last time we did the surge test on BW8. By the end of the test, the TDS is

85ppm, PH is 7.65, and the water temperature is 9.9 C°
We measured the pumping rate all the time during the test as follows:

Time	Pumping rate(gpm)
11:45	1.2
11:48	2.8
12:00	3.2
12:02	2.1
12:10	3.3
12:13	3.1
12:22	2.7
12:28	2.8
12:31	2.6
12:33	2.8
12:35	2.7
12:40	2.3
12:42	2.2
12:46	4.0
12:50	4.0
12:54	3.3
13:00	3.1
13:07	2.8
13:10	2.6

#	Test	Purpose	Date	Duration	Results	Comments
4	**BW1 constant rate pumping test** Target rate= 7 gpm	Estimate large scale equivalent T and S integrated over the open interval of BW1; The 4th of a series of sequential cross-hole pumping tests for a "2D" hydraulic tomography among BW 1, 6, 7, 8, and 9. **Chemistry:** the pH of water produced from BW1 was 7.70, and TDS is 82ppm.	10/25/2017	97+29+35=161 minutes, from 12:35 pm to 1:52pm; 2:30pm to 2:59pm; 4:02pm to 4:37pm.	Final WL of BW1 is 20.5m, and the total drawdown is 6.5m. No significant drawdown are found at BW6, BW7, BW8, and BW9. The total drawdown during the test for each well are 0.033m, -0.005m, -0.010m, and -0.011m for BW6, BW7, BW8, and BW9, respectively.	The distance between the top of metal casing and the top of the pump is ~21.03m. The initial water level at BW1 was 13.493m. The pumping test was started at 12:35pm on 10/25/2017 and we wanted to make it at a constant rate of 5gpm. During the first 45 minutes, the flow rate was changing all the time, and the pumped water was dirty with bubbles. Then at 1:20pm, the flow rate became stable at 5gpm. The water level was stable at ~17m, for almost 30 minutes, and the pump was off at 1:52pm, at which the water level was 17.012m. We

		During the 97+29+35=161 minutes pumping (3 times), we totally pumped about 988 gallons.			Above: "+" means water level drawdown while pumping, "-" means water level went up while pumping.	observed that when the flow rate was getting smaller (under 5gpm), the water level went up, which indicated that the recharge rate was greater than the pumping rate. At 1:07pm, pumping water TDS is 82ppm, PH is 7.70, and the water temperature is 9.5 C°
						We waited until 2:30pm, at which time the water level was recovered to 13.629m, and then pumped again. We wanted to make a constant rate at 8gpm, but we failed, and the pumping rate was changing all the time. However, the flow rate was greater than 6gpm, which made the water level in BW1 draw down all the time. We stopped at 2:59pm, at which the water level was 20.50m. This time, the pumping water was dirty during the pumping period. Then we waited until 4:02pm, at which the water level was 13.752m, and we pumped the third time. This time we also wanted to make a constant rate at 8gpm, however, we still cannot control well. Then we stopped the pump at 4:37pm, at which the water level was 20.50m. The pumped water was still dirty but was clearer than last time.

We measured the pumping rate all the time during the test as follows:

Time	Pumping rate(gpm)
12:35 to 13:20	/
13:20 to 13:52	5
14:35	8.15
14:37	8.26
14:39	6.17
14:41	10.71
14:43	5.60
14:45	10.60

14:47	6.47
14:52	12.40
14:54	9.01
14:56	6.70
16:05	7.82
16:07	5.87
16:09	5.90
16:14	6.25
16:16	5.98
16:23	5.75
16:25	9.28
16:27	8.79
16:28	7.37
16:30	9.67
16:31	8.11
16:33	5.45
16:36	8.93
16:37	8.44

#	Test	Purpose	Date	Duration	Results	Comments
5	**BW6 constant rate pumping test** Target rate= 8 gpm	Estimate large scale equivalent T and S integrated over the open interval of BW6; One of the last of sequential cross-hole pumping tests for a "2D" hydraulic tomography among BW 1, 6, 7, 8, and 9. **Chemistry:** the pH of water produced from BW1 was 8.13, and TDS is 84ppm. During the 114 minutes pumping, we totally pumped about 912 gallons.	11/15/2017	114 minutes, from 1:40 pm to 3:34pm	Final WL of BW6 is 55m, and the total drawdown is 41m. At 2:35pm, the manual drawdown for each monitoring well is 4.6cm for BW1, 3.0cm for BW7, no obvious drawdown was found at BW8, and 7.8cm for BW9. These are not the maximum drawdown observed, which will be obtained from the transducer data.	The distance between the top of PVC casing and the top of pump is ~55m. The initial water level at BW6 was 14.043m. The pumping test was started at 1:40pm on 11/15/2017, we want to make it at a constant rate of 8gpm. During the whole test, the flow rate was changing all the time, ranging from 6 to 10 gpm. We observed that when the flow rate was getting smaller (under ~6gpm), the water level went up, which indicate the recharge rate was greater the pumping rate. At 2:30pm, pumping water TDS is 84ppm, PH is 8.13, and the water temperature is 7.4 C° We stopped the test at 3:34pm when the WL reached 55m. The pumped water was very clean during the test. We measured the pumping rate all the time during the test as follows:

Time	Pumping rate(gpm)
14:02	6
14:05	9.1
14:15	9
14:25	5.5
14:35	9
14:42	10.5
14:48	7.9
14:50	6.5
14:57	8
15:05	7.5
15:10	7.2
15:15	6
15:23	6.5
15:30	7.7

#	Test	Purpose	Date	Duration	Results	Comments
6	**BW6 constant rate pumping test** Target rate= 5 gpm	Estimate large scale equivalent T and S integrated over the open interval of BW6; The last of a series of sequential cross-hole pumping tests for a "2D" hydraulic tomography among BW 1, 6, 7, 8, and 9. **Chemistry:** the pH of water produced from BW1 was 7.86, and TDS is 85ppm. During the 245 minutes pumping, we totally pumped about 1225 gallons.	11/16/2017 The second test for BW6	245 minutes, from 1:50 pm to 5:55pm	Final WL of BW6 is 21.742m, and the total drawdown is 7.604m. The final drawdown for each monitoring well is 8.5cm for BW1, 5.7cm for BW7, 4.3cm for BW8, and 13.9cm for BW9.	The pumping test was started at 1:50pm on 11/16/2017, we want to make it at a constant rate of 5gpm. During the first 25 minutes, the flow rate was changing all the time, ranging from 6 to 9 gpm. At 2:15pm, we made it stable at 4gpm. Then at 2:45pm at ~4.6gpm, 2:53pm at~4.9gpm, 3:09pm at~4.7gpm, and 3:15pm at ~5.3gpm. From then on, the pumping rate stabilize at 5.3gpm until the end of the test. The WL became stable at 4:50 pm. Pumping water TDS is 85ppm, PH is 7.86, and the water temperature is 7.5 C° We stopped the test at 5:55pm. The pumped water was very clean during the test. We measured the pumping rate all the time during the test as follows: Time Pumping rate(gpm) 14:15 4

					14:45	~4.6
					14:53	~4.9
					15:09	~4.7
					15:15	~5.3
					15:25	~5.3
					15:40	~5.3
					16:00	~5.3
					16:30	~5.3
					17:00	~5.3
					17:30	~5.3
					17:40	~5.2