2021 RiverEyes Monitoring Report

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2021 RiverEyes Monitoring Report

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Name	Affiliation	Role
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EXECUTIVE SUMMARY

GeoSystems Analysis Inc. was contracted by the U.S. Bureau of Reclamation (Reclamation) to conduct daily river monitoring and reporting during 2021 as part of a cooperative interagency effort to document the extent and duration of channel drying in the Middle Rio Grande (MRG). In this report, the MRG refers to the Rio Grande from Cochiti Dam to Elephant Butte Reservoir. The monitoring effort (referred to as "RiverEyes") assists with meeting requirements under Reasonable and Prudent Measure 4, and Terms and Conditions 3.2, 9.1, and 9.2 of the December 2016 *Final Biological and Conference Opinion for Bureau of Reclamation, Bureau of Indian Affairs (BIA), and Non-federal Water Management and Maintenance Activities on the Middle Rio Grande, New Mexico* (2016 BO). When flows fell below key thresholds known to increase flow intermittency risk, field observations were relayed to an interagency water management team and, particularly when flow intermittency was detected, reported to the U.S. Fish and Wildlife Service (USFWS) to support endangered Rio Grande silvery minnow (*Hybognathus amarus*) rescue and relocation activities.

The U.S. Geological Survey (USGS) maintains a network of streamflow monitoring stations throughout the MRG that publish real-time, provisional streamflow volumes to the internet (e.g., https://waterdata.usgs.gov/nm/nwis/current/?type=flow) . Per the contractual agreement with Reclamation, field reconnaissance within specific high-risk segments of the MRG was conducted when streamflow was below 300 cubic feet per second (cfs) at USGS 08354900 Rio Grande Floodway at San Acacia, New Mexico (NM); below 80 cfs at USGS 08331160 Rio Grande Near Bosque Farms, NM; or below 100 cfs at USGS 08330000 Rio Grande in Albuquerque, NM.

During 2021, streamflow fell below this threshold at the San Acacia gauge on June 11 and the monitoring team conducted regular field reconnaissance in this reach from June 14 through October 16. The Bosque Farms gauge fell below the 80 cfs threshold for the first time on June 21 and crews started regular monitoring in the Isleta Reach on June 23. Monitoring officially ended in the Isleta Reach on October 17. The Albuquerque gauge fell below the 100 cfs threshold periodically from July 9 through October 27. Sporadic monitoring was completed and channel drying never occurred in Albuquerque. From June 16 to June 20, the Middle Rio Grande Conservancy District (MRGCD) pumped 65 acre-feet of water into the Rio Grande at the Socorro Hub (the former Neil Cupp pump site, near river mile (RM) 90) to augment the river recession in the San Acacia Reach (Marken, 2021).

Drying was first observed in the San Acacia and Isleta Reaches on June 17 and June 27, respectively. The last day that drying occurred was October 3rd in both the San Acacia and Isleta Reaches. The total number of unique RMs affected by drying at some point throughout the 2021 monitoring year was 32.05 in the San Acacia Reach and 14.04 in the Isleta Reach (46.09 RMs in total for the entire Middle Rio Grande) while the maximum single day dried extent was slightly lower in each reach. Table 1 summarizes relevant dates and the maximum

single day dried extent. The largest single day drying event the San Acacia Reach was on June 27 (31.89 RMs; the "Reachwide" field on Table 1), while the maximum extent dried on a single day in the Isleta Reach occurred on August 26 (11.93 RMs). Riverwide, the maximum extent dried on a single day happened on September 23 (38.97 RMs; 29.67 RM in the San Acacia Reach plus 9.3 RMs in the Isleta Reach). The dried channel conditions affected 108 days and 79 days in the San Acacia and Isleta Reaches, respectively, and drying affected one distinct segment of the San Acacia Reach and two segments of the Isleta Reach.

Table 1. River segments affected by drying in each reach with important dates and maximum dried extent.

Reach	**Approximate RM Affected in Segment**	**Segment Description**	**First Day Drying Occurred**	**Last Day Drying Occurred**	**Maximum One-Day Extent (RM)**	**Date the Maximum One-Day Extent Occurred**
San Acacia	RM 62.75 to RM 98.71	Socorro to below Fort Craig	6/17/2021	10/3/2021	31.89	6/27/2021
	Reachwide		***6/17/2021***	***10/3/2021***	***31.89***	***6/27/2021***
Isleta		Near Peralta Wasteway	7/16/2021	10/3/2021	8.93	8/26/2021
		Downstream of Sabinal Drain Near Abeytas Heading	8/22/2021	10/2/2021	4.94	9/20/2021
	Reachwide		***7/16/2021***	***10/3/2021***	***11.93***	***8/26/2021***
TOTAL	**Riverwide**		**6/17/2021**	**10/3/2021**	**38.97**	**9/23/2021**

INTRODUCTION

For this report, "channel drying," "drying," and "flow intermittency" all refer to an episode when continuous surface water flow becomes interrupted, creating occasionally short segments of exposed riverbed. "Rewetting" refers to an event where surface water flow reenters a location affected by channel drying, reducing the dried length, but surface flow may not necessarily reconnect through the entire affected area. "Reconnection" refers to an event where a segment of river channel affected by channel drying entirely rewets and there is continuous surface flow throughout the entire extent.

Channel drying has been actively monitored since 1996. The monitoring effort became more formal in 2002 when SS Papadopulos and Associates, Inc. (SSPA) systematically mapped the extent of flow intermittency under contract with New Mexico Interstate Stream Commission (NMISC). Monitoring and reporting flow intermittency was required beginning in 2003 (USFWS 2003) and more recent documents describe the negative effect of channel drying on federally listed species conservation efforts (USFWS 2016).

The RiverEyes project has numerous important monitoring responsibilities which include reporting the extent of channel drying and remnant pool formation, providing information to facilitate coordination among water operations staff and biologists to prevent unexpected drying, slow the rate of drying, and alleviate negative effects to riverine habitat including federally threatened and endangered fish and wildlife species, mainly the endangered Rio Grande silvery minnow (*Hybognathus amarus*, silvery minnow; USFWS 2016). Timely and accurate reporting is essential to provide U.S. Fish and Wildlife Service (USFWS) silvery minnow relocation crews with key information to assist with their field planning and site prioritization, plus provide water managers with observations to inform their management decisions.

While RiverEyes encompasses potential monitoring that may occur anywhere between Cochiti Dam and Elephant Butte Reservoir, channel drying episodes have historically concentrated in two MRG reaches – the Isleta and San Acacia. Due to low flow conditions through Albuquerque, GeoSystems also expanded monitoring upstream into the Angostura Reach during 2021.

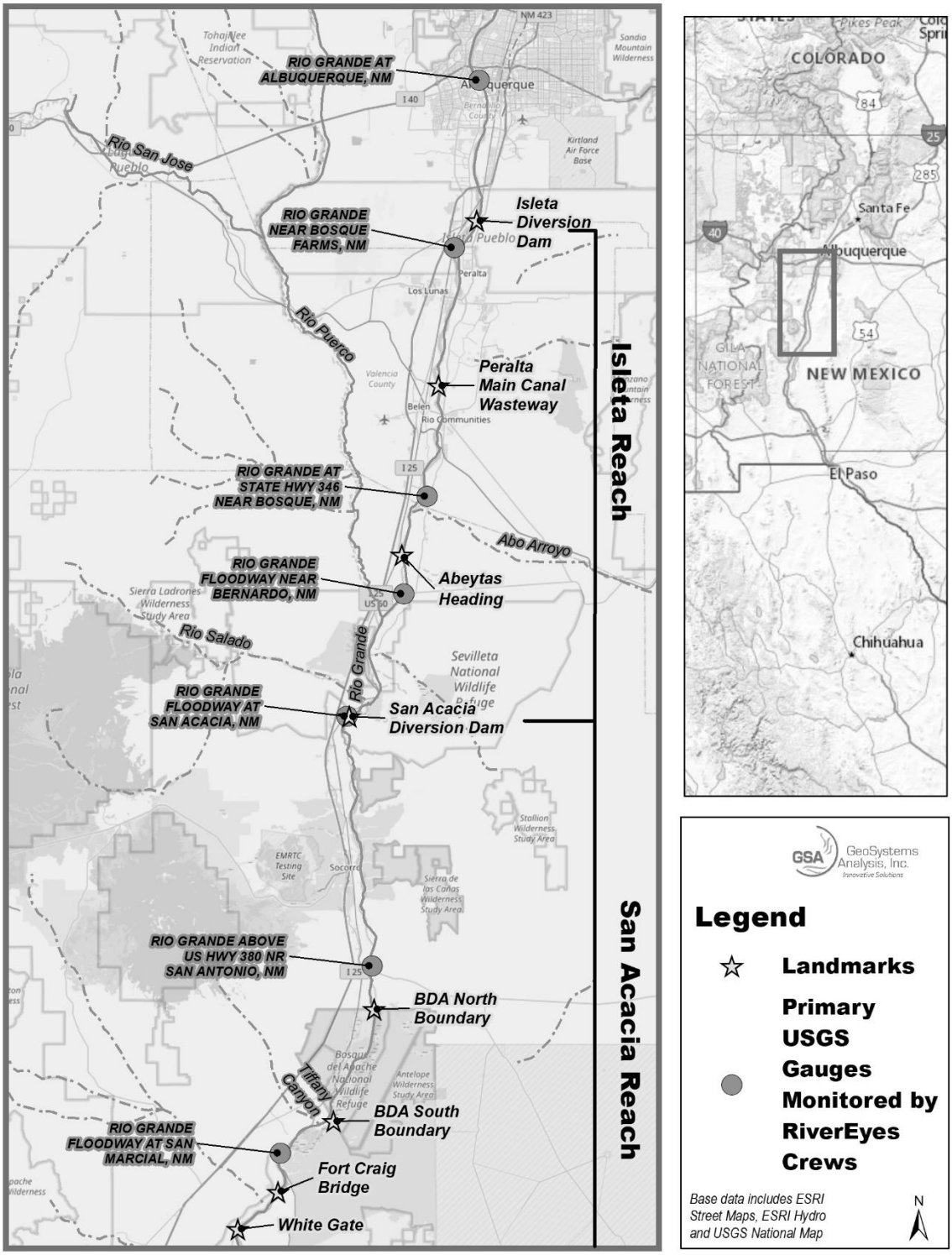

Figure 1. Map showing the location of Isleta and San Acacia Reaches of the Middle Rio Grande plus other landmarks mentioned in this report.

Table 2. Total number of river miles affected by drying at some point during the year in the Isleta and San Acacia Reaches (adapted and expanded from USFWS 2016). Note that the total RMs affected does not numerically coincide with the longest single day dried extent in a year.

	Isleta		**San Acacia**		**Combined**	
	53 Miles		58.5 Miles		111.5 Miles	
Year	Miles	Percent	Miles	Percent	Miles	Percent
2001	0	0	7	12	7	6.3
2002	18.2	34.3	25	42.7	43.2	38.7
2003	30	56.6	40	68.4	70	62.8
2004	31	58.5	37	63.2	68	61
2005	4	7.5	24.5	41.9	28.5	25.6
2006	9.5	17.9	16.5	28.2	26	23.3
2007	9.5	17.9	20.5	35	30	26.9
2008	0	0	0	0	0	0
2009	0	0	20	34.2	20	17.9
2010	8.5	16	19.7	33.7	28.2	25.3
2011	12.9	24.3	27.1	46.3	40	35.9
2012	19.2	36.2	31.8	54.4	51	45.7
2013	9.7	18.3	26.8	45.8	36.5	32.7
2014	3.3	6.2	23.1	39.5	16.4	23.7
2015	6.4	12.1	13.2	22.6	19.6	17.6
2016	10	18.9	20	34.2	30	26.9
2017	2.4	4.5	21.3	36.4	23.7	21.3
2018	7.8	14.7	37.9	64.8	45.7	41.0
2019	0	0	17.4	27.7	17.4	15.6
2020	13.0	24.5	39.7	67.8	52.7	47.3
2021	14.0	26.4	32.1	54.7	46.1	41.2
MEAN	**10.0**	**18.8**	**23.8**	**40.6**	**33.3**	**30.3**

METHODS

Field Reconnaissance and Mapping

Per the contract with Reclamation, annual field activities begin when directed by Reclamation, and generally soon after streamflow falls below these thresholds at the following gauges:

- 300 cubic feet per second (cfs) at Rio Grande Floodway at San Acacia, NM (USGS 08354900)
- 80 cfs at Rio Grande Near Bosque Farms, NM (USGS 08331160)
- 100 cfs at Rio Grande at Albuquerque, NM (USGS 08330000)

Daily field reconnaissance typically began at daybreak and crews initially focused on determining whether separation of continuous surface water (or "drying") occurred. Periodic afternoon site visits were also conducted when specific segments appeared to be nearing separation or when gauges or field observations indicated that volume declined to a level during the heat of the afternoon that could trigger drying. As soon as drying was detected, field personnel located and documented the upstream and downstream extent of flow separation for each affected channel segment. The extent of drying was reported to the nearest 0.01 River Mile (RM; note that Reclamation's RMs are not exactly one mile) via a Global Positioning System (GPS) enabled field application on a smartphone or tablet. Additional observations related to pool distribution, discharge measurements, etc., were collected after affected dry length was mapped and reported.

Reconnaissance targeted specific Rio Grande segments known to be most vulnerable to drying. Based on previous years' RiverEyes data, daily reconnaissance primarily targeted the following locations, though additional areas were checked on a regular (typically weekly) basis.

Angostura Reach Segments

1. Just upstream of the City of Albuquerque Wastewater Treatment Plant outfall: approximately RM 178

Isleta Reach Segments

1. Near Peralta Wasteway: approximately RM 151 to RM 160
2. Downstream of Sabinal Drain near Abeytas Heading: approximately RM 132 to RM 136

San Acacia Reach Segments

1. Socorro to below Fort Craig: approximately RM 63 to RM 99
2. Additional segments below Fort Craig near RM 60 and RM 55 dried during 2018 and 2020; these locations were spot checked regularly but never became intermittent during the 2021 monitoring season.

Where access was permitted, the entirety of each reach was checked at least once during the monitoring season to verify that no atypical drying occurred.

Dried extent, pools, flow measurements, and general field observations were logged within a custom-designed field application. All observations were spatially correlated to a latitude and longitude plus the nearest 0.01 RM using the 2012 Reclamation centerline. Customized, GPS-enabled smart phone applications also facilitated the following optimizations:

1) Provided field personnel an intuitive and automated means to plot their location to the nearest 0.01 RM in real-time.
2) Ability to validate the RM location with underlying latitude and longitude coordinates during post-processing.
3) Streamlined collection of drying, remnant pool, flow measurement, and other field observations and encouraged consistent observations across personnel and over time.
4) Improved field data collection and data management efficiency.
5) Automated multi-user data compilation, backup, and secure storage on the cloud.
6) Facilitated the transfer of large files (e.g., photos) to an intentionally targeted pool of staff.
7) Shared observations between individual field crews and office staff, even in real-time.
8) Streamlined daily report development.
9) Batched export data into widely used formats such as .xls, .pdf, .shp, .kml.
10) Geo-tagged all field photos and videos.
11) Ensured crew observations could immediately be conveyed by GeoSystems project and data managers to agency staff.

When field conditions allowed, crews accessed the riverbed with ATVs, since this has historically been the most efficient method of travel to locate the dried extent quickly and confidently. On occasion, reconnaissance was performed on foot when mud, debris, deep holes, or other circumstances blocked access. Due to widespread quicksand, ATVs regularly became temporarily stuck in the riverbed during the 2021 monitoring season. Quicksand was more prominent in 2021 than any year since at least 2017, which was the first year GSA supported Reclamation with RiverEyes monitoring.

Figure 2. Sample RiverEyes field maps from the 2020 monitoring season. When accessed via the Avenza Maps app, current field location is clearly marked with a large blue dot and the interface allows for panning and zooming.

Discharge Measurements

One key aspect of RiverEyes monitoring involves rapid and accurate measurements of flow discharge. Depending on the measurement objective and timing, the field crew quantified stream flow volume (in cfs) using three methods with differing accuracy:

1) Metered discharge measurements, measured with a SONTEK Flow Tracker 2 flow meter or similar. This method was used as requested by Reclamation or when MRGCD or USGS-reported gauge discharge appeared to be grossly inconsistent with field observations.
2) Ball and tape discharge measurements, per EPA 1997. With this method, field crews used a measuring tape, depth rod, small floating ball (e.g., golf ball), and stopwatch to rapidly measure the width of wetted flow, average depth, and velocity of a floating object to quantify discharge, though with less accuracy (but much quicker) than using a flow meter.
3) Trained visual estimates, recorded as a visual estimate of discharge after field personnel were well calibrated following repeated discharge measurements with either a flow meter or the ball and tape method. With this method, the custom field app required an observer to enter their minimum and maximum flow estimate, thus the value was reported as an average and the observer's estimation range helps with understanding observer confidence.

Daily Reports

Email and text summaries were regularly circulated between the RiverEyes team, Reclamation, and USFWS when low flow conditions warranted. The RiverEyes team also reported current conditions during water operations conference calls. Daily email summary reports (submitted electronically with this report) focused on:

- the extent of drying as number of RMs and distance to major landmarks;
- the RM change of drying or rewetting since the previous report;
- location accessibility;
- current river conditions;
- visual flow estimates in "hot spots" or other locations that might be useful for predicting flow trends or intermittency risk;
- observations of disconnected lateral pools;
- representative field photos;
- summarizing reported flows at USGS gauges over the past 24 hours;
- 24-hour precipitation in the Rio Grande watershed (per Reclamation's ET Toolbox; Reclamation 2020), because it may affect channel drying.

Safety

GeoSystems authored a project-specific Health and Safety Plan (see Appendix B). Field personnel certified that they reviewed the document and complied with it. Geosystem's COVID-19 Safety Manual was also provided to field staff. All staff who operated ATVs received a formal safety instruction and were accompanied by other staff until they could confidently and safely operate the ATV and practice all safety protocols. Motor vehicle and ATV inspections were conducted at the start of each day. Field personnel communicated between themselves regularly and checked in via phone call or text message after daily monitoring responsibilities were finished. All safety guidelines were followed, no injuries occurred on the project, and none of the field staff contracted COVID-19 during fieldwork.

RESULTS

Dried Extent

Channel drying occurred in both the San Acacia and Isleta Reaches during the 2021 monitoring season and intermittency affected multiple segments in each reach. Drying began in the San Acacia Reach on June 17 and reconnected on October 3. The Isleta Reach initially dried on July 16 and the last day of drying in the reach was October 3. Based on provisional USGS data, mean daily discharge at the San Acacia gauge was 121 cfs when drying began in the San Acacia Reach while mean daily discharge at the Bosque Farms gauge was 46.8 cfs on the first day with drying in the Isleta Reach. The total number of days with flow intermittency in the San Acacia and Isleta reaches was 70 and 50, respectively (Table 3 and Table 4). A description of each of

the segments affected by drying is shown in the list below. Longitudinal limits of drying (to the nearest 0.5 RM) and mean daily discharge reported at the various USGS gauges in the Isleta and San Acacia reaches is included as Appendix A, while more precise (reported to the nearest 0.01) RM dried extent is shown for each day in Appendix E. The RM location of landmarks frequently mentioned in this report and daily summary reports is included as Appendix D.

Isleta Reach Segments

1) Near Peralta Wasteway: A total of 9.08 unique RMs were affected from RM 151.12 (drying extended to this point on August 27) to RM 160.2 (intermittency extended upstream to this point on July 27). Occasionally, this section was divided into two dry sub-segments via irrigation return flow out of the Los Chavez Wasteway, however, rewetting from Los Chavez never extended more than about a half mile. This segment experienced drying for a total of 70 days during 2021 in four drying events (i.e., it dried and then reconnected four times).

2) Downstream of Sabinal Drain near Abeytas Heading: A total of 4.96 unique RMs were affected from RM 132.16 (drying extended downstream to this point on September 19) to RM 137.12 (intermittency extended to this point upstream on September 20). This segment experienced four drying events spanning a total of 38 days.

San Acacia Reach Segments

1) Socorro to below Fort Craig: A total of 32.05 RMs were affected from RM 64.12 (drying extended this far downstream on September 18) to RM 96.17 (intermittency extended to this point upstream on June 27). This segment experienced five drying events separated by typically brief periods of reconnection totaling 50 days.

The longest consecutive drying event in the San Acacia Reach lasted for 24 days (September 9 to October 3). In the Isleta Reach, the longest drying event was 56 consecutive days (Peralta Wasteway segment, August 8 to October 3). Drying reached its maximum length in the San Acacia Reach on June 27 when the total dry length was 31.89 RMs. The maximum dry length in the Isleta Reach occurred on August 26 (11.93 RMs), spread across two segments. Note that as shown in Table 1, the maximum single day dried extent occurred on different days in each reach, and the river-wide maximum single day dried extent occurred on September 23 (38.97 RMs), a different day from when the largest drying episode occurred in either reach individually.

In 2021, MRGCD pumped a total of 65 acre-feet of supplemental water to the Rio Grande from the LFCC through the Socorro Hub facility near RM 90.2 to slow river recession in the San Acacia reach from June 16 to June 20 (Marken, 2021).

Table 3. Summary of RiverEyes channel drying observations in the San Acacia Reach during 2021.

San Acacia Reach			
Month	**Total Number of Intermittent Days**	**Maximum Length (RMs)**	**Mean Length (RMs)**
June	14	31.9	21.7
July	7	30.4	4.3
August	4	21.2	1.8
September	22	29.7	17.6
October	3	12.8	0.9
Grand Total	**50**	**31.9**	**9.3**

Table 4. Summary of RiverEyes channel drying observations in the Isleta Reach during 2021.

Isleta Reach			
Month	**Total Number of Intermittent Days**	**Maximum Length (RMs)**	**Mean Length (RMs)**
June	2	2.8	0.3
July	11	7.8	1.9
August	24	11.9	5.1
September	30	11.6	9.2
October	3	7.3	0.6
Grand Total	**70**	**11.9**	**3.4**

When channel drying expanded into new segments, remnant pools often formed in the thalweg, scour holes, and/or other depressional features. After a more prolonged period of dewatering (typically after a few days to a week), remnant pools dried, creating an entirely dry riverbed. The presence, size, and location of remnant pools were sometimes (though inconsistently) recorded and often communicated to the managing agencies via daily emails; however, RM locations where remnant pools entirely dried were not systematically differentiated from segments where remnant pools persisted during fieldwork.

Raw data (provided electronically with this report in various formats) include crew observations related to the distribution and size of remnant pools as well as visual estimates of flow in various locations. Note that these data are not intended to represent a complete log of remnant pools in the channel during the season.

DISCUSSION

The Rio Grande watershed had below average snowpack during the winter 2020-2021 (Reclamation 2021). Spring runoff peaked at less than 1,500 cfs at the San Acacia gauge but numerous monsoonal flow spikes occurred during the summer, beginning in early July (Figure 3). High volume but short-lived monsoon-triggered flow pulses occurred in numerous arroyos and tributaries including the Rio Puerco, Rio Salado, and Abo Arroyo which entirely reconnected flows on multiple occasions and created widespread deposition of fine sediment, particularly in the San Acacia Reach.

Freshly carved deep holes also formed in the channel in both reaches, but especially in the Isleta Reach below Abo Arroyo. Fine sediment deposition that mobilized from arroyos appeared to reduce riverbed infiltration rates and created conditions that sustained continuous flows at discharges that have historically triggered drying. Fine, saturated surface sediments and newly formed holes made ATV travel in the riverbed difficult, sometimes even impossible.

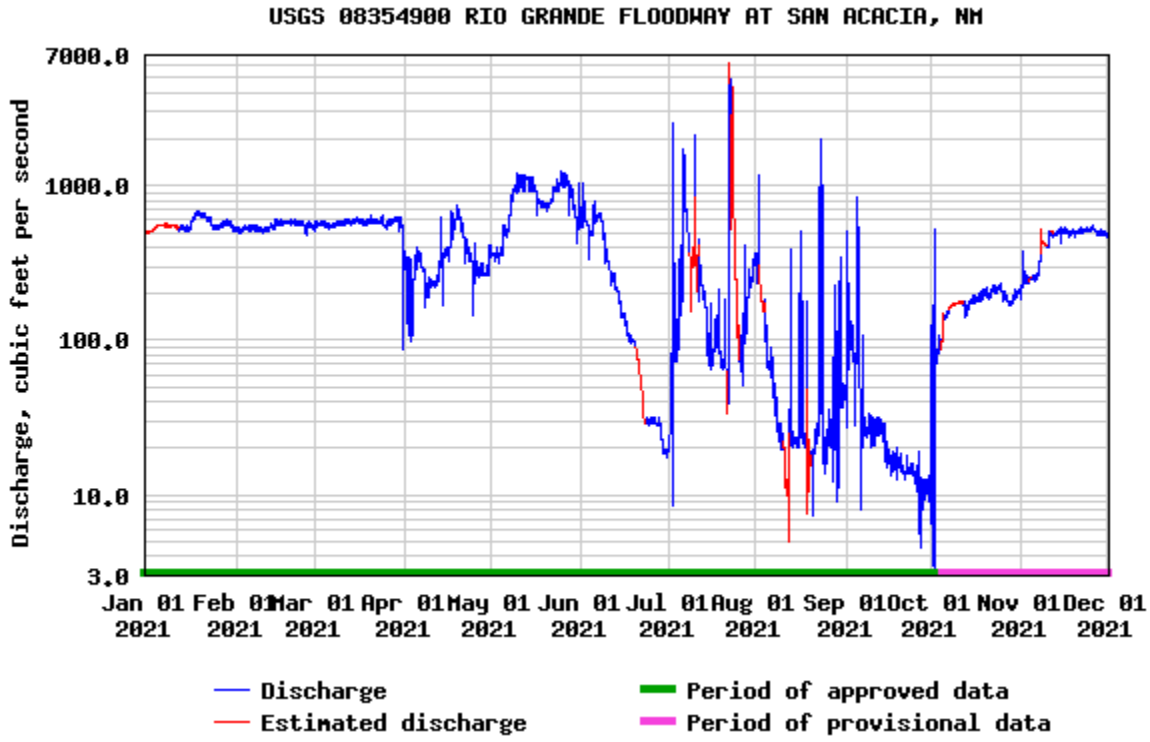

Figure 3. Annual hydrograph from the San Acacia USGS gauge. Note that some data are still provisional.

Based on the experience gained from this year's drone study (Appendix C), it appears that UAVs could become a valuable tool for supplementing field reconnaissance activities, particularly when riverbed conditions become difficult for ATV travel, to confirm flow connectivity in

difficult to access riverbed segments (especially below Fort Craig), and/or to validate drying extents.

The RiverEyes monitoring team regularly monitored flow conditions in the Angostura Reach, particularly from Bridge Street down to the Wastewater Treatment Plant inflow channel, when USGS reported discharge at the Albuquerque gauge fell below 100 cfs. Flow never separated through Albuquerque, but discharge appeared to decrease to about 15 cfs (visual estimate). Flow separation risk was highest immediately upstream of the Wastewater Treatment Plant and in several natural flow constrictions between Bridge Street and Rio Bravo Boulevard.

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Appendix A. Longitudinal Limits of Drying and Mean Daily Discharge as Reported by USGS for Various Gages in the Isleta and San Acacia Reaches (discharge data Provisional)

Confirmed Discontinuous Segments Indicated in Red. Suspected Discontinuous Segments Indicated in Orange for Days When Field Monitoring Was Not Conducted but Surface Flow Remained Disconnected. Coninuous Segments Indicated in Blue.

June

Landmark	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Isleta Diversion 169.4	169.0																														
	168.5																														
	168.0																														
	167.5																														
	167.0																														
Alejandro Drain 166.6	166.5																														
	166.0																														
	165.5																														
240 Wasteway 165.2	165.0																														
Cottonwood Rd 164.5	164.5																														
USGSS @ Bosque Farms (CFS)		1,070	675	601	832	859	905	844	644	455	410	387	386	316	226	193	158	135	105	104	89.7	77.6	64.3	57.1	45.6	43.2	44.8	48.2	51.1	72.5	161
	164.0																														
	163.5																														
	163.0																														
	162.5																														
	162.0																														
	161.5																														
Los Lunas (HWY 6) 161.4	161.0																														
	160.5																														
	160.0																														
	159.5																														
	159.0																														
	158.5																														
El Cerro Tome / Los Lunas Airport	158.0																														
	157.5																														
Los Lunas River Widening	157.0																														
Los Chavez Wasteway 156.7	156.5																														
	156.0																														
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	154.5																														
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	153.5																														
	153.0																														
Peralta Wasteway 152.5	152.5																														
	152.0																														
	151.5																														
	151.0																														
	150.5																														
LP1DR (Allsups) 149.6	150.0																														
Belen Br (NM 6 Hwy 309) 149.5	149.5																														
	149.0																														
	148.5																														
	148.0																														
AT&SF RR 147.7	147.5																														
New Belen Wasteway 147.2	147.0																														
	146.5																														
	146.0																														
	145.5																														
	145.0																														
LP2DR 144.6	144.5																														
	144.0																														
Aerial Gas Line 143.7	143.5																														
	143.0																														
Feeder 3 Wasteway 142.7	142.5																														
	142.0																														
	141.5																														
	141.0																														
Jarales Rd Br 140.8	140.5																														
USGSS @ HWY 346 (CFS)		780	584	478	464	748	677	721	573	398	345	298	277	288	202	161	122	92.5	76.9	58.7	52.6	44.9	37.0	32.3	27.7	25.1	20.8	24.1	27.5	48.7	69.6
Storrie Wasteway 140.1	140.0																														
	139.5																														
Abo Arroyo 139.3	139.0																														
	138.5																														
	138.0																														
Sabinal Drain Outfall 137.9	137.5																														
	137.0																														
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Abeytas Heading 134.4	133.0																														
	132.5																														
	132.0																														
	131.5																														
	131.0																														
Bernardo (U.S. 60 Br) 130.6	130.5																														
USGSS @ Bernardo (CFS)		551	666	469	445	685	684	736	629	441	355	309	265	315	225	171	117	89.3	67.3	46.2	31.3	25.6	19.7	14.3	11.4	9.77	7.33	6.17	9.01	11.7	57.9
	130.0																														
	129.5																														
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	128.5																														
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Lower San Juan Drain 127.2	127.0																														
Rio Puerco 126.6	126.5																														
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	124.5																														
La Joya 124	124.0																														
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	123.0																														
	122.5																														
Lower San Juan Drain 2 122.1	122.0																														
Sevilleta North Boundary 121.7	121.5																														
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	120.5																														
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Rio Salado 118.9	118.5																														
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June

Landmark	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
San Acacia Diversion Dam 116.2	116.0																														
USGS @ San Acacia (CFS)		609	772	577	497	548	646	639	627	485	353	281	251	236	191	157	142	121	103	98.6	88.8	71.2	51.2	30.5	30.2	30.1	30.5	29.4	28.9	22.0	18.8
	115.5																														
	115.0																														
One Mile Stop 114.8	114.5																														
	114.0																														
	113.5																														
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	107.5																														
	107.0																														
Lemitar Diversion 106.7	106.5																														
	106.0																														
	105.5																														
	105.0																														
9 Mile Outfall 104.5	104.5																														
USGS @ Escondida (CFS)		572	662	496	430	412	584	549	559	466	319	269	228	230	198	176	159	144	134	129	125	113	96.6	81.5	78.0	74.9	72.2	71.9	75.1	72.5	64.5
Escondida Br 104.1	104.0																														
	103.5																														
	103.0																														
N. Socorro Div. Channel 102.5	102.5																														
	102.0																														
	101.5																														
Escondida Drain Outfall 101.0	101.0																														
	100.5																														
	100.0																														
	99.5																														
Otero Street 99.0	99.0																														
	98.5																														
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Brown Arroyo 94.0	94.0																														
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Neil Cupp 90.2	90.0																														
	89.5																														
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	87.5																														
USGS @ Highway 380 (CFS)		468	491	466	312	275	467	461	507	431	257	197	139	133	110	83.9	58.1	46.6	39.3	26.3	14.6	5.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
San Antonio (U.S. 380) 87.1	87.0																														
	86.5																														
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BDA North Boundary 84.1	84.0																														
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	81.5																														
Realignment Channel Inlet 81.4	81.0																														
	80.5																														
	80.0																														
	79.5																														
Realignment Channel Outlet 79.4	79.0																														
BDA HQ 78.7	78.5																														
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Former Mid BDA Pump Site 77.6	77.5																														
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South BDA Boundary Pumps 73.8	73.5																														
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	69.5																														
	69.0																														
San Marcial RR Bridge 68.6	68.5																														
USGS @ San Marcial (CFS)		370	441	558	381	314	315	479	451	461	352	202	125	117	99.3	47.4	25.0	10.1	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
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S Curve 60	60.0																														
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White Gate 59.2	59.0																														
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July

Landmark	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Isleta Diversion 169.4	169.0																															
	168.5																															
	168.0																															
	167.5																															
	167.0																															
Alejandro Drain 166.6	166.5																															
	166.0																															
	165.5																															
240 Wasteway 165.2	165.0																															
Cottonwood Rd 164.5	164.5																															
USGSS @ Bosque Farms (CFS)		232	197	200	593	281	291	373	253	197	210	173	116	88.5	73.7	63.4	46.8	30.0	36.6	18.0	16.5	23.2	27.8	20.7	142	54.8	75.1	150	372	196	174	211
	164.0																															
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	162.5																															
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Los Lunas (HWY 6) 161.4	161.0																															
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El Cerro Tome / Los Lunas Airport	158.0																															
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Los Lunas River Widening	157.0																															
Los Chavez Wasteway 156.7	156.5																															
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Peralta Wasteway 152.5	152.5																															
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LP1DR (Allsups) 149.6	150.0																															
Belen Br (NM 6 Hwy 309) 149.5	149.5																															
	149.0																															
	148.5																															
	148.0																															
AT&SF RR 147.7	147.5																															
New Belen Wasteway 147.2	147.0																															
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LP2DR 144.6	144.5																															
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Aerial Gas Line 143.7	143.5																															
	143.0																															
Feeder 3 Wasteway 142.7	142.5																															
	142.0																															
	141.5																															
	141.0																															
Jarales Rd Br 140.8	140.5																															
USGSS @ HWY 346 (CFS)		102	135	123	223	287	189	324	298	223	200	189	165	135	103	83.5	75.2	79.8	81.1	56.5	39.3	34.8	43.4	41.0	44.9	45.8	49.1	35.5	90.7	144	90.1	82.2
Storrie Wasteway 140.1	140.0																															
	139.5																															
Abo Arroyo 139.3	139.0																															
	138.5																															
	138.0																															
Sabinal Drain Outfall 137.9	137.5																															
	137.0																															
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Abeytas Heading 134.4	133.0																															
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	131.0																															
Bernardo (U.S. 60 Br) 130.6	130.5																															
USGSS @ Bernardo (CFS)		82.5	132	283	154	405	260	508	382	273	217	222	194	162	109	73.0	58.7	130	78.1	62.0	12.6	5.70	9.07	5.45	110	67.6	52.0	23.8	33.3	170	85.5	63.9
	130.0																															
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Lower San Juan Drain 127.2	127.0																															
Rio Puerco 126.6	126.5																															
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Lower San Juan Drain 2 122.1	122.0																															
Sevilleta North Boundary 121.7	121.5																															
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Rio Salado 118.9	118.5																															
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July

Landmark	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
San Acacia Diversion Dam 116.2	116.0																															
USGS @ San Acacia (CFS)		19.1	28.5	705	97.3	217	310	1,040	543	285	351	471	343	233	181	125	97.9	87.4	106	130	72.1	82.6	41.6	1,740	1,160	224	92.0	66.5	177	195	235	297
	115.5																															
	115.0																															
One Mile Stop 114.8	114.5																															
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	107.5																															
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Lemitar Diversion 106.7	106.5																															
	106.0																															
	105.5																															
	105.0																															
9 Mile Outfall 104.5	104.5																															
USGS @ Escondida (CFS)		59.4	68.3	335	153	189	292	733	653	381	463	486	397	278	225	192	162	145	151	168	132	127	120	965	1,130	245	91.7	84.6	120	118	162	176
Escondida Br 104.1	104.0																															
	103.5																															
	103.0																															
N. Socorro Div. Channel 102.5	102.5																															
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Escondida Drain Outfall 101.0	101.0																															
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Otero Street 99.0	99.0																															
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Brown Arroyo 94.0	94.0																															
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Neil Cupp 90.2	90.0																															
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USGS @ Highway 380 (CFS)		0.00	0.00	405	167	77.3	393	---	908	462	334	651	304	276	194	154	103	79.0	89.7	115	115	---	---	1,360	2,350	411	133	81.6	103	146	198	203
San Antonio (U.S. 380) 87.1	87.0																															
	86.5																															
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	84.5																															
BDA North Boundary 84.1	84.0																															
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Realignment Channel Inlet 81.4	81.0																															
	80.5																															
	80.0																															
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Realignment Channel Outlet 79.4	79.0																															
BDA HQ 78.7	78.5																															
	78.0																															
Former Mid BDA Pump Site 77.6	77.5																															
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South BDA Boundary Pumps 73.8	73.5																															
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	69.0																															
San Marcial RR Bridge 68.6	68.5																															
USGS @ San Marcial (CFS)		0.00	0.00	22.9	166	41.6	104	456	373	289	125	197	277	189	118	65.8	46.2	47.1	44.8	54.5	58.3	49.3	37.4	247	814	229	126	28.9	15.3	56.9	85.7	122
	68.0																															
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S Curve 60	60.0																															
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White Gate 59.2	59.0																															
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August

Landmark	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Isleta Diversion 169.4	169.0																															
	168.5																															
	168.0																															
	167.5																															
	167.0																															
Alejandro Drain 166.6	166.5																															
	166.0																															
	165.5																															
240 Wasteway 165.2	165.0																															
Cottonwood Rd 164.5	164.5																															
USGSS @ Bosque Farms (CFS)		333	283	143	104	91.9	67.1	58.6	54.0	48.5	38.9	33.1	32.8	32.6	35.2	36.7	57.0	118	38.3	34.0	32.2	32.4	29.9	28.2	28.0	28.2	28.9	27.9	27.1	26.5	26.6	27.5
	164.0																															
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	162.0																															
	161.5																															
Los Lunas (HWY 6) 161.4	161.0																															
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El Cerro Tome / Los Lunas Airport	158.0																															
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Los Lunas River Widening	157.0																															
Los Chavez Wasteway 156.7	156.5																															
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Peralta Wasteway 152.5	152.5																															
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LP1DR (Allsups) 149.6	150.0																															
Belen Br (NM 6 Hwy 309) 149.5	149.5																															
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	148.5																															
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AT&SF RR 147.7	147.5																															
New Belen Wasteway 147.2	147.0																															
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LP2DR 144.6	144.5																															
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Aerial Gas Line 143.7	143.5																															
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Feeder 3 Wasteway 142.7	142.5																															
	142.0																															
	141.5																															
	141.0																															
Jarales Rd Br 140.8	140.5																															
USGSS @ HWY 346 (CFS)		109	133	94.6	66.5	52.6	52.7	52.9	36.0	24.9	16.4	14.6	13.2	12.9	12.6	12.9	12.5	14.6	19.9	23.4	14.1	10.8	13.2	12.6	7.37	6.46	6.23	6.89	6.13	5.53	6.79	5.83
Storrie Wasteway 140.1	140.0																															
	139.5																															
Abo Arroyo 139.3	139.0																															
	138.5																															
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Sabinal Drain Outfall 137.9	137.5																															
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Abeytas Heading 134.4	133.0																															
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	132.0																															
	131.5																															
	131.0																															
Bernardo (U.S. 60 Br) 130.6	130.5																															
USGSS @ Bernardo (CFS)		71.0	136	120	62.0	46.6	36.8	35.8	30.0	18.0	8.55	6.08	3.90	15.4	7.24	2.13	7.48	2.34	2.91	8.74	8.61	0.61	0.00	2.03	0.27	0.00	0.00	0.00	181	5.92	5.14	5.69
	130.0																															
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La Joya 124	124.0																															
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Lower San Juan Drain 2 122.1	122.0																															
Sevilleta North Boundary 121.7	121.5																															
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Rio Salado 118.9	118.5																															
	118.0																															
	117.5																															
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	116.5																															

August

Landmark	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
San Acacia Diversion Dam 116.2	116.0																															
USGS @ San Acacia (CFS)		307A	366A e	177A e	135A e	83.4A	69.5A	46.1A	32.4A	25.8A	20.8A e	14.0A e	12.4A e	81.1A	22.3A	21.6A	43.3A	119A	24.0A	28.8A e	15.6A e	18.4A	135A	281A	310A	17.7A	24.6A	29.4A	79.1A	52.4A	117A	45.5A
	115.5																															
	115.0																															
One Mile Stop 114.8	114.5																															
	114.0																															
	113.5																															
	113.0																															
	112.5																															
	112.0																															
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	111.0																															
	110.5																															
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	109.5																															
	109.0																															
	108.5																															
	108.0																															
	107.5																															
	107.0																															
Lemitar Diversion 106.7	106.5																															
	106.0																															
	105.5																															
	105.0																															
9 Mile Outfall 104.5	104.5																															
USGS @ Escondida (CFS)		221A	219A	119A	145A	90.8A	66.9A	54.1A	39.0A	27.3A	22.5A	13.0A	11.2A	72.0A	26.2A e	21.2A	35.5A	80.7A	25.8A	26.8A	6.00A	7.26A e	21.1A	184A	212A	32.8A	32.8A	41.4A	58.6A	79.7A	86.1A	78.3A
Escondida Br 104.1	104.0																															
	103.5																															
	103.0																															
N. Socorro Div. Channel 102.5	102.5																															
	102.0																															
	101.5																															
Escondida Drain Outfall 101.0	101.0																															
	100.5																															
	100.0																															
	99.5																															
Otero Street 99.0	99.0																															
	98.5																															
	98.0																															
	97.5																															
	97.0																															
	96.5																															
	96.0																															
	95.5																															
	95.0																															
	94.5																															
Brown Arroyo 94.0	94.0																															
	93.5																															
	93.0																															
	92.5																															
	92.0																															
	91.5																															
	91.0																															
	90.5																															
Neil Cupp 90.2	90.0																															
	89.5																															
	89.0																															
	88.5																															
	88.0																															
	87.5																															
USGS @ Highway 380 (CFS)		284A	316A	115A	156A	104A	70.1A	66.5A	49.9A	37.2A	26.2A	18.8A	17.7A	61.5A	68.7A	21.5A	130A	175A	137A	114A	79.6A	63.3A	54.0A	554A	552A	68.5A	37.5A	53.4A	103A	96.8A	51.1A	106A
San Antonio (U.S. 380) 87.1	87.0																															
	86.5																															
	86.0																															
	85.5																															
	85.0																															
	84.5																															
BDA North Boundary 84.1	84.0																															
	83.5																															
	83.0																															
	82.5																															
	82.0																															
	81.5																															
Realignment Channel Inlet 81.4	81.0																															
	80.5																															
	80.0																															
	79.5																															
Realignment Channel Outlet 79.4	79.0																															
BDA HQ 78.7	78.5																															
	78.0																															
Former Mid BDA Pump Site 77.6	77.5																															
	77.0																															
	76.5																															
	76.0																															
	75.5																															
	75.0																															
	74.5																															
	74.0																															
South BDA Boundary Pumps 73.8	73.5																															
	73.0																															
	72.5																															
	72.0																															
	71.5																															
	71.0																															
	70.5																															
	70.0																															
	69.5																															
	69.0																															
San Marcial RR Bridge 68.6	68.5											---	---																			
USGS @ San Marcial (CFS)		144A	229A	134A	72.2A	92.3A	47.2A	25.6A	22.8A	14.7A	7.12A	---	---	6.42A	47.9A	15.0A	35.9A	4.59A	31.9A	11.7A	10.5A	0.82A	0.24A	124A	429A e	117A e	17.0A	6.85A	40.7A e	24.8A e	46.1A e	43.7A e
	68.0																															
	67.5																															
	67.0																															
	66.5																															
	66.0																															
	65.5																															
	65.0																															
Ft Craig 64.5	64.5																															
	64.0																															
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	62.5																															
	62.0																															
	61.5																															
	61.0																															
	60.5																															
S Curve 60	60.0																															
	59.5																															
White Gate 59.2	59.0																															
	58.5																															
	58.0																															
	57.5																															
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	54.5																															
	54.0																															
	53.5																															

September

Landmark	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Isleta Diversion 169.4	169.0																														
	168.5																														
	168.0																														
	167.5																														
	167.0																														
Alejandro Drain 166.6	166.5																														
	166.0																														
	165.5																														
240 Wasteway 165.2	165.0																														
Cottonwood Rd 164.5	164.5																														
USGSS @ Bosque Farms (CFS)		30.0	41.0	28.3	27.6	26.9	26.3	27.8	30.7	36.0	35.3	34.9	34.9	34.8	35.0	35.1	33.0	32.2	31.5	32.0	30.1	31.0	32.2	31.1	27.6	28.5	29.4	28.7	30.2	29.5	32.2
	164.0																														
	163.5																														
	163.0																														
	162.5																														
	162.0																														
	161.5																														
Los Lunas (HWY 6) 161.4	161.0																														
	160.5																														
	160.0																														
	159.5																														
	159.0																														
	158.5																														
El Cerro Tome / Los Lunas Airport	158.0																														
	157.5																														
Los Lunas River Widening	157.0																														
Los Chavez Wasteway 156.7	156.5																														
	156.0																														
	155.5																														
	155.0																														
	154.5																														
	154.0																														
	153.5																														
	153.0																														
Peralta Wasteway 152.5	152.5																														
	152.0																														
	151.5																														
	151.0																														
	150.5																														
LP1DR (Allsups) 149.6	150.0																														
Belen Br (NM 6 Hwy 309) 149.5	149.5																														
	149.0																														
	148.5																														
	148.0																														
AT&SF RR 147.7	147.5																														
New Belen Wasteway 147.2	147.0																														
	146.5																														
	146.0																														
	145.5																														
	145.0																														
LP2DR 144.6	144.5																														
	144.0																														
Aerial Gas Line 143.7	143.5																														
	143.0																														
Feeder 3 Wasteway 142.7	142.5																														
	142.0																														
	141.5																														
	141.0																														
Jarales Rd Br 140.8	140.5																														
USGSS @ HWY 346 (CFS)		6.31	7.08	6.49	6.45	6.69	6.31	5.90	5.57	5.27	5.53	5.36	4.89	4.69	4.55	4.72	4.33	4.32	4.52	4.00	3.86	4.00	4.70	6.31	5.92	6.55	7.57	7.80	8.89	9.62	10.9
Storrie Wasteway 140.1	140.0																														
	139.5																														
Abo Arroyo 139.3	139.0																														
	138.5																														
	138.0																														
Sabinal Drain Outfall 137.9	137.5																														
	137.0																														
	136.5																														
	136.0																														
	135.5																														
	135.0																														
	134.5																														
	134.0																														
	133.5																														
Abeytas Heading 134.4	133.0																														
	132.5																														
	132.0																														
	131.5																														
	131.0																														
Bernardo (U.S. 60 Br) 130.6	130.5																														
USGSS @ Bernardo (CFS)		2.64	2.23	2.31	2.45	303	17.7	12.5	11.2	9.68	6.78	4.17	3.01	3.32	3.23	3.11	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
	130.0																														
	129.5																														
	129.0																														
	128.5																														
	128.0																														
	127.5																														
Lower San Juan Drain 127.2	127.0																														
Rio Puerco 126.6	126.5																														
	126.0																														
	125.5																														
	125.0																														
	124.5																														
La Joya 124	124.0																														
	123.5																														
	123.0																														
	122.5																														
Lower San Juan Drain 2 122.1	122.0																														
Sevilleta North Boundary 121.7	121.5																														
	121.0																														
	120.5																														
	120.0																														
	119.5																														
	119.0																														
Rio Salado 118.9	118.5																														
	118.0																														
	117.5																														
	117.0																														
	116.5																														

September

Landmark	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
San Acacia Diversion Dam 116.2	116.0																														
USGS @ San Acacia (CFS)		48.7[A]	160[A]	107[A]	60.5[A]	419[A]	82.0[A]	31.0[A]	24.7[A]	27.4[A]	26.3[A]	25.6[A]	27.3[A]	26.9[A]	25.4[A]	18.5[A]	16.9[A]	14.9[A]	15.7[A]	15.8[A]	15.9[A]	14.2[A]	14.4[A]	14.6[A]	14.9[A]	13.4[A]	12.5[A]	8.44[A]	10.5[A]	11.1[A]	13.2[A]
	115.5																														
	115.0																														
One Mile Stop 114.8	114.5																														
	114.0																														
	113.5																														
	113.0																														
	112.5																														
	112.0																														
	111.5																														
	111.0																														
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	109.5																														
	109.0																														
	108.5																														
	108.0																														
	107.5																														
	107.0																														
Lemitar Diversion 106.7	106.5																														
	106.0																														
	105.5																														
	105.0																														
9 Mile Outfall 104.5	104.5																														
USGS @ Escondida (CFS)		53.9[P]	120[P]	100[P]	76.0[P]	210[P]	135[P]	37.5[P]	32.3[P]	28.3[P]	24.7[P]	26.7[P]	29.4[P]	29.8[P]	30.8[P]	23.6[P]	19.4[P]	15.9[P]	14.4[P]	15.9[P]	15.5[P]	13.6[P]	8.53[P,e]	11.7[P,e]	10.5[P,e]	12.1[P,e]	12.3[P,e]	9.81[P,e]	7.22[P,e]	7.52[P]	27.2[P]
Escondida Br 104.1	104.0																														
	103.5																														
	103.0																														
N. Socorro Div. Channel 102.5	102.5																														
	102.0																														
	101.5																														
Escondida Drain Outfall 101.0	101.0																														
	100.5																														
	100.0																														
	99.5																														
Otero Street 99.0	99.0																														
	98.5																														
	98.0																														
	97.5																														
	97.0																														
	96.5																														
	96.0																														
	95.5																														
	95.0																														
	94.5																														
Brown Arroyo 94.0	94.0																														
	93.5																														
	93.0																														
	92.5																														
	92.0																														
	91.5																														
	91.0																														
	90.5																														
Neil Cupp 90.2	90.0																														
	89.5																														
	89.0																														
	88.5																														
	88.0																														
	87.5																														
USGS @ Highway 380 (CFS)		62.4[P]	119[P]	67.2[P]	109[P]	258[P,e]	200[P,e]	64.0[P,e]	28.9[P,e]	13.1[P]	12.6[P]	10.3[P]	8.33[P]	7.55[P]	5.41[P]	3.61[P]	0.88[P]	0.28[P]	0.02[P]	0.00[P]	0.00[P]	0.00[P]	0.00[P]	0.00[P]	0.00[P]	0.00[P]	0.00[P]	0.00[P]	0.00[P]	0.00[P]	30.7[P]
San Antonio (U.S. 380) 87.1	87.0																														
	86.5																														
	86.0																														
	85.5																														
	85.0																														
	84.5																														
BDA North Boundary 84.1	84.0																														
	83.5																														
	83.0																														
	82.5																														
	82.0																														
	81.5																														
Realignment Channel Inlet 81.4	81.0																														
	80.5																														
	80.0																														
	79.5																														
Realignment Channel Outlet 79.4	79.0																														
BDA HQ 78.7	78.5																														
	78.0																														
Former Mid BDA Pump Site 77.6	77.5																														
	77.0																														
	76.5																														
	76.0																														
	75.5																														
	75.0																														
	74.5																														
	74.0																														
South BDA Boundary Pumps 73.8	73.5																														
	73.0																														
	72.5																														
	72.0																														
	71.5																														
	71.0																														
	70.5																														
	70.0																														
	69.5																														
	69.0																														
San Marcial RR Bridge 68.6	68.5																														
USGS @ San Marcial (CFS)		44.5[P,e]	28.0[P,e]	146[P,e]	104[P,e]	33.8[P,e]	217[P,e]	66.6[P,e]	5.90[P]	0.00[P]	0.00[P,e]	0.00[P,e]	0.00[P,e]	0.00[P,e]	0.00[P,e]	0.00[P,e]	0.00[P,e]	0.00[P,e]	0.00[P,e]	0.00[P,e]	0.00[P,e]	0.00[P,e]	0.00[P,e]	0.00[P,e]	0.00[P,e]	0.00[P,e]	0.00[P,e]	0.00[P,e]	0.00[P,e]	0.00[P,e]	0.00[P,e]
	68.0																														
	67.5																														
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	66.5																														
	66.0																														
	65.5																														
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Ft Craig 64.5	64.5																														
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	63.5																														
	63.0																														
	62.5																														
	62.0																														
	61.5																														
	61.0																														
	60.5																														
S Curve 60	60.0																														
	59.5																														
White Gate 59.2	59.0																														
	58.5																														
	58.0																														
	57.5																														
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	56.0																														
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October

Landmark	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Isleta Diversion 169.4	169.0																															
	168.5																															
	168.0																															
	167.5																															
	167.0																															
Alejandro Drain 166.6	166.5																															
	166.0																															
	165.5																															
240 Wasteway 165.2	165.0																															
Cottonwood Rd 164.5	164.5																															
USGSS @ Bosque Farms (CFS)		69.4[e]	110[r]	184[r,a]	205[r,a]	222[r,a]	224[r,a]	221[r,a]	223[r,a]	200[r,a]	198[r]	200[r]	218[r]	241[r]	226[r]	208[r]	200[r]	222[r]	236[r]	221[r]	217[r]	213[r]	205[r]	221[r]	189[r]	191[r]	172[r]	169[r]	170[r]	182[r]	199[r]	220[r]
	164.0																															
	163.5																															
	163.0																															
	162.5																															
	162.0																															
	161.5																															
Los Lunas (HWY 6) 161.4	161.0																															
	160.5																															
	160.0																															
	159.5																															
	159.0																															
	158.5																															
El Cerro Tome / Los Lunas Airport	158.0																															
	157.5																															
Los Lunas River Widening	157.0																															
Los Chavez Wasteway 156.7	156.5																															
	156.0																															
	155.5																															
	155.0																															
	154.5																															
	154.0																															
	153.5																															
	153.0																															
Peralta Wasteway 152.5	152.5																															
	152.0																															
	151.5																															
	151.0																															
	150.5																															
LP1DR (Allsups) 149.6	150.0																															
Belen Br (NM 6 Hwy 309) 149.5	149.5																															
	149.0																															
	148.5																															
	148.0																															
AT&SF RR 147.7	147.5																															
New Belen Wasteway 147.2	147.0																															
	146.5																															
	146.0																															
	145.5																															
	145.0																															
LP2DR 144.6	144.5																															
	144.0																															
Aerial Gas Line 143.7	143.5																															
	143.0																															
Feeder 3 Wasteway 142.7	142.5																															
	142.0																															
	141.5																															
	141.0																															
Jarales Rd Br 140.8	140.5																															
USGSS @ HWY 346 (CFS)		13.3[r]	35.3[r]	56.7[r]	79.6[r]	117[r]	134[r]	135[r]	139[r]	152[r]	137[r]	145[r]	146[r]	165[r]	176[r]	170[r]	165[r]	170[r]	186[r]	194[r]	179[r]	189[r]	188[r]	186[r]	198[r]	178[r]	183[r]	172[r]	174[r]	185[r]	191[r]	204[r]
Storrie Wasteway 140.1	140.0																															
	139.5																															
Abo Arroyo 139.3	139.0																															
	138.5																															
	138.0																															
Sabinal Drain Outfall 137.9	137.5																															
	137.0																															
	136.5																															
	136.0																															
	135.5																															
	135.0																															
	134.5																															
	134.0																															
	133.5																															
Abeytas Heading 134.4	133.0																															
	132.5																															
	132.0																															
	131.5																															
	131.0																															
Bernardo (U.S. 60 Br) 130.6	130.5																															
USGSS @ Bernardo (CFS)		0.05[r]	0.00[r]	15.5[r]	35.0[r]	80.5[r]	107[r]	111[r]	113[r]	128[r]	121[r]	130[r]	136[r]	157[r]	174[r]	175[r]	165[r]	162[r]	187[r]	196[r]	184[r]	184[r]	191[r]	187[r]	201[r]	186[r]	186[r]	171[r]	166[r]	186[r]	197[r]	207[r]
	130.0																															
	129.5																															
	129.0																															
	128.5																															
	128.0																															
	127.5																															
Lower San Juan Drain 127.2	127.0																															
Rio Puerco 126.6	126.5																															
	126.0																															
	125.5																															
	125.0																															
	124.5																															
La Joya 124	124.0																															
	123.5																															
	123.0																															
	122.5																															
Lower San Juan Drain 2 122.1	122.0																															
Sevilleta North Boundary 121.7	121.5																															
	121.0																															
	120.5																															
	120.0																															
	119.5																															
	119.0																															
Rio Salado 118.9	118.5																															
	118.0																															
	117.5																															
	117.0																															
	116.5																															

October

Landmark	RM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
San Acacia Diversion Dam 116.2	116.0																															
USGS @ San Acacia (CFS)		36.2	76.0	85.2	95.8	137	146	159	169	172	174	177	172	157	171	185	185	189	193	199	202	194	213	212	215	216	191	185	173	183	198	205
	115.5																															
	115.0																															
One Mile Stop 114.8	114.5																															
	114.0																															
	113.5																															
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	107.5																															
	107.0																															
Lemitar Diversion 106.7	106.5																															
	106.0																															
	105.5																															
	105.0																															
9 Mile Outfall 104.5	104.5																															
USGS @ Escondida (CFS)		35.7	71.9	84.4	102	122	144	149	144	156	158	151	154	157	170	178	178	176	178	190	197	191	202	206	207	221	197	195	187	190	205	207
Escondida Br 104.1	104.0																															
	103.5																															
	103.0																															
N. Socorro Div. Channel 102.5	102.5																															
	102.0																															
	101.5																															
Escondida Drain Outfall 101.0	101.0																															
	100.5																															
	100.0																															
	99.5																															
Otero Street 99.0	99.0																															
	98.5																															
	98.0																															
	97.5																															
	97.0																															
	96.5																															
	96.0																															
	95.5																															
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	94.5																															
Brown Arroyo 94.0	94.0																															
	93.5																															
	93.0																															
	92.5																															
	92.0																															
	91.5																															
	91.0																															
	90.5																															
Neil Cupp 90.2	90.0																															
	89.5																															
	89.0																															
	88.5																															
	88.0																															
	87.5																															
USGS @ Highway 380 (CFS)		103	48.1	108	82.2	55.7	86.0	92.0	89.9	98.4	96.7	99.8	102	101	111	127	138	144	148	163	175	170	169	184	180	186	167	157	142	129	146	161
San Antonio (U.S. 380) 87.1	87.0																															
	86.5																															
	86.0																															
	85.5																															
	85.0																															
	84.5																															
BDA North Boundary 84.1	84.0																															
	83.5																															
	83.0																															
	82.5																															
	82.0																															
	81.5																															
Realignment Channel Inlet 81.4	81.0																															
	80.5																															
	80.0																															
	79.5																															
Realignment Channel Outlet 79.4	79.0																															
BDA HQ 78.7	78.5																															
	78.0																															
Former Mid BDA Pump Site 77.6	77.5																															
	77.0																															
	76.5																															
	76.0																															
	75.5																															
	75.0																															
	74.5																															
	74.0																															
South BDA Boundary Pumps 73.8	73.5																															
	73.0																															
	72.5																															
	72.0																															
	71.5																															
	71.0																															
	70.5																															
	70.0																															
	69.5																															
	69.0																															
San Marcial RR Bridge 68.6	68.5																															
USGS @ San Marcial (CFS)		0.00	0.00	0.00	21.9	28.4	39.2	70.5	75.3	69.5	78.7	85.3	82.1	86.2	81.1	90.7	100	101	98.6	95.8	101	106	97.8	104	107	108	112	96.3	96.2	81.2	78.2	93.3
	68.0																															
	67.5																															
	67.0																															
	66.5																															
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Ft Craig 64.5	64.5																															
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	61.0																															
	60.5																															
S Curve 60	60.0																															
	59.5																															
White Gate 59.2	59.0																															
	58.5																															
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Appendix B. GeoSystems Job Safety Analysis Forms

GeoSystems Analysis, Inc.

PROJECT-SPECIFIC FIELD HEALTH AND SAFETY PLAN SIGNATURE PAGE

Project Information			
Project and Field Site Name	River Eyes Project		
Location	The project is located throughout the Rio Grande Corridor in Bernalillo, Valencia, and Socorro Counties, New Mexico		
Anticipated Start Date	4/15/2021	**Duration of Work**	To be determined, no later than 10/31

Name	**Email**	**Signature**	**Date**
Prepared by: I verify that I personally prepared this Field Health and Safety Plan, based on my review of the project and the associated hazards and health and safety requirements.			
Chad McKenna	chad@gsanalysis.com		**3/29/2021**

FIELD PERSONNEL ACKNOWLEDGEMENT SIGNATURE PAGE

I acknowledge that the safety concerns addressed in this Field Health and Safety Plan (HASP) have been communicated to me and that my questions regarding project safety have been answered to my satisfaction prior to the beginning of field work. I understand that failure to comply with the requirements outlined in this Field HASP may result in disciplinary action up to and including termination of employment.

Name	**Signature**	**Date**

SITE AND LOGISTICS INFORMATION

Project, Site, Communication, and Transportation/Travel	
Scope of Work and Activities Description	Conducting, regular, often daily, early morning field reconnaissance of Rio Grande flow conditions throughout the Middle Rio Grande (MRG) Valley in New Mexico. Fieldwork is conducted on foot and with all-terrain vehicles (ATVs) in sometimes remote portions of the state.
Site Information	Reconnaissance visits occur throughout the MRG, depending on flow conditions. Sites are potentially found on property owned and managed by federal and state agencies, Native American lands, private lands, and various municipalities. Only sites where access permission is authorized with a written permit should be entered. Land ownership is visible on electronic project maps within the Avenza Maps app. Most of the monitoring occurs within the Rio Grande's mainstem active channel where conditions are often muddy, contain varying volumes of flowing water, and adjacent floodplains commonly contain thick vegetation.
Communication Procedures	Check ins must occur daily. A GeoSystems group text thread will be used for regular communication amongst crew members. In addition, either the Project Manager (Chad McKenna), the Project Supervisor (Tyler Mobraten), or another pre-designated person will be always available via cell phone when staff are in the field. All crew members should notify the group thread after they have safely returned home or to the office. If staff feel unsafe for any reason, they should take steps to improve their immediate situation and then contact the Project Manager to discuss the situation and improve protocols to ensure sufficient safety measures are in place.
General Topics	Before entering the field, check upstream USGS stream flow monitoring gages. This is especially important during monsoon season. Under no conditions should staff enter the active channel during a flash flood or if they believe a flash flood is imminent. If field and/or gage conditions suggest there is a high risk of flash flooding, check upstream channel conditions from bridges or other readily accessible access points prior to entering the channel. Properly dispose of trash and remove litter as a courtesy. Stay hydrated. Wear appropriate clothing as weather conditions can change quickly. Ensure all required PPE and a first aid kit is accessible at all times. No fieldwork shall occur before sunrise, but vehicular travel to the site is permitted prior to daybreak. Be prepared to extinguish small fires, particularly if they are ignited by the ATV or our vehicle. Contact information, lock combinations, access permits, this HASP, and other information is contained within the River Eyes binder kept within each truck.
Field Transportation	4WD vehicle(s) with chocks, fire extinguisher, recovery boards, shovels, first aid kit, and other supplies to aid in self rescue/getting unstuck. Avoid having loose objects in vehicles. ATV's with winch, straps, helmet, and fire extinguisher. ATVs should not be driven on paved roads; they are only intended (and insured) to be used off road. Personnel can only operate ATVs after they are trained and certified. Helmets must be worn at all times when operating or riding on ATVs. GeoSystems vehicle inspection forms should be completed regularly. Additionally, inspect the ATV for mechanical or other physical damages prior to using each day. Any required service or maintenance should immediately be reported on the GeoSystems group text thread. The Project Supervisor will be maintaining ATVs on a regular maintenance schedule. A more detailed cleanup and inspection of equipment will be conducted at least once every two weeks to ensure the equipment is in safe and operable condition.

Project, Site, Communication, and Transportation/Travel	
Travel to Site	Crew will be mobilizing from Albuquerque, Socorro, and portions of Valencia County. Two 4WD vehicles will be dedicated to the River Eyes project along with two ATVs. Access behind locked gates will often be required. Gate keys will be stored inside vehicles. Also, lock combinations are available in the River Eyes binder within each vehicle.
Nearby Facilities	Emergency services are available in Albuquerque, Los Lunas, Belen, and Socorro. Use the field phone to locate the nearest medical office, if needed. Gas, food, water, etc. are available in multiple locations. Mechanics and tire shops are also available in Albuquerque, Los Lunas, Belen, and Socorro.
Cell Phone Coverage	Cellular signal is good overall, with occasional intermittency. Certain cell phone providers have more optimal coverage, for example, Verizon has coverage south of Bosque del Apache where other providers such as AT&T and Sprint do not. Typically a field cell phone will be provided to the crew in each reach.
Insurance	If an incident occurs that requires an insurance claim is filed, immediately contact GeoSystems Office Manager Bere Torres at (520) 465-4474 and the Project Manager (Chad McKenna). GeoSystems carries workman's compensation coverage, professional liability, automobile insurance that meets or exceeds industry standards and contract requirements. Insurance cards are also available within each vehicle.

JOB HAZARD ANALYSIS

Job Hazard Analysis – Consult with Project Manager and Safety Coordinator regarding appropriate training and documentation requirements based on hazards identified.	
COVID-19 Exposure Hazards	Per GeoSystems COVID-19 prevention measures, the following is implemented until safety restrictions are lifted by the Governor and the Reclamation Contracting Officer concurs: • Please inform the Project Manager of your vaccination status • If working in groups, face masks must be always worn • Social distance (6+ ft) should be maintained whenever possible • No more than 2 people may share a 4-door vehicle, with the passenger seated in the back seat on the righthand side • Frequent handwashing and disinfecting of shared touchpoints • Regular COVID testing for staff that will be sharing vehicles
Physical Demands	Manage fatigue, take breaks as needed. Sometimes prolonged ATV use. Hiking in slippery, uneven terrain sometimes through dense vegetation. Occasionally dramatic temperature swings from early morning to midday. High heat is possible. Procedures for mitigating hazards associated with terrain and weather are specified below.
Mental Demands	Early mornings and occasional long workdays may be mentally draining, reducing the ability for the field crew to maintain focus. The project involves rigorous field activities in remote locations, which requires focus and the ability to assess risk quickly and accurately. Sufficient staff are available to re-delegate monitoring days. Please contact the Project Manager if you are experiencing exhaustion, not able to focus, or have other concerns.

Job Hazard Analysis – Consult with Project Manager and Safety Coordinator regarding appropriate training and documentation requirements based on hazards identified.	
Work Tools	The standard work tools will be ATVs, measuring tapes, flow meter, floating ball, GPS enabled tablet or smartphone, electronic field maps, four-wheel drive vehicles, straps, loading ramps, and helmets. Proper strapping and securing of ATVs should always be employed in truck beds or trailers as instructed during the training day.
Expected Weather	High midday heat is possible, along with cold early morning conditions. For this project, the safe environment will be the field vehicle. A second hazard associated with the weather is flash flooding. This hazard will be mitigated by parking the vehicle on high ground above drainages. The active channel will not be entered, either in the ATV or on foot when there is flash flood risk. As stated above, always check gages and upstream river conditions prior to entering the channel. Do not enter the channel if intense precipitation is falling in the area and there is a high density of undammed arroyos in the reach.
Expected Terrain	Floodplain vegetation is dense. Expected hazards of this type of terrain consist primarily of steep slopes, loose rocks and other slip/trip hazards, especially along banks and levees, and overhanging branches. The slip/trip hazards will be mitigated by wearing appropriate footwear (ankle supporting boots with rough-terrain tread). Where appropriate., crew members may choose to employ a walking stick for assistance on steep slopes. The hazard of overhanging branches mainly involves small cuts and scrapes, but could be dangerous to the eyes.
Drinking Water Availability	☐ Plumbed water available ☐ Water cooler with ice ☒ Bottled water (please bring your own water in a refillable container to avoid creating plastic bottle waste) ☐ Natural source and treatment methods require specific discussion with Safety Coordinator (e.g., filtration, boiling, chemical disinfection)
Access to Shade/Shelter	☐ Building structures ☒ Trees ☐ Temporary Canopy/Tarp ☒ Vehicle with A/C
High Heat Procedures	☒ Direct supervision ☐ Buddy system ☒ Reliable cell or radio contact ☒ Other: Prior to fieldwork each day, check weather conditions and verify that appropriate clothing and plenty of water is available.
Security Hazards	Securely lock all vehicles and ensure that no valuables are in clear sight within the vehicle. On occasion, bonfire parties and open drug or alcohol use has been observed by River Eyes field staff. Avoid interactions with people engaging in illicit activities and report illegal actions to local authorities, as appropriate. In addition, if abandoned firearms, stolen vehicles, etc. are observed, please report to local authorities immediately. Any incidents reported to local authorities should also be reported to the Project Manager.

Job Hazard Analysis – Consult with Project Manager and Safety Coordinator regarding appropriate training and documentation requirements based on hazards identified.	
Deep Water	On rare occasions, deep water may be entered unexpectedly while travelling within the active channel either on foot or on ATV. If you fall into deep water, remain calm and swim facing downstream diagonally towards the shore. If the current is too strong, float on your back with your feet pointed downstream until you get to a calmer area where you can swim. Do not attempt to stand in deep, flowing water if you cannot see the ground surface, to avoid foot entrapment. If you do not know how to swim please notify the Project Manager prior to beginning work on this project.
Quicksand	At all costs, avoid entering quicksand areas with the ATVs or on foot. If you encounter quicksand or impassible muddy areas, notify the GeoSystems text message thread immediately. If you are stuck in quicksand with the ATV, use the winch to extract the ATV. A sand spike is also provided. If extraction isn't possible, call the Project Manager to arrange for backup.
Other Environmental Hazards	In the event of an active lightning storm, crew will return to the vehicle for safety and wait until the storm has cleared. We recommend waiting until the time between seeing lightning and hearing thunder is at least 30 seconds apart and the time interval between lightning and thunder is increasing. Vehicle will be parked in a high location, to avoid flash flood conditions. No drainages will be crossed in the event of a thunderstorm or if running water is present. Project team will monitor NWS weather alert systems and USGS flows, and ensure the field crew is aware of regional and local alerts by alerting the crew via cell phone. Slip/trip on steep slopes and loose rocks, muddy conditions, quicksand. Dress appropriately. No opened toed shoes are allowed. Quick dry, long sleeved shirts, and quick dry pants are recommended, along with a hat. Aggressive, venomous, or otherwise hazardous insects, snakes, and other wildlife may be present. Watch hand and foot placement. Crew will be equipped with snake gaiters. Avoid entering deep pools, quicksand, and excessively muddy areas whenever possible with the ATV. A winch is mounted to each ATV and safe operation will be covered in detail during the ATV operating training class. Field vehicles are also equipped with 4WD recovery tracks.
UAV (drone) Hazards	Unmanned Aerial Vehicles (UAV, or "drone") will only be operated by appropriately licensed personnel and in locations where Federal Aviation Administration (FAA) airspace authorizes UAV operation. If special FAA permissions are required due to airspace designations in certain areas, UAVs will only be operated after FAA permission is gained. Similarly, certain jurisdictions including Department of the Interior (DOI) property and private lands also require either pre-authorization from appropriate authorities prior to UAV operation or UAVs are not permitted at all. Do not fly a UAV within any location without Project Manager approval. Note: It is the responsibility of the pilot in command (PIC) to check airspace and Temporary Flight Restrictions prior to each flight.

Job Hazard Analysis – Consult with Project Manager and Safety Coordinator regarding appropriate training and documentation requirements based on hazards identified.	
Heavy Equipment Hazards	On occasion, heavy equipment is present on levee roads, within the mainstem channel, or along drains and ditches. Only approach heavy equipment on foot if you have proper PPE (hard hat and safety vest). If passing with a motor vehicle, ensure that the heavy equipment operator is aware of your presence, and initiate eye contact with the operator if possible. Follow their guidance and if they want you to pass, pass with caution.
Chemical Hazards	No chemicals will be used or encountered.
Excavation Hazards	No excavations will be conducted
Other Hazards	The hazards involved in this project are related to terrain and weather, and are described in detail (along with mitigation measures) above.
No-go Criteria	Flash flooding, weather conditions, or other security considerations may warrant "no-go" criteria. Please consult with the Project Manager or other designated personnel, if in question. Do not under any circumstances enter an area that feels unsafe or engage in any activity that unnecessarily threatens your wellbeing.
Injury Reporting Requirements	In the event of a serious injury, immediately dial 911 and if possible, notify the GeoSystems group thread and call the Project Manager or other designated safety officer. Maintain scene safety. Trained contractor personnel should render first aid to any incident victims as needed. Reclamation will also be notified about any injuries requiring medical care. If an incident requires immediate notification to government agencies, the area must be secured and nothing disturbed or removed after evacuation of the injured employee until approval from all Government Agencies, and GeoSystems representatives is received. OSHA must be notified within 8 hours of any such incident, as appropriate given the jurisdiction of the working location. In addition to serious injury or fatality, any medical incidents that create lost time or restricted duty should be reported to GeoSystems, Reclamation, and OSHA (if applicable). First aids and near misses should also be reported to GeoSystems in addition to anything that is required to be reported to OSHA.

FIRST AID AND OTHER TRAINING REQUIREMENTS

Health/First Aid and Training Information	
First Aid Training & Supplies	First aid training and type: previous Wilderness First Aid courses and certifications through NOLS (National Outdoor Leadership School) is encouraged. Location and description of group medical/first aid kit: Each truck and ATV will have a first aid kit. At least one backpack first aid kit will be with the crew at all times.

Health/First Aid and Training Information	
ATV Training	Training: ATVs can only be operated by individuals who have successfully completed the project ATV operation course and certification.
UAV Operation Certification	Unmanned Aerial Vehicles (UAV) or "drones" may only be operated by Federal Aviation Administration Licensed Part 107 pilots.

PERSONAL PROTECTIVE AND SAFETY EQUIPMENT REQUIREMENTS

Personal Protective Equipment (PPE) and Other Safety Equipment		
PPE (include notes as appropriate)	**Required**	**Recommended/ Optional**
Fluorescent safety vest	☒	☐
Hiking boots	☒	☐
Drinking water		
ATV helmet	☒	☐
Hard hat	☐	☒
Safety glasses	☒	☐
Gloves	☒	☐
Pants (no shorts)	☒	☐
Long-sleeved shirt	☐	☒
Sun hat	☒	☐
Insect repellant	☒	☐
Handkerchief for neck protection	☐	☒
Sunscreen	☒	☐
Personal floatation device (Reclamation approved)	☐	☒
Snake gaiters	☒	☒
Whistle	☒	☐
Fire extinguisher in the ATV	☒	☐
Vehicle first aid kit	☒	☐
Field first aid kit	☒	☐
Walking stick	☐	☒
Bear spray	☒	☐
Cell phone (protected in waterproof case)	☒	☐
Phone charger	☒	☐
Safety Supplies	Face masks for the duration of the COVID-19 pandemic safety restrictions.	
Vehicle Safety Requirements	Provide any special requirements for vehicles on the project: ☒ Fire extinguisher ☒ Spare tire ☒ Vehicle recovery device ☒ Other: First aid kit, tire repair kit, air compressor, straps, ATV ramps	

Appendix C. UAV Pilot Study

Appendix C: UAV Pilot Study

Background

As part of the 2021 RiverEyes monitoring season, GeoSystems Analysis (GeoSystems) implemented an Unmanned Aerial Vehicle (UAV, or "drone") pilot study to test whether drones could be used during future years to either replace ATVs under certain scenarios, or at the very least, supplement data collected on foot or by ATV. UAVs are an emerging technology that might increase efficiency, improve safety, and provide value-added datasets from RiverEyes monitoring in the future. Drones could allow access to inaccessible channel segments and expand the depth and potential of RiverEyes data for benefiting other monitoring and modeling projects. However, several potential uncertainties would need to be addressed before the RiverEyes project could fully or primarily rely on UAVs for project data acquisition. These limitations are mainly related to possible reductions in data acquisition efficiency and accuracy.

Accurately determining the extent of drying and quickly reporting this information to silvery minnow rescue crews is essential. UAVs might delay locating and reporting the extent of flow separation, particularly to the nearest 0.01 RM precision as current field techniques allow. Also, in some (potentially outlier) cases, UAVs may entirely prevent an observer from confidently and reliably detecting flow separation in the field, requiring post-processing and/or office review to validate dried extent. Flow separations may be short and difficult to discern from the narrow-connected ribbons of flow that often connect adjacent pools before continuous flow splits. Current Federal Aviation Administration (FAA) UAV regulations require that the Pilot in Command (PIC) has a clear, constant line of sight with the drone throughout the entire flight. Thus, it would be difficult to fly a UAV more than 1-2 miles away from the PIC, which could also reduce monitoring efficiency, as drying locations may change significantly from day to day.

To formally understand and document the potential benefits and challenges of UAV-based monitoring utility, efficiency, and accuracy, GeoSystems compared data gathered using a UAV to mapping conducted via current monitoring practices. The comparison was used to guide how UAVs could be utilized for the remaining years of the RiverEyes contract. Specific considerations and elements of the drone pilot study included:

- To inform the potential utility of UAVs during future years, the pilot study compared the efficiency and accuracy of standard (in person foot or ATV accessed) monitoring with UAV-based monitoring.
- During 2021, UAV imagery was limited to three-band, true-color imagery, though additional (e.g., near infrared) bands could be considered for future years. Also, during 2021, imagery was limited to two-dimensional products, though LiDAR and/or RTK integration might be possible during future years.

- Attempt to acquire imagery during rewetting events (if they occur when certified PIC is available). This was ultimately not possible because the channel had entirely reconnected before the study was implemented.
- Attempt to automate the creation of a UAV flight-line guided by the 2012 centerline.
- Determine whether it is realistic to use rotor based UAVs (e.g., DJI Phantom 4, DJI Mavic) given the battery life, or if a fixed wing is required.
- Is a separation easier to detect at a specific elevation threshold above ground?
- Is a straight overhead view versus angular view preferable for locating the extent of drying?
- Optimize battery management and charging protocols for this project.
- Optimize flight plans within UAV acquisition software (e.g., Drone Deploy and/or Pix4D).
- Determine specific conditions when drones might improve project safety by acquiring data in difficult to access sites.
- Identify situations when a visual observer would be needed to assist with data collection and at what point the cost of a second person could be justified.

UAV Evaluation Methods

Drone data were acquired with a DJI Mavic Air in each of the three study reaches on the dates listed below. Specific acquisition locations within a reach targeted RiverEyes monitoring priority locations where drying typically occurs.

- 10/17/2021 – Isleta Reach: Peralta Wasteway and Abeytas Heading areas
- 10/26/2021 – San Acacia Reach: Upstream of Highway 380
- 10/27/2021 – San Acacia Reach: within arroyos and the Socorro Flood Control Channel
- 11/3/2021 – San Acacia Reach: below Fort Craig from about river mile 64 to river mile 60
- 11/4/2021 – Angostura Reach: from Rio Bravo to the Wastewater Treatment Plant Outfall and at constrictions vulnerable to flow separation between Bridge Street and Rio Bravo.

An FAA licensed PIC led each flight while supported by at least one visual observer (VO). Flights were initially launched from within the riverbed and on the levee. The PIC and VO were typically stationary during the flight, but potential approaches for tracking drones from moving vehicles were also tested. Rio Grande flows were continuous by the time the first flight (10/17/2021) was completed, so it was not possible to check the viability of using UAVs to reliably detect flow separation within the Rio Grande active channel. However, drones were used to locate and map the extent of drying and isolated pools that formed in arroyos adjacent to the Rio Grande.

Daily RiverEyes monitoring is typically conducted either on foot or using ATVs. Two main techniques are used for RiverEyes monitoring: 1) rapid evaluation spot checks from known access points (typically range lines or other clearings); and 2) walking or riding the ATV within the channel to locate a specific flow separation point or confirm flow connectivity. When conducting spot checks, a crew member uses easy access points to rapidly check the river at various locations until visible flow terminates, and then travels the channel to map the extent of drying. The ATV is used to travel large sections of channel and inspect for any flow separations that might be missed during spot checks.

During the drone pilot study, we attempted to closely mimic conventional monitoring techniques by using the drone to spot check the river like spot checks completed on foot, as well as flying a longer section of river to monitor and map drying like conventional methods with an ATV.

Related to the second technique, FAA regulations require the drone to be always within visual line of sight (VLOS) of the PIC, which limits the distance the drone can be flown up or down the channel. However, according to Section 107.25 of the FAA regulations:

> "No person may operate a small unmanned aircraft system—
>
> (a) From a moving aircraft; or
>
> (b) From a moving land or water-borne vehicle unless the small unmanned aircraft is flown over a sparsely populated area and is not transporting another person's property for compensation or hire."

Environmental Limitations

There are times when environmental conditions preclude the use of UAVs for monitoring, such as during high winds in spring. Gusts above about 15 mph greatly increase the crash risk, especially during takeoff or landing operations. It's also important to note that the winds aloft are typically greater than the winds on the ground. Other examples of "no fly" weather include rain, snow, or fog. FAA regulations prohibit the use of drones if visibility drops below 3 statute miles. Also, excessive moisture in the air can cause damage to electronics, and if freezing occurs, water vapor can cause icing to form on the propellors, potentially causing a crash.

The most common environmental concern to mitigate is the sun. Throughout the San Acacia Reach and most of the Isleta Reach, the levee roads are in better driving conditions and landowner permission is generally easier to gain on the west side of the river. Thus, the UAV must fly directly into the sun when launching from the levee road during morning.

Birds are another hazard to drone use that must be considered. It is not uncommon for birds of prey or territorial birds to interfere with drone operations. This is especially a concern near any bridges over the river where swallows commonly nest. A visual observer can be used to help the PIC keep an eye out for any birds, however the flight will have to be aborted if it appears that birds will interfere with the flight to prevent damage to equipment or injury to wildlife.

Rules and Regulations

Drone use for the purpose of RiverEyes falls under FAA Part 107 regulations, so all flights must be conducted by a Part 107 licensed PIC, and all drones have to be registered with the FAA for commercial use. Depending on the frequency of drone use during future years, GeoSystems will have to keep multiple pilots on staff. Unlicensed staff members can be tasked as VOs to assist the PIC with watching for hazards such as birds and other aircraft. Drones are not permitted to fly more than 400 feet above ground level (AGL) and cannot be flown beyond the line of sight of the pilot. Most of the river corridor is in uncontrolled Class G airspace, with the exception of sections of the Angostura reach near the Albuquerque International Sunport, which are within Class C airspace.

Key Takeaway Results

- While current monitoring techniques provide efficient and accurate results, environmental factors can make walking and ATV travel challenging, inefficient, and at times unsafe. For example, after a storm pulse, the channel can become treacherous making it impossible to use the ATV. Dislodging stuck ATVs was a regular activity during the 2021 monitoring season. There are also certain sections of active channel that are very difficult to access, due to the perched height of the bank, sharp bankline gradient, and/or dense vegetation or deadfall in burn areas. A UAV clearly provides safer, more efficient, and vastly quicker access into less accessible locations.

- The UAV will be an invaluable tool to support spot checks on foot because the drone can be launched from anywhere on the levee road and not be limited to existing access points and/or rangelines. An observer can easily fly above the brush and check the river in areas where access would be difficult or impossible on foot or ATV. The viewing elevation of the drone also makes it easy to observe relatively large sections of river channel with a single spot check, as demonstrated in Figure 1 below.

Figure 1: Photo Taken at 150 feet AGL above RM 87.58 Note the US380 bridge 0.46 miles to the south.

- A VO is helpful in many situations, and occasionally necessary, depending on the complexity of the drone flight. Daily spot checks can be completed safely with only a PIC in the more rural sections of river, however visual observers should be employed in certain areas where birds or air traffic are a higher concern. This would include the Angostura reach due to increased air traffic in Class C airspace, and the Peralta segment of the Isleta reach because drying has historically occurred in immediate proximity to the Mid Valley Airpark.

- Spot checks can be conducted by flying manually without any special flight planning software or autopilot, however collecting supplemental data would require software such as Drone Deploy or PiX4D. Examples of this would be collecting geo-rectified imagery for the purposes of creating orthophotography. An autopilot software could

also be employed to smoothly fly down a section of channel in the case where a pilot is operating the UAV from a moving truck or ATV.

- Three batteries are sufficient for daily monitoring using spot checks in most cases. Batteries can be recharged in the truck using a 12v charger between sites. In the case of a more complex UAV operation, such as inundation mapping, a lithium generator would prevent having to carry fuel into the field and provide plenty of power to charge batteries in the field. Depending on the model, UAV batteries can be charged in 45-90 minutes, and offer up to 30 minutes of flight time. Multiple spot checks can be completed using a single battery.

- For mapping the extent of drying, hovering directly above the suspected extent and taking a photo straight down is a viable technique, particularly if also validated with traditional methods when the location is in question. An example of an extent of drying captured with a drone is shown in Figure 2 below.

- The GPS coordinates for the extent of drying can be extracted from the drone photo (EXIF) metadata and transcribed into a river mile from the field by plotting the point on top of the RiverEyes base map in Avenza Maps. The difference between the coordinates marked by a person on foot versus with the drone was only typically about 20 feet, or within 0.01 river miles.

- Ideal flight elevations for detecting drying appears to be between 100 and 200 feet AGL. At this height. The drone is well above the height of the tallest trees but flow conditions are also clearly visible. This elevation would also be above the typical flight elevation of songbirds.

- Challenges with the sun angle can be mitigated by flying at angles, rather than flying directly east into the sun, however it will limit the extent of channel that can be flown when performing spot checks from the levee road in some locations.

- There are certain areas along the Rio Grande that prohibit drone launching, such as the Bosque del Apache (BdA) and Sevilleta wildlife refuges. To implement drone use in these areas, special use permits will need to be obtained, however, BdA and Sevilleta staff both denied this type of special use permit in 2020 and 2021.

- Obtaining authorization to fly in Class C airspace for the purpose of this study was easily accomplished through the FAA LAANC system because the land above the river near the Sunport is gridded for auto approval up to 400-foot AGL. However, flights in the

Angostura reach must be planned beforehand to allow sufficient time to obtain authorization.

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Figure 1: Example of an extent of drying taken at 100' AGL

Appendix D. RiverEyes Landmark River Miles

Reach	Site	River Mile
Angostura	Angostura Dam	210.1
Angostura	Jemez River Confluence	208.57
Angostura	HWY 550 Bridge	203.81
Angostura	Rio Ranch North Beach	199.9
Angostura	Harvey Jones Canal	198.28
Angostura	Romero Road	197.97
Angostura	Sandia Lakes Wasteway	195.67
Angostura	Dixon Road	195.54
Angostura	North Diversion Channel	194.18
Angostura	South Boundary Sandia Pueblo	193.91
Angostura	Andrews Lane	193.87
Angostura	Cabezon Channel	192.66
Angostura	Upper Corrales Riverside Drain Outlet	192.14
Angostura	Alameda Bridge	192.07
Angostura	ABQ Drinking Water Diversion	191.76
Angostura	Calabacillas Arroyo	191.24
Angostura	Paseo del Norte Bridge	190.9
Angostura	Corrales Main Canal Wasteway	188.9
Angostura	Montano Bridge	187.87
Angostura	San Antonio Arroyo	187.02
Angostura	Cambell Rd Entrance	186.17
Angostura	Interstate 40 Crossing	184.97
Angostura	Central Wasteway	184.1
Angostura	Central Ave Bridge	183.4
Angostura	Tingley Beach	182.98
Angostura	Cesar Chavez Bridge	181.59
Angostura	Rio Bravo Bridge	178.41
Angostura	ABQ Wastewater Treatment Plant Outfall	177.71
Angostura	South Diversion Channel	177.12
Angostura	SW Valley Channel	176.39
Angostura	Brown Burn	174.73
Angostura	Valle de Oro	174.12
Angostura	Interstate 25 Crossing	172.59
Angostura	Isleta Pueblo North Boundary	172.4
Isleta	Isleta Diversion Dam	169.38
Isleta	Alejandro Drain	166.59
Isleta	Isleta Pueblo South Boundary	166.14
Isleta	240 Wasteway	165.18
Isleta	Los Lunas Highway 6	161.39
Isleta	Los Chavez Wasteway	156.68
Isleta	Peralta Main Canal Wasteway	152.45
Isleta	Lower Peralta Riverside Drain #1	149.59
Isleta	Belen Br (NM 6 Hwy 309)	149.51
Isleta	Belen Railroad Bridge	147.73
Isleta	New Belen Wasteway	147.16

Reach	Site	River Mile
Isleta	Lower Peralta Riverside Drain #2	144.6
Isleta	Aerial Gas Line	143.74
Isleta	Feeder 3 Wasteway	142.72
Isleta	Jarales Rd Br	140.83
Isleta	Storrie Wasteway	140.07
Isleta	Abo Arroyo	139.26
Isleta	Sabinal Drain Outfall	137.86
Isleta	Abeytas Heading	134.39
Isleta	Bernardo (U.S. 60 Bridge)	130.62
Isleta	San Francisco Riverside Drain	127.23
Isleta	Rio Puerco	126.63
Isleta	Lower San Juan Riverside Drain	126.45
Isleta	Lower San Juan Riverside Drain 2	122.06
Isleta	Sevilleta North Boundary	121.64
Isleta	Rio Salado	118.88
San Acacia	San Acacia Diversion Dam	116.17
San Acacia	Lemitar Diversion	106.65
San Acacia	9-Mile Outfall	104.44
San Acacia	Escondida Br	104.12
San Acacia	N. Socorro Div. Channel	102.48
San Acacia	Escondida Drain Outfall	100.9
San Acacia	Socorro Wastewater Treatment Plant Outfall (Otero St)	99.04
San Acacia	Brown Arroyo Wasteway	94
San Acacia	Neil Cupp Pumping Station	90.2
San Acacia	San Antonio (U.S. 380)	87.13
San Acacia	Socorro Drain	84.25
San Acacia	BDA North Boundary	84.1
San Acacia	North End of Pilot Channel	81.44
San Acacia	South End of Pilot Channel	79.4
San Acacia	Md BDA Pumps (Old Site)	77.55
San Acacia	BdA South Boundary	73.75
San Acacia	San Marcial RR Bridge	68.57
San Acacia	San Marcial Gauge	68.26
San Acacia	Fort Craig Bridge	64.5
San Acacia	S Curve	60
San Acacia	White Gate	59.21
San Acacia	Power Line	57.5

Appendix E. Summary Table Showing the Daily Discontinuous Length (in RMs) by Affected Segment

Summary of the total length (RMs) affected by drying for each day by segment, reach, and riverwide					
Date	***San Acacia Reach***	***Peralta Wasteway Segment***	***Abeytas Heading Segment***	***Isleta Reach Total***	***Riverwide Total***
6/15/2021	0	0	0	***0***	***0***
6/16/2021	0	0	0	***0***	***0***
6/17/2021	0.22	0	0	***0***	***0.22***
6/18/2021	15.92	0	0	***0***	***15.92***
6/19/2021	18.68	0	0	***0***	***18.68***
6/20/2021	21.56	0	0	***0***	***21.56***
6/21/2021	21.85	0	0	***0***	***21.85***
6/22/2021	24.08	0	0	***0***	***24.08***
6/23/2021	27.49	0	0	***0***	***27.49***
6/24/2021	31	0	0	***0***	***31***
6/25/2021	31.14	0	0	***0***	***31.14***
6/26/2021	31.76	0	0	***0***	***31.76***
6/27/2021	31.89	2.82	0	***2.82***	***34.71***
6/28/2021	30.47	1.8	0	***1.8***	***32.27***
6/29/2021	29.21	0	0	***0***	***29.21***
6/30/2021	31.24	0	0	***0***	***31.24***
7/1/2021	30.17	0	0	***0***	***30.17***
7/2/2021	30.42	0	0	***0***	***30.42***
7/3/2021	29.15	0	0	***0***	***29.15***
7/4/2021	0	0	0	***0***	***0***
7/5/2021	0	0	0	***0***	***0***
7/6/2021	0	0	0	***0***	***0***
7/7/2021	0	0	0	***0***	***0***
7/8/2021	0	0	0	***0***	***0***
7/9/2021	0	0	0	***0***	***0***
7/10/2021	0	0	0	***0***	***0***
7/11/2021	0	0	0	***0***	***0***
7/12/2021	0	0	0	***0***	***0***
7/13/2021	0	0	0	***0***	***0***
7/14/2021	0	0	0	***0***	***0***
7/15/2021	0	0	0	***0***	***0***
7/16/2021	0	2.12	0	***2.12***	***2.12***
7/17/2021	2.18	5.08	0	***5.08***	***7.26***
7/18/2021	18.99	6.87	0	***6.87***	***25.86***
7/19/2021	14.65	3.52	0	***3.52***	***18.17***
7/20/2021	9.28	6.43	0	***6.43***	***15.71***
7/21/2021	0	5.68	0	***5.68***	***5.68***
7/22/2021	0	5.39	0	***5.39***	***5.39***
7/23/2021	0	5.93	0	***5.93***	***5.93***
7/24/2021	0	5.1	0	***5.1***	***5.1***
7/25/2021	0	0	0	***0***	***0***
7/26/2021	0	5.34	0	***5.34***	***5.34***
7/27/2021	0	7.76	0	***7.76***	***7.76***
7/28/2021	0	0	0	***0***	***0***
7/29/2021	0	0	0	***0***	***0***

Summary of the total length (RMs) affected by drying for each day by segment, reach, and riverwide					
Date	***San Acacia Reach***	***Peralta Wasteway Segment***	***Abeytas Heading Segment***	***Isleta Reach Total***	***Riverwide Total***
7/30/2021	0	0	0	***0***	***0***
7/31/2021	0	0	0	***0***	***0***
8/1/2021	0	0	0	***0***	***0***
8/2/2021	0	0	0	***0***	***0***
8/3/2021	0	0	0	***0***	***0***
8/4/2021	0	0	0	***0***	***0***
8/5/2021	0	0	0	***0***	***0***
8/6/2021	0	0	0	***0***	***0***
8/7/2021	0	0	0	***0***	***0***
8/8/2021	0	1.46	0	***1.46***	***1.46***
8/9/2021	0	2.01	0	***2.01***	***2.01***
8/10/2021	0	1.6	0	***1.6***	***1.6***
8/11/2021	16.8	4.87	0	***4.87***	***21.67***
8/12/2021	21.19	5.83	0	***5.83***	***27.02***
8/13/2021	1.7	6.39	0	***6.39***	***8.09***
8/14/2021	0	6.15	0	***6.15***	***6.15***
8/15/2021	0	6.52	0	***6.52***	***6.52***
8/16/2021	0	5.99	0	***5.99***	***5.99***
8/17/2021	0	5.09	0	***5.09***	***5.09***
8/18/2021	0	4.64	0	***4.64***	***4.64***
8/19/2021	0	5.01	0	***5.01***	***5.01***
8/20/2021	0	5.23	0	***5.23***	***5.23***
8/21/2021	0	5.09	0	***5.09***	***5.09***
8/22/2021	16.87	5.14	1.43	***6.57***	***23.44***
8/23/2021	0	5.3	0	***5.3***	***5.3***
8/24/2021	0	7.27	1.17	***8.44***	***8.44***
8/25/2021	0	8.33	3.4	***11.73***	***11.73***
8/26/2021	0	8.93	3	***11.93***	***11.93***
8/27/2021	0	7.95	2.54	***10.49***	***10.49***
8/28/2021	0	7.82	0	***7.82***	***7.82***
8/29/2021	0	7.84	0.23	***8.07***	***8.07***
8/30/2021	0	8.76	1.21	***9.97***	***9.97***
8/31/2021	0	8.34	2.65	***10.99***	***10.99***
9/1/2021	0	8.24	3.39	***11.63***	***11.63***
9/2/2021	0	8.17	2.33	***10.5***	***10.5***
9/3/2021	0	4.81	2.5	***7.31***	***7.31***
9/4/2021	0	5.85	2.56	***8.41***	***8.41***
9/5/2021	0	5.66	0	***5.66***	***5.66***
9/6/2021	0	6.53	0	***6.53***	***6.53***
9/7/2021	0	6.42	2.05	***8.47***	***8.47***
9/8/2021	0	6.3	2.68	***8.98***	***8.98***
9/9/2021	5.74	6.21	3.32	***9.53***	***15.27***
9/10/2021	18.5	6.16	3.41	***9.57***	***28.07***
9/11/2021	18.14	6.16	3.41	***9.57***	***27.71***
9/12/2021	18.78	6.02	4.1	***10.12***	***28.9***

Summary of the total length (RMs) affected by drying for each day by segment, reach, and riverwide					
Date	***San Acacia Reach***	***Peralta Wasteway Segment***	***Abeytas Heading Segment***	***Isleta Reach Total***	***Riverwide Total***
9/13/2021	19.87	6	4.3	***10.3***	***30.17***
9/14/2021	20.21	5.94	4.46	***10.4***	***30.61***
9/15/2021	20.33	5.94	4.46	***10.4***	***30.73***
9/16/2021	22.58	5.83	4.52	***10.35***	***32.93***
9/17/2021	23.09	5.77	4.7	***10.47***	***33.56***
9/18/2021	23.28	5.69	4.82	***10.51***	***33.79***
9/19/2021	23.1	5.6	4.71	***10.31***	***33.41***
9/20/2021	23.09	4.72	4.94	***9.66***	***32.75***
9/21/2021	28.14	4.66	4.94	***9.6***	***37.74***
9/22/2021	28.98	4.65	4.82	***9.47***	***38.45***
9/23/2021	29.67	4.58	4.72	***9.3***	***38.97***
9/24/2021	29.06	4.55	4.47	***9.02***	***38.08***
9/25/2021	29.56	4.52	4.52	***9.04***	***38.6***
9/26/2021	29.09	4.41	4.19	***8.6***	***37.69***
9/27/2021	29.59	4.33	4.01	***8.34***	***37.93***
9/28/2021	29.57	4.28	3.96	***8.24***	***37.81***
9/29/2021	27.1	4.16	3.78	***7.94***	***35.04***
9/30/2021	29.51	4.16	3.73	***7.89***	***37.4***
10/1/2021	9.52	4.08	3.18	***7.26***	***16.78***
10/2/2021	6.09	4.08	3.18	***7.26***	***13.35***
10/3/2021	12.8	2.63	0	***2.63***	***15.43***
10/4/2021	0	0	0	***0***	***0***
10/5/2021	0	0	0	***0***	***0***
10/6/2021	0	0	0	***0***	***0***
10/7/2021	0	0	0	***0***	***0***
10/8/2021	0	0	0	***0***	***0***
10/9/2021	0	0	0	***0***	***0***
10/10/2021	0	0	0	***0***	***0***
10/11/2021	0	0	0	***0***	***0***
10/12/2021	0	0	0	***0***	***0***
10/13/2021	0	0	0	***0***	***0***
10/14/2021	0	0	0	***0***	***0***
10/15/2021	0	0	0	***0***	***0***
10/16/2021	0	0	0	***0***	***0***
10/17/2021	0	0	0	***0***	***0***
10/18/2021	0	0	0	***0***	***0***
10/19/2021	0	0	0	***0***	***0***
10/20/2021	0	0	0	***0***	***0***
10/21/2021	0	0	0	***0***	***0***
10/22/2021	0	0	0	***0***	***0***
10/23/2021	0	0	0	***0***	***0***
10/24/2021	0	0	0	***0***	***0***
10/25/2021	0	0	0	***0***	***0***
10/26/2021	0	0	0	***0***	***0***
10/27/2021	0	0	0	***0***	***0***

Summary of the total length (RMs) affected by drying for each day by segment, reach, and riverwide					
Date	***San Acacia Reach***	***Peralta Wasteway Segment***	***Abeytas Heading Segment***	***Isleta Reach Total***	***Riverwide Total***
10/28/2021	0	0	0	***0***	***0***
10/29/2021	0	0	0	***0***	***0***
10/30/2021	0	0	0	***0***	***0***
10/31/2021	0	0	0	***0***	***0***
MAX	31.89	8.93	4.94	***11.93***	***38.97***
Date of Max	6/27/2021	8/26/2021	9/20/2021	***8/26/2021***	***9/23/2021***
First Day Drying	6/17/2021	7/16/2021	8/22/2021	***7/16/2021***	***6/17/2021***
Last Day Drying	10/3/2021	10/3/2021	10/2/2021	***10/3/2021***	***10/3/2021***