Fluvial Geomorphological Assessment and Baseline Monitoring

Tributary of Etobicoke Creek

Snell's Hollow Secondary Plan
Town of Caledon, Ontario

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GEO MORPHIX
Geomorphology
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Observations

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1 Introduction and Background

GEO Morphix Ltd. (GEO Morphix) was retained to complete a fluvial geomorphological assessment and baseline surface water monitoring in support of the Snell's Hollow Secondary Plan in the Town of Caledon, hereafter referred to as the subject lands. The subject lands are bounded by Highway 410 to the north and east, Kennedy Road to the west, and Mayfield Road to the south. A portion of the Heart Lake Wetland Complex, a provincially significant wetland (PSW), is located in the southern portion of the subject lands. The wetland complex and associated drainage features are located within the Etobicoke Creek watershed and the jurisdiction of Toronto and Region Conservation Authority (TRCA).

The following activities were completed as part of the fluvial geomorphological assessment:

- Conduct rapid geomorphological assessments and collect general observations to document existing conditions
- Complete a detailed geomorphological assessment, including a survey of the longitudinal profile and six (6) cross sections (including two monumented cross sections)
- Complete grain size analysis using a modified Wolman (1954) pebble count or through collection of bed samples to characterize channel substrate and observe changes in bed composition over time, as appropriate
- Determine an erosion threshold for the reach downstream of Mayfield Road
- Collect time stamped monumented photographs to provide a record of existing conditions

The following activities were completed as part of the surface water baseline monitoring program:

- Install stream monitoring equipment in four (4) locations within the subject lands to record water level and temperature at 15-minute intervals
- Install pond water level monitoring equipment in open water features north and south of Mayfield Road to record water elevation at 15-minute intervals
- Record local atmospheric temperature and pressure at 15-minute intervals
- Install monumented cross-sections at each monitoring station for the periodic collection of velocity measurements
- Install a rain gauge in the subject lands to monitor precipitation at 15-minute intervals
- Collect time stamped monumented photographs to provide a record of existing conditions

2 Background Review and Desktop Assessment

2.1 Historical Assessment

A series of historical aerial photographs were reviewed to determine changes to the channel and surrounding land use and land cover. This information, in part, provides an understanding of the historical factors that have contributed to current channel morphodynamics and potentially how past changes may affect channel planform in the future. Aerial photographs from 1960 (1:25,000) and 1974 (1:25,000) from the National Air Photo Library, 1982 (1:30:000) from Kenting Earth Sciences Ltd. and recent satellite imagery (2005 to 2018) from Google Earth Pro were reviewed to understand site history. Copies of select imagery are provided in **Appendix A** for reference.

Since prior to 1960, the predominant land use within and upstream of the subject lands was agriculture. Natural areas associated with the Heart Lake Wetland Complex were present, although natural riparian vegetation was absent in the eastern portion of the PSW. Open pasture/cultivation occurred to the edge of the online pond and the likely previously channelized drainage feature immediately upstream. The drainage feature that flowed into the PSW from the northwest was also straightened prior to 1960, as it is visible as a linear feature adjacent to a farmstead. Roadwork was underway along Mayfield Road in the 1960 imagery and appeared to be related to the installation of hydro poles on the north side of the road, and potential grading/road widening. The portion of Heart Lake Road south of Mayfield Road also appeared to be under construction.

In the 1974 imagery, a minor disturbance in the PSW was visible, with access likely gained from the south side of the PSW. A homestead and driveway were also present north of Mayfield Road, approximately midway between Kennedy Road and Heart Lake Road. Overall, there was generally no discernable change to land use or drainage feature configuration between 1960 and 1982.

Between 1982 and 2005, the eastern portion of the PSW had begun to naturalize, with a minor increase in woody vegetation in previously cleared areas. By 2009, construction of Highway 410 north of the subject lands and the existing stormwater management pond (SWMP) immediately northeast of the intersection of Mayfield Road and Kennedy Road were underway. In addition, a retaining wall appeared to be constructed along Mayfield Road to accommodate road widening from 2 lanes to four lanes, as well as additional turning lanes. Lands generally consistent with the staked top of bank continued to naturalize, with a visible increase in woody vegetation.

In 2016, vehicle access to the valley is apparent in multiple locations, and a portion of the western section of the PSW downstream of the SWMP, was cleared and cultivated. By 2018, this area appeared to be no longer utilized.

Overall, historical land uses resulted in the channelization of a drainage feature in the northwest portion of the subject lands and likely the short section of drainage feature within the PSW upstream of the online pond north of Mayfield. Although there were no discernable changes to the alignment of minor drainage features that discharge to the PSW since 1960, portions of the PSW appeared to have been periodically accessed and modified. Likely the most significant changes to land use over the period of available imagery include the implementation of the SWMP that outlets to the upstream extent of the PSW and the gradual naturalization of areas below the top of bank.

2.2 Physiography and Geology

Channel morphodynamics are largely governed by the flow regime and the availability and type of sediments (i.e., surficial geology) within the stream corridor. These factors are explored as they not only offer insight into existing conditions, but also potential changes that could be expected in the future as they relate to a proposed activity.

The subject lands are located within the gently sloping drumlinized till plains of South Slope physiographic region (Chapman and Putnam, 2007). Published mapping indicates that the local surficial geology within and north of the subject lands consists of clay to silt-textured till derived from glaciolacustrine deposits or shale. These fine-grained till deposits are relatively resistant to erosion. In areas where wetlands are currently present, surficial geology consists of organic deposits (OGS, 2010).

2.3 Reach Delineation

Reaches are homogeneous segments of channel used in geomorphological investigations. They are studied semi-independently as each is expected to function in a manner that is at least slightly different from adjoining reaches. This allows for the meaningful characterization of a watercourse as the aggregate of reaches, or an understanding of a particular reach, for example, as it relates to a proposed activity. Reaches in the study area were delineated first through a desktop assessment using the Ministry of Natural Resources and Forestry (MNRF) stream layer and recent digital aerial photography from Google Earth Pro. Reaches were delineated based on changes in the following:

- Channel planform
- Channel gradient
- Physiography
- Land cover (land use or vegetation)
- Flow, due to tributary inputs
- Soil type and surficial geology
- Certain types of anthropogenic channel modifications

This follows scientifically defensible methodology proposed by Montgomery and Buffington (1997), Richards et al. (1997), Brierley and Fryirs (2005), and the Toronto and Region Conservation Authority (2004). A reach map is provided in **Appendix B**. Reaches were numbered from downstream to upstream to provide geographic context and then verified during field reconnaissance.

Five reaches were delineated within the subject lands. **Reach EC-1** extended from Mayfield Road to Heart Lake. **Reach EC-2** consisted of the pond feature north of Mayfield Road. **Reach EC-2a** extended from an agricultural field at the north extent of the subject lands to the pond feature. **Reach EC-3** contained the wetland that extended from Kennedy Road to the pond feature. **Reach EC-3a** extended from the property line of a landowner in the western extent of the subject lands to the wetland feature.

R.J. Burnside and Associates Limited (Burnside) completed headwater drainage feature assessments (HDFAs) within the subject lands in 2019. Existing conditions documented herein focus on geomorphologic observations and should be considered in conjunction with HDFA assessment results prepared by Burnside under separate cover.

3 Field Assessment

Field assessments of reaches within the subject lands were completed on May 10, 2019 and included the following activities:

- Observations of riparian conditions
- Estimates of bankfull channel dimensions, as appropriate
- Characterization of bed and bank material composition and structure
- Observations of erosion, scour, or deposition
- Collection of georeferenced photographs

These observations and measurements are summarized below and in **Table 1** in the following section. The descriptions are supplemented and supported with representative photographs, which are included in **Appendix C**. Reach summary field sheets are provided in **Appendix D**. The Rapid Geomorphological Assessment (RGA; MOE, 2003) and the Rapid Stream Assessment Technique (RSAT; Galli, 1996) were not applicable due to the poorly defined nature of the features.

3.1 General Reach Observations

Reach EC-1 began at the outlet of the pond feature (**EC-2**) and flowed through a steel culvert under Mayfield Road, continuing south through a confined valley towards Heart Lake. The reach had a low gradient and where defined, contained a wide, shallow channel. Riparian vegetation was mainly comprised of mature trees and was greater than 10 channel widths. Bank materials ranged from clay to sand and little to no bank erosion was observed. There were no riffles or pools. Bed materials consisted of organic material, clay, silt, and fine sand. Two trail crossings were present across the channel and valley. Woody debris was present in the channel but was not attributed to channel widening. **Reach EC-1** was chosen as the location for the detailed geomorphological assessment and erosion threshold analysis.

EC Reach -2 consisted of a pond feature that separated wetland **Reach EC-3** upstream to the west and Mayfield Road downstream to the southeast. **Reach EC-2a** extended from the border of an agricultural field to the north. This feature was characterized as poorly defined and had a moderate gradient. Burnside identified the upstream portion of this reach as a headwater drainage feature. The riparian vegetation buffer was continuous and comprised of grasses that extended more than 10 channel widths. The feature was extensively encroached with grasses, and a large, man-made woody debris pile was present in the middle of the reach. Bankfull width and depth at the downstream extent of the reach were 6.0 m and 0.4 m, respectively. Bank materials consisted of clay, silt, and sand. Bank angles ranged from 30 – 60 degrees with little to no erosion. There was no evidence of riffle-pool morphology. Bed materials were comprised of clay, silt, and sand.

Reach EC-3 consisted of a large wetland feature that began at the southwest extent of the subject lands. The southwest corner of the feature was bound by a retaining wall adjacent to Mayfield Road and the SWMP at the corner of Kennedy Road and Mayfield Road. Recorded velocity measurements showed that the wetland slowly drained eastwards into the pond feature (**EC-2**). Vegetation within the wetland consisted of cattails, deciduous trees, shrubs and grasses.

Reach EC-3a began at the property line of a landowner in the northwest corner of the subject lands. The reach was unconfined and consisted of a low gradient channelized feature that was moderately entrenched. Burnside identified the upstream portion of this reach as a headwater drainage feature. The riparian buffer zone was wide and mainly comprised of grasses. Average bankfull width and depth were 1.4 m and 0.3 m, respectively. Bank angles ranged from 60 – 90 degrees and the reach showed minimal signs of erosion. Bank materials consisted of clay, silt, and sand. Riffle-pool morphology was not present. Bed materials were comprised of sand and gravel.

Table 1. General channel characteristics

Reach	Average Bankfull Width (m)	Average Bankfull Depth (m)	Substrate		Riparian Vegetation	Notes
			Bed	Bank		
EC-1	17.95	0.32	Organic material, clay, silt, Find Sand	Clay, silt, sand	Mature trees	Wetland-like channel; confined valley; wide, shallow channel; no evidence of channel widening
EC-2	N/A-Pond Feature		N/A		Grasses	Outlets south to steel culvert crossing at Mayfield Road
EC-2a	6.0	0.4	Clay, Silt, Sand	Clay, Silt, Sand	Grasses	Extensive vegetation encroached; large man-made woody debris pile mid-reach
EC-3	N/A; Wetland Feature		N/A		Grasses	Unconfined; no defined channel; cattails, trees, shrubs, grasses present
EC-3a	1.4	0.3	Clay, Silt, Sand	Sand, Gravel	Grasses	Channelized feature; moderately entrenched

3.2 Detailed Geomorphological Assessment

A detailed geomorphological assessment was completed on May 6, 2019 within **Reach EC-1** as this reach was identified as the most sensitive to erosion. The specific location within the reach was chosen as it had the most defined section of channel. The assessment included a longitudinal survey of the channel bed and water level to determine gradients, and the completion of six detailed cross-section surveys. Two of these cross-sections were monumented and included the installation of erosion pins. At each cross section, bankfull geometry was recorded, as well as riparian conditions, bank material, bank height/angle, the presence of undercutting, and bank root density. Characterization of channel bed material at each cross section was completed using a modified Wolman (1954) pebble count technique or through collection of bed samples, as appropriate. Photographs of each cross section and both channel banks were also collected at the time of the survey. Results from the detailed assessment are summarized in **Table 2**. A complete summary of the detailed assessment is provided in **Appendix E**.

Table 2. Measured and computed channel parameters

Channel Parameter	EC-1
Measured	
Average bankfull channel width (m)	17.95
Average bankfull channel depth (m)	0.32
Bankfull channel gradient (%)	0.66
D_{50} (mm)	< 2.0
Manning's n roughness coefficient	0.050
Computed	
Bankfull discharge (m^3/s) *	4.30
Average bankfull velocity (m/s)*	0.76

* Based on Manning's Equation

4 Erosion Threshold Assessment

4.1 Methodology

Erosion thresholds are used to determine the magnitude of flow required to potentially entrain and transport bed and/or bank materials. As such, they may be used to inform erosion reduction strategies in channels influenced by conceptual flow management plans. The erosion threshold analysis provides a depth, velocity, or discharge at which sediment of a particular size may potentially be entrained. This is then field-validated through sediment transport observations under a range of flows. Due to the variability between bed and bank composition and structure, erosion thresholds are typically determined for both bed and bank materials. Threshold targets are determined using different methods that are dependent on channel and sediment characteristics. For example, thresholds for non-cohesive sediments are commonly estimated using a shear stress approach, similar to that of Miller et al. (1977), which is based on a modified Shield's curve. A velocity approach could also be applied. For non-cohesive materials, a method such as that described by Komar (1987), or empirically-derived values such as those compiled by Fischenich (2001) or Julien (1994), could be applied.

An erosion threshold is quantified based on the bed and bank materials and local channel geometry, in the form of a critical discharge. Theoretically, above this discharge, entrainment and transport of sediment can occur. The velocity, *U* is calculated at various depths, until the average velocity in the cross section slightly exceeds the critical velocity of the bed material. The velocity is determined using a Manning's approach, where the Manning's *n* value is visually estimated through a method described by Arcement and Schneider (1989) or calculated using Limerinos's (1970) approach. The velocity is mathematically represented as

$$U = \frac{1}{n} d^{2/3} S^{1/2} \qquad \text{[Eq. 1]}$$

where, *d* is depth of water, *S* is channel slope, and *n* is the Manning's roughness. The discharge is then calculated using the area of a typical cross section at that depth.

For the bank materials, following Chow (1959) in a simplified cross section, 75% of the bed shear stress acts on the channel banks. In a similar approach, the depth of flow is increased until the shear stress acting on the banks exceeds the resisting shear strength of the bank materials.

4.2 Results

Erosion thresholds were determined for the bed and bank materials within **Reach EC-1** of the Tributary of Etobicoke Creek. This reach was deemed to be the most sensitive to erosion of the reaches assessed, although it was still considered to be a low-risk environment as it was depositional.

Channel bed and bank materials were considered equivalent, and conservatively estimated to consist of a fairly compact to loose clay. A critical shear stress approach was taken using the criteria of Julien (1994) for this material, which has a critical shear stress of 6.2 N/m^2. This threshold shear stress was then applied to a representative cross section measured from the detailed assessment to calculate the critical discharge, or the discharge at which it is expected that sediment entrainment will begin to occur. The results of the erosion assessment are provided in **Table 4**. Using the criteria of Chow, the critical discharge to entrain the bed materials within **Reach EC-1**, was determined to be 1.25 m^3/s.

We note that **Reach EC-1,** as well as the others that may receive stormwater flows in the subject lands, are relatively resilient to potential erosion given their low gradient and wide, oversized bankfull channels. Consequently, we do not advocate for using the erosion threshold assigned to **Reach EC-1** to aid in designing the associated SWMP and outlet structure given the high volume of water the channel has the capacity to tolerate. Doing so could conceivably cause downstream erosion concerns in other reaches that are more sensitive to erosion. Instead, we suggest using the 24- or 48-hour detention of the 25 mm event to prevent erosion both within the study area, and downstream within Etobicoke Creek.

Table 3. Erosion thresholds and average channel parameters

Channel Parameter	Reach EC-1
Average bankfull channel width (m)	17.95
Maximum bankfull channel depth (m)	0.32
Average channel gradient (%)	0.66
Calculated bankfull discharge (m^3/s)	4.3

Channel Parameter	Reach EC-1
Bankfull shear stress (N/m^2)	20.53
Erosion thresholds for bed and bank materials	
Critical shear stress (N/m^2)	6.2
Critical discharge (m^3/s)	1.25

5 Erosion Hazard Assessment

Most watercourses in southern Ontario have a natural tendency to develop and maintain a meandering planform, provided there are no topographical constraints. A meander belt width assessment estimates the lateral extent that a meandering channel has historically occupied and will likely occupy in the future. This assessment is therefore useful for determining the potential hazard to proposed activities in the vicinity of a stream.

When defining the meander belt width for a creek system, the TRCA (2004) protocol treats watercourses differently based on the degree of valley confinement. Unconfined systems are those with poorly defined valleys or slopes well-outside where the channel could realistically migrate. In unconfined systems, the meander belt boundaries centre along the general valley orientation and are defined as parallel lines drawn tangentially to the outside bends of the most laterally extreme meanders within the reach (TRCA, 2004). Georeferenced historic aerial imagery can be used to examine past positions and configurations of the channel planform and to delineate the channel centreline, and its central tendency (i.e., meander belt axis).

Partially confined systems are those where meander bends are adjacent to only one valley wall and the watercourse is therefore restricted in migration and floodplain occupation on one side of the valley system. Confined systems are those where the watercourse position is such that meander bends are adjacent to both valley walls and meander migration is restricted on both sides of the valley.

Golder Associates Ltd. (2019) completed a slope stability assessment for the subject lands following MNR (2002) guidelines. Where the drainage associated with the wetland within the valley was within 15 m of the valley slope toe, a toe erosion allowance was recommended. From this location, a stable slope allowance was projected landward to determine the stable top of slope. Recommended toe erosion allowances ranging from 2 m to 7 m were applied across the subject lands. These recommendations adequately address the erosion hazard along the valley from a geomorphological perspective.

The Terms of Reference for the Comprehensive Environmental Impact Study and Management Strategy (CEISMP) notes that a meander belt width assessment and delineation of the 100-year erosion limit is required to characterize watercourses on the property. The drainage features assessed by GEO Morphix that outlet to the PSW were generally poorly defined and received run-off from agricultural fields on the tablelands. No evidence of active erosion was documented at the time of the assessment. As the drainage features are low order and showed very limited change in position over the period of available historical record, 100-year erosion limits could not be delineated. In addition, Reaches **EC-2a** and **EC-3a** are vegetation controlled, and have been assessed as headwater drainage features by Burnside. As these drainage features are unlikely to migrate or adjust their channel planform, delineating an erosion hazard specific to these features is not warranted.

6 Baseline Monitoring

During 2019 and 2020, flow monitoring was conducted at four (4) locations on the subject lands to assess water quantity characteristics. A map of monitoring locations is provided for reference in **Appendix B**. **Table 4**, below, summarizes monitoring activities at each location.

Table 4. Flow monitoring sites, sampling parameters, and sampling duration in 2019 and 2020

Station	Monitoring Duration		No. of Site Visits	
	2019	2020	2019	2020
W Inlet	April 4 – November 30	April 1 – November 30	8	9
S Inlet	April 4 – November 30	April 1 – November 30	8	9
Bridge	April 4 – November 30	April 1 – November 30	8	9
Outlet	April 4 – October 30*	April 1 – November 30	8	9

*Sensor stolen/lost between October 30, 2019 visit and sensor removal for the 2019 season

Activities at all locations included the following:

- Collect water level and temperature data at 15-minute intervals using a HOBO U20 pressure and temperature logger, with an additional control sensor to measure atmospheric pressure and air temperature on-site
- Record velocity measurements using Acoustic Doppler Velocimeter (ADV), when possible, to calculate discharge
- Collect monumented photographs of all sampling activities to verify location and timing

All sampling activities adhere to the Ontario Stream Assessment Protocol outlined by the Ontario Ministry of Natural Resources and Forestry (MNRF, 2017). A GEO Morphix rain gauge was installed on June 19, 2020 within the subject lands to provide accurate estimates of rainfall during the monitoring period. Data collected on site is compared to data collected from a Weather Underground weather station (Climate ID: ICALED1) located approximately 1.5 km west of the subject lands.

6.1 Instream Water Level Monitoring

Water level loggers recorded continuous pressure throughout the entire 2019 and 2020 monitoring season (April 1 – November 30). Discrete stilling well measurements were taken during each site visit in order to ensure data quality and data verification. We note that 2020 was a dry monitoring season on record with precipitation recorded on 72 of 244 monitoring days, with 12 occurrences of rainfall >10 m, compared to 25 in 2019.

Baseflow is the portion of streamflow derived from natural storage sources and does not include direct runoff from precipitation. There must not be any evidence in the stage discharge hydrograph of any recent storm events to be considered baseflow. Due to the intermittent/ephemeral nature of these watercourses, all four sites were dry following the spring freshet. During the spring of 2019, the baseflow levels of the **W inlet, S inlet, Bridge,** and **Outlet** sites were approximately 0.02 m, 0.13 m, 0.10 m, and 0.03 m, respectively. During spring of 2020, the baseflow levels of the **W inlet**, **S inlet**, **Bridge**, and **Outlet** sites were approximately 0.01 m, 0.04 m, 0.08 m, and 0.02 m, respectively. Following the spring freshet/seasonal flows, all monitoring sites remained dry between rain events, with short responses to precipitation events.

Water level responses are dependent on the magnitude of the rainfall event and antecedent conditions. The maximum water levels during 2019 for the **W Inlet** site was observed on May 25 following a 33.53 mm rain event. The maximum water depth at the **W Inlet** site was 0.09 m on this day. Maximum water depths at the **S Inlet, Bridge,** and **Outlet** sites were 0.20 m, 0.19 m, and 0.09 m respectively, recorded on April 26, following a 23.37 mm rain event.

The maximum water level observed during 2020 at the **W Inlet** was 0.17 m on August 2 following a 69.0 mm rain event. The maximum water depth at the **S Inlet** site was 0.14 m and occurred on June 11 following a 52.3 mm rain event. The maximum water depth recorded at the **Bridge** site was 0.13 m on April 1, during spring freshet. Maximum water depth at the **Outlet** was 0.05 m recorded on August 5 following 102.2 mm of rainfall in the previous 96 hours.

Minimum and maximum water levels recorded by monitoring equipment in 2019 and 2020 are summarized below in **Table 5**. The full set of continuous water level measurements, as well as discrete measurements, are provided in **Appendix F.**

Table 5. Minimum and maximum water depths at each sampling location

Sampling Location	2019 Water Depth (m)		2020 Water Depth (m)	
	Minimum	Maximum	Minimum	Maximum
W Inlet	0.00	0.09	0.00	0.17
S Inlet	0.00	0.20	0.00	0.14
Bridge	0.00	0.19	0.00	0.13
Outlet	0.00	0.09	0.00	0.05

6.2 Velocity and Discharge Monitoring

In addition to continuous water level and temperature monitoring, discrete measurements of velocity (**W Inlet, S Inlet,** and **Bridge** sites) were recorded, when possible. A summary of measured discharge at each sampling location is summarized below in **Table 6**.

Table 6. Average velocity and measured discharge at each sampling location in 2019

Measurement Date (yyyy-mm-dd)	Location	Average Velocity (m/s)	Discharge (m^3/s)
2019-04-09	W Inlet	0.0114	0.0002
	S Inlet	0	0
	Bridge	0	0
	Outlet	0.2734	0.0150
2019-05-10	W Inlet	0.0538	0.0009
	S Inlet	0	0

Measurement Date (yyyy-mm-dd)	Location	Average Velocity (m/s)	Discharge (m^3/s)
	Bridge	0.0400	0.0023
	Outlet	0.3392	0.0180
2019-06-20	W Inlet	0	0
	S Inlet	N/A*	N/A*
	Bridge	N/A*	N/A*
	Outlet	0.0170	0.0004

*Channel dry or too shallow for measurement

In 2019, due to the intermittent/ephemeral nature of these sites, velocity measurements were only possible during the spring freshet. A full record of attempted velocity readings is provided in **Appendix F**. Velocity measurements were not possible during monitoring visits at the **S Inlet** site. This is due to the lack of channel definition and wetland characteristics at the sensor location. Maximum discharges at the **W Inlet, Bridge,** and **Outlet** sites were 0.0009 m^3/s, 0.0025 m^3/s, and 0.0180 m^3/s, respectively, which occurred on May 10, 2019 following 21.59 mm of rainfall in 24 hours.

Due to drier conditions during the 2020 monitoring season, velocity measurements were not collected at the four locations during site visits. Low water levels and dense vegetation made conditions unfavourable for accurate acoustic doppler velocimeter measurements.

6.3 Pond Water Elevation Monitoring

During the 2020 monitoring season, HOBO U20 water level loggers were installed in two ponds within the subject lands. Water level was recorded at 15-minute intervals and converted to a geodetic datum. The **N Pond** site is located north of Mayfield Road at the south east extent of the subject lands. The pond stores water between the Bridge and the Outlet instream flow monitoring sites. The **S Pond** site is located south of Mayfield Road and has no discernable input or output channels. Pond monitoring locations are provided in **Appendix B**. A summary of minimum, maximum, and average water level elevations for both ponds is summarized below in **Table 7**.

Table 7. Pond monitoring minimum, maximum, and average pond water level elevations for each location in 2020

Sampling Location	Pond Water Level					
	Minimum		Maximum		Average	
	Depth (m)	Elevation (asl)	Depth (m)	Elevation (asl)	Depth (m)	Elevation (asl)
N Pond	0.74	255.020	0.97	255.253	0.84	255.118
S Pond	12.74	252.693	12.83	252.785	12.77	252.721

Maximum water elevation for **N Pond** was recorded by continuous pressure loggers on May 18, 2020 following a 25.9 mm rain event. Maximum water elevation for **S Pond** was recorded on sensor installation date of June 16, 2020. The pond was likely still within its drawdown time from a 52.3 mm rain event on June 10, 2020. Higher water level elevations are expected earlier in the monitoring season due to the wetter season, spring freshet, and long drawdown times of natural pond systems.

7 Summary and Conclusions

GEO Morphix was retained to complete a fluvial geomorphological assessment of the drainage features within the subject lands. This assessment included a background review, reach delineation and rapid field reconnaissance to confirm existing conditions. A detailed geomorphic assessment was completed downstream of the subject lands, along **Reach EC-1**, to determine an appropriate erosion threshold in support of the stormwater management strategy. The critical discharge to entrain the bed materials within **Reach EC-1** was determined to be 1.25 m^3/s. Notably, reaches within and downstream of the subject lands are relatively resilient to potential erosion due to their generally low gradients and wide, oversized bankfull channels. Consequently, the erosion threshold assigned to **Reach EC-1** could potentially cause downstream erosion concerns in other reaches that are more sensitive to erosion. Rather, the 24- or 48-hour detention of the 25 mm event is recommended to prevent erosion both within the study area, and downstream within Etobicoke Creek.

Golder Associates Ltd. (2019) completed a slope stability assessment for the subject lands following MNR (2002) guidelines. As the PSW and associated drainage features are contained within a defined valley, recommended toe erosion allowances ranging from 2 m to 7 m were applied. These recommendations adequately address the erosion hazard along the valley from a geomorphological perspective. Meander belt widths and 100-year erosion migration rates were not delineated as the minor drainage features that traverse the valley slope were assessed to be headwater drainage features, were vegetation controlled, and are unlikely to migrate or adjust their channel planform.

Water level and temperature data were collected at 15-minute intervals at 4 sites within the subject lands in 2019 and 2020. Monumented cross sections were installed at each site to collect periodic velocity measurements to determine discharge. Monitoring results revealed that these drainage features are ephemeral, as they only contained water during the spring freshet.

We trust this report meets your requirements. Should you have any questions please contact the undersigned.

Respectfully submitted,

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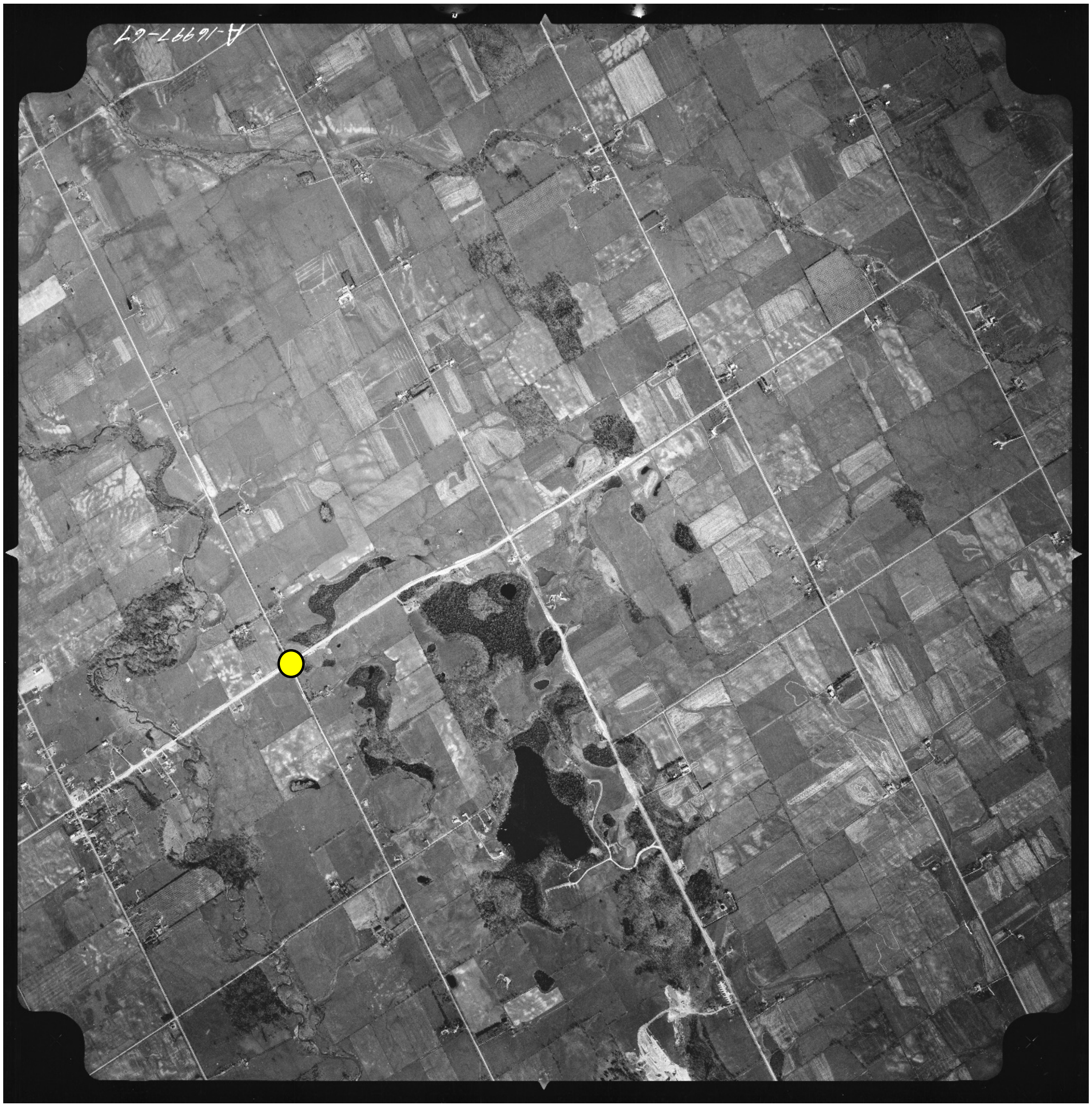
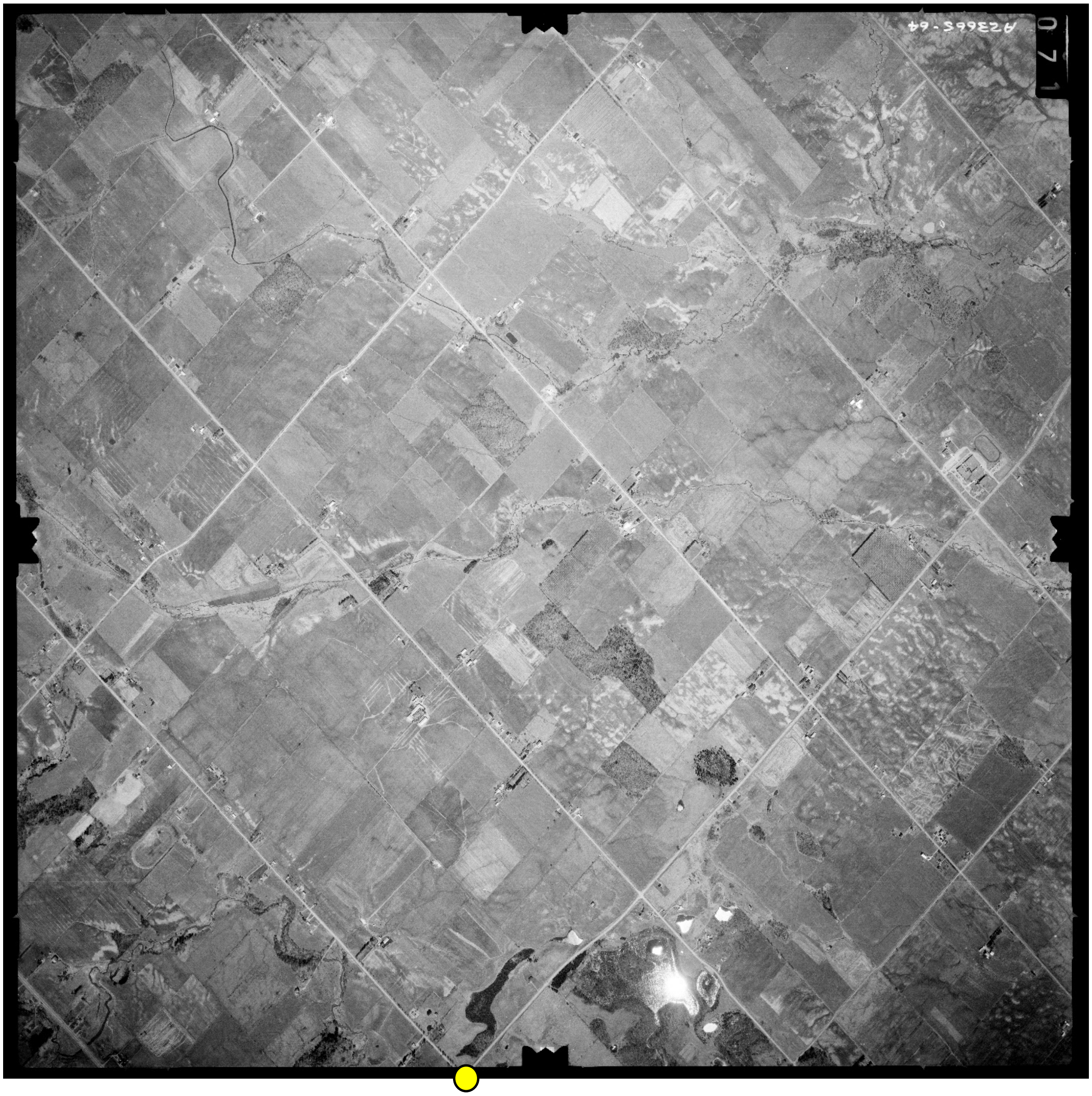
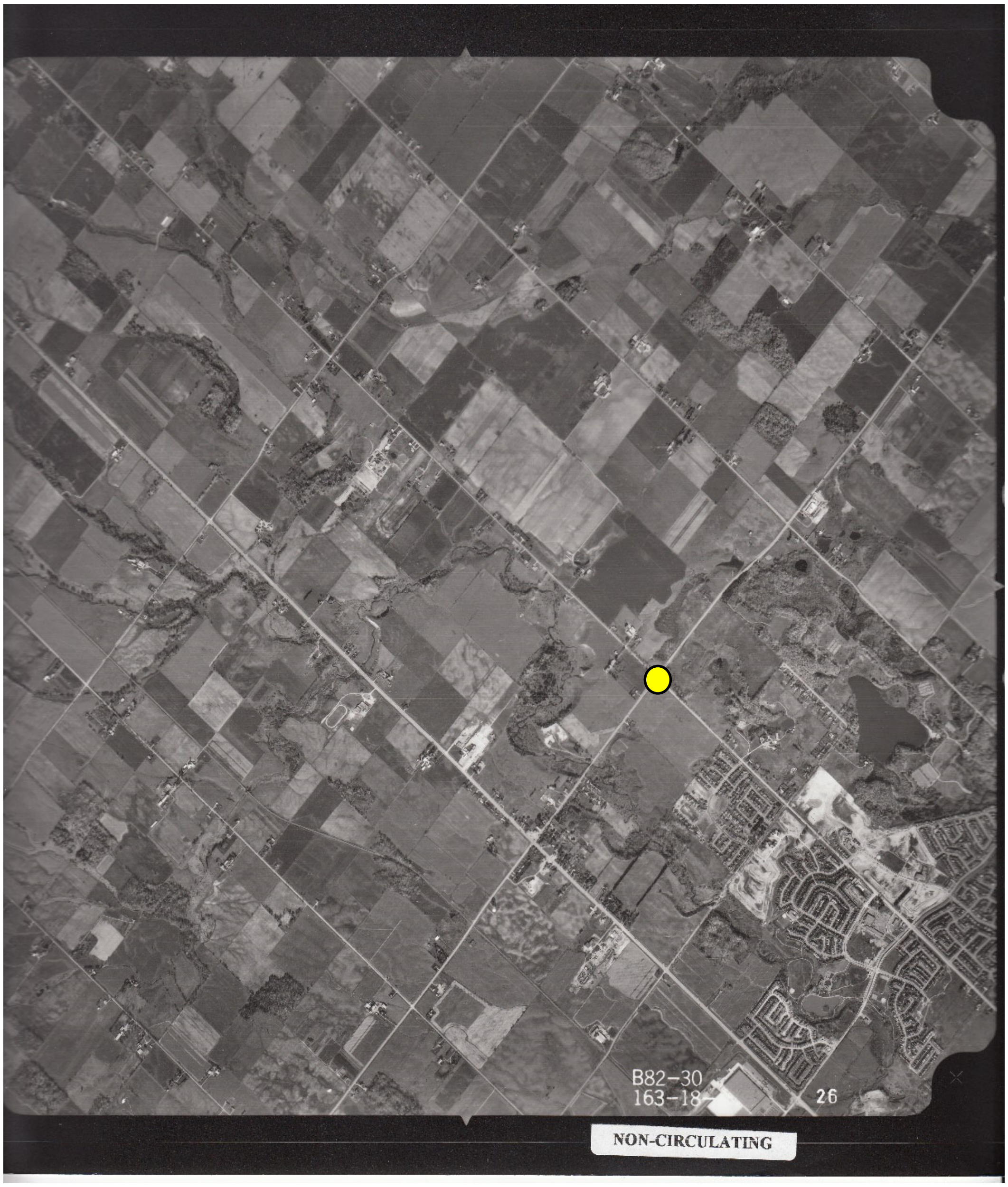
Appendix A
Historical Aerial Imagery



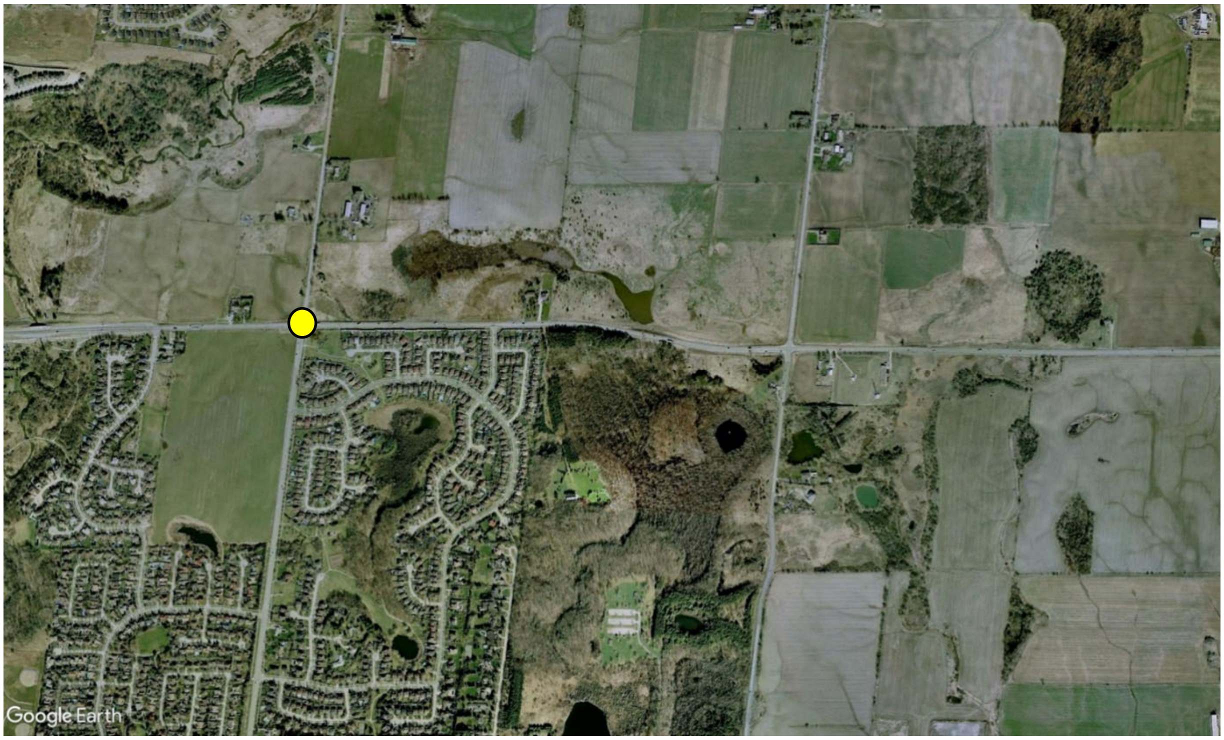
Location: Mayfield Road and Kennedy Road (yellow dot), Town of Caledon
Year: 1960
Scale: 1:25,000
Source: National Air Photo Library



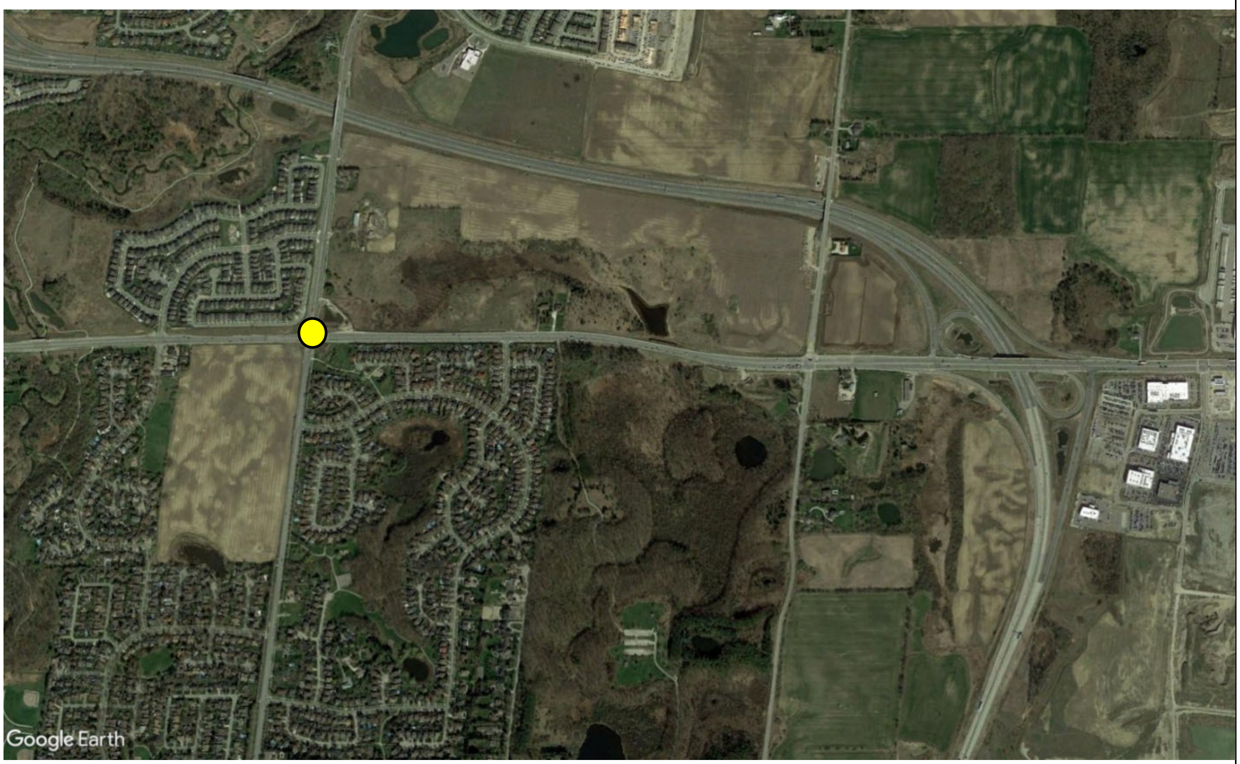
Location: Mayfield Road and Kennedy Road (yellow dot), Town of Caledon
Year: 1974
Scale: 1:25,000
Source: National Air Photo Library



Location: Mayfield Road and Kennedy Road (yellow dot), Town of Caledon
Year: 1982
Scale: 1: 30,000
Source: Kenting Earth Sciences Ltd.

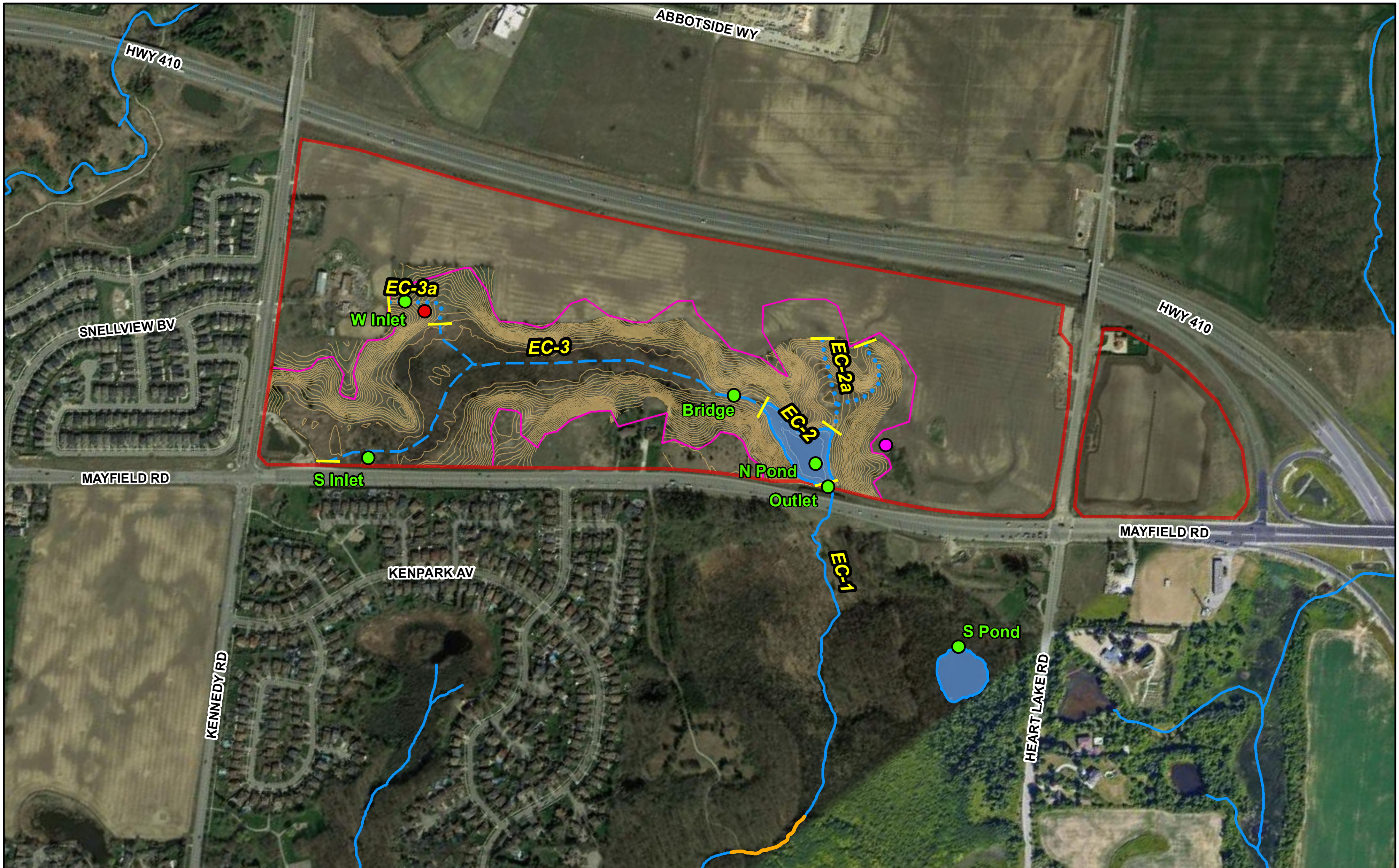


Location: Mayfield Road and Kennedy Road (yellow dot), Town of Caledon
Year: 2005
Scale: N/A
Source: Google Earth Pro



Location: Mayfield Road and Kennedy Road (yellow dot), Town of Caledon
Year: 2018
Scale: N/A
Source: Google Earth Pro

Appendix B
Reach Delineation and Monitoring Station Locations



Legend

- Reach Break and Label
- Atmospheric Sensor
- Pressure Logger
- Rain Gauge
- Top of Bank*
- Detailed Assessment
- Watercourse
- Wetland
- Headwater Drainage Feature
- Contour (0.5 m)
- Waterbody
- Secondary Plan Area

*Staked by TRCA (Oct. 23, 2018) and Biason Surveying Inc. (Sept. 20, 2011)

Reach Delineation and Monitoring Station Locations

Tributary of Etobicoke Creek

Snell's Hollow Secondary Plan Area

GEO MORPHIX™

0 50 100 200

Metres

N

Imagery: Google Earth Pro, 2018.
Top of bank: GSAI, 2019.
Reach break and Label, Monitoring locations, and Detailed assessment: GEO Morphix Ltd., 2019.
Watercourse, Wetland, and Headwater Drainage Feature: MNRF and GEO Morphix Ltd., 2019.
Contour and Waterbody: GEO Morphix Ltd., 2020.
Printed: February 2021. PN19033. Drawn By: W.B., M.H., T.R., S.S.

Appendix C
Photographic Record

Photo 1
Tributary of Etobicoke Creek
Reach EC-1 Cross section 1

Channel flowed through a confined, wooded valley with a low gradient. Yellow arrow denotes flow direction.

Photo 2
Tributary of Etobicoke Creek,
Reach EC-1 Cross section 1

Woody debris present in the channel was not attributed to channel adjustment (e.g. widening or planform adjustment) as there was limited erosion in the reach.

Photo 3
Tributary of Etobicoke Creek
Reach EC-1 Cross section 2

Channel was wide and shallow, with low bank angles on both sides.

Photo 4
Tributary of Etobicoke Creek,
Reach EC-1 Cross section 2

View of one of two pedestrian crossings observed in the reach.

Photo 5 **Tributary of Etobicoke Creek** **Reach EC-1 Cross section 3-M**	 Representative view of one of two monumented cross sections installed as part of the detailed geomorphological assessment.
Photo 6 **Tributary of Etobicoke Creek** **Reach EC-1 Cross section 3-M**	 Vegetation established in the channel bed was indicative of low flow velocities

Photo 7 Tributary of Etobicoke Creek Reach EC-1 Cross section 4-M	 Channel showed wetland-like characteristics and contained clay, silt and sand substrates. No riffles or pools were present.
Photo 8 Tributary of Etobicoke Creek, Reach EC-1 Cross section 4-M	 View of the left bank and associated riparian vegetation, which provided shade to the feature.

Photo 9 Tributary of Etobicoke Creek Reach EC-1 Cross section 5	
	Photo taken from the downstream trail crossing facing upstream.
Photo 10 Tributary of Etobicoke Creek Reach EC-1 Cross section 5	
	Photo taken facing downstream towards tail crossing, near the downstream extent of the detailed assessment.

Photo 11
Tributary of Etobicoke Creek
Reach EC-1 Cross section 6

Photo taken facing upstream towards trail crossing.

Photo 12
Tributary of Etobicoke Creek
Reach EC-1 Cross section 6

Photo taken from the trail crossing downstream into the reach.

Photo 13 Tributary of Etobicoke Creek, Reach EC-2	
	Photo taken from the upstream extent of the reach showing the open water feature.
Photo 14 Tributary of Etobicoke Creek Reach EC-2	
	Photo taken from Mayfield Road, facing north towards the pond.

Photo 15 **Tributary of Etobicoke Creek** **Reach EC-2a**	
	View of conditions mid-reach. Flows drain from adjacent agricultural fields and flow downslope to the pond feature.
Photo 16 **Tributary of Etobicoke Creek** **Reach EC-2a**	
	Photo taken from mid-reach towards the pond feature. The channel was poorly defined and lacked riffles and pools

Photo 17
Tributary of Etobicoke Creek
Reach EC-2a

A large brush pile was present mid-reach.

Photo 18
Tributary of Etobicoke Creek,
Reach EC-3

View from the southwest corner of the subject lands. The wetland receives input from an adjacent stormwater management pond.

Photo 19
Tributary of Etobicoke Creek
Reach EC-3

Middle of the wetland feature, where standing water was present.

Photo 20
Tributary of Etobicoke Creek
Reach EC-3

Photo taken from the west side of **Reach EC-3**, facing east across the wetland feature towards Mayfield Road.

Photo 21 **Tributary of Etobicoke Creek** **Reach EC-3**	 Photo taken near the **W Inlet** flow monitoring station facing northeast.
Photo 22 **Tributary of Etobicoke Creek** **Reach EC-3**	 Photo taken near the **Bridge** flow monitoring site facing southwest.

Photo 23 Tributary of Etobicoke Creek Reach EC-3a	
	Photo taken at the **W Inlet** flow monitoring site facing downstream. Reach was a ditch feature draining a property upstream.
Photo 24 Tributary of Etobicoke Creek Reach EC-3a	
	Photo taken facing upstream.

Photo 25
Tributary of Etobicoke Creek,
Flow Monitoring Site: W Inlet

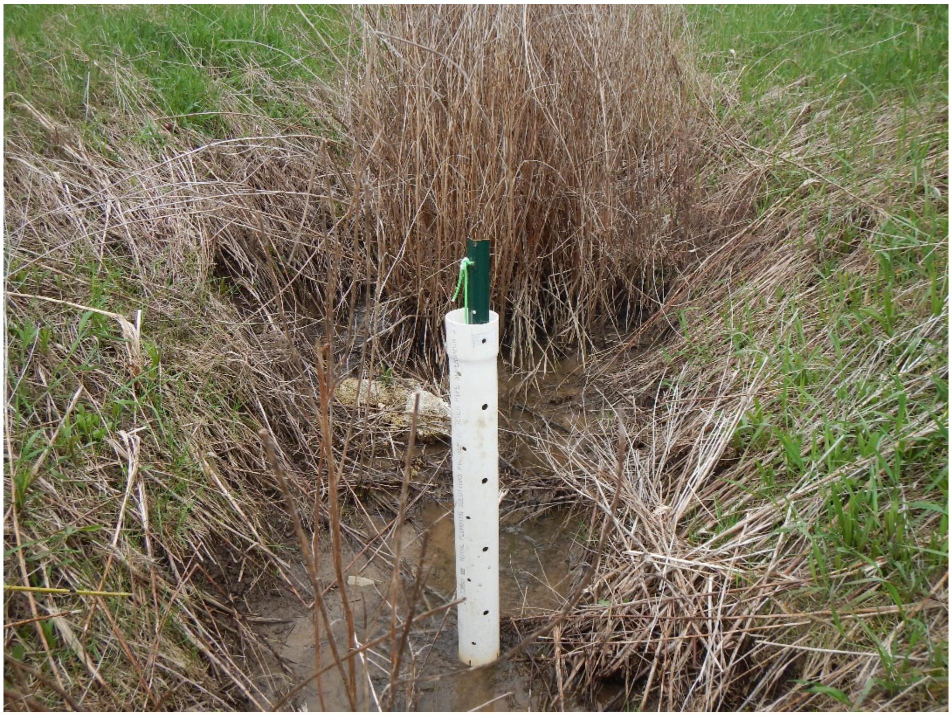


Photo taken facing upstream after a 21.59 mm rain event.

Photo 26
Tributary of Etobicoke Creek
Flow Monitoring Site: W Inlet

Photo taken facing site showing baseline conditions.

Photo 27 **Tributary of Etobicoke Creek** **Flow Monitoring Site: S Inlet**	 Photo taken facing downstream after a 21.59 mm rain event.
Photo 28 **Tributary of Etobicoke Creek** **Flow Monitoring Site: S Inlet**	 Photo taken facing upstream showing baseline conditions.

Photo 29 Tributary of Etobicoke Creek Flow Monitoring Site: Bridge	 Photo taken facing upstream after a 21.59 mm rain event.
Photo 30 Tributary of Etobicoke Creek Flow Monitoring Site: Bridge	 Photo taken facing upstream showing baseline conditions.

Photo 31 Tributary of Etobicoke Creek Flow Monitoring Site: Outlet	 Photo taken facing downstream towards the Mayfield Road culvert after a 21.59 mm rain event.
Photo 32 Tributary of Etobicoke Creek Flow Monitoring Site: Outlet	 Photo taken facing downstream showing baseline conditions.

Appendix D
Field Observations

GEO | MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics

Project Code: PN 19033

Date:	2019-05-10	**Stream/Reach:**	Pond U/S Mayfield Rd. / EC-2
Weather:	Overcast 8°C	**Location:**	Mayfield Rd + Kennedy Rd
Field Staff:	LG + KIM	**Watershed/Subwatershed:**	Etobicoke Crk
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 3 **Valley Type** (Table 2): 3 **Channel Type** (Table 3): NA **Channel Zone** (Table 4): NA **Flow Type** (Table 5): NA ☐Groundwater Evidence: None

Riparian Vegetation

Dominant Type: (Table 6) 3
Species: ______

Coverage: ☐ None ☐ Fragmented ☒ Continuous

Channel widths: ☒ 1-4 ☐ 4-10 ☐ > 10

Age Class (yrs): ☐ Immature (<5) ☒ Established (5-30) ☐ Mature (>30)

Encroachment: (Table 7) 1

Aquatic/Instream Vegetation

Type (Table8) NA Coverage of Reach (%) 0

Woody Debris: ☐ Present in Cutbank ☐ Present in Channel ☒ Not Present

Density of WD: ~~☐ Low ☐ Moderate ☐ High~~ WDJ/50m: NA

Water Quality

Odour (Table 16) 1
Turbidity (Table 17) 1

Channel Characteristics

Sinuosity (Type) (Table 9) NA **Sinuosity (Degree)** (Table 10) NA **Gradient** (Table 11) NA **Number of Channels** (Table 12) NA

Entrenchment (Table 13) NA **Type of Bank Failure** (Table 14) NA **Downs's Classification** (Table 15) NA

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	N/A ☐	☐	☐	☐	☐	☐	☐
Pool Substrate	N/A ☐	☐	☐	☐	☐	☐	☐
Bank Material	☒	☐	☐	☐	☐	☐	☐

Bankfull Width (m) NA → **Wetted Width (m)** NA →

Bankfull Depth (m) NA → **Wetted Depth (m)** NA →

Riffle/Pool Spacing (m) NA **% Riffles:** NA **% Pools:** NA **Meander Amplitude:** NA

Pool Depth (m) NA **Riffle Length (m)** NA **Undercuts (m)** NA **Comments:** Pond.

Velocity (m/s) NA → **Wiffle ball / ADV / Estimated**

N/A

Bank Angle	**Bank Erosion**
☐ 0 – 30	☐ < 5%
☐ 30 – 60	☐ 5 – 30%
☐ 60 – 90	☐ 30 – 60%
☐ Undercut	☐ 60 – 100%

Notes:

Completed by: [signature] Checked by: ______

GEO | MORPHIX
Geomorphology
Earth Science
Observations

Reach Characteristics

Project Code: PN19033

Date:	2019-05-16	**Stream/Reach:**	N inlet of Wetland / EC-2a
Weather:	overcast, 8°C	**Location:**	Mayfield Rd @ Kennedy Road
Field Staff:	LG + WM	**Watershed/Subwatershed:**	Etobicoke Crk.
UTM (Upstream)	595897.89 m E 4845049.02 m N	**UTM (Downstream)**	595954.91 m E 4844971.78 m N

Land Use (Table 1): 3 **Valley Type** (Table 2): 2 **Channel Type** (Table 3): 11 **Channel Zone** (Table 4): 2 **Flow Type** (Table 5): 3 ☐ Groundwater Evidence: ____________

Riparian Vegetation

Dominant Type: (Table 6) 3

Species: ____________

Coverage: ☐ None ☐ Fragmented ☒ Continuous

Channel widths: ☐ 1-4 ☐ 4-10 ☒ > 10

Age Class (yrs): ☒ Immature (<5) ☐ Established (5-30) ☐ Mature (>30)

Encroachment: (Table 7) 4

Aquatic/Instream Vegetation

Type (Table8) 1 Coverage of Reach (%) 100

Woody Debris: ☐ Present in Cutbank ☒ Present in Channel ☐ Not Present

Density of WD: ☒ Low ☐ Moderate ☐ High

WDJ/50m: 1

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 1

Channel Characteristics

Sinuosity (Type) (Table 9): 2

Sinuosity (Degree) (Table 10): 1

Gradient (Table 11): 2

Number of Channels (Table 12): 1

Entrenchment (Table 13): 1

Type of Bank Failure (Table 14): 1

Downs's Classification (Table 15): d

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	N/A	☐	☐	☐	☐	☐	☐
Pool Substrate	☒	☒	☐	☐	☐	☐	☐
Bank Material	☒	☒	☐	☐	☐	☐	☐

Bankfull Width (m)	6	N/A	N/A
Bankfull Depth (m)	0.4	N/A	N/A
Wetted Width (m)	4	N/A	N/A
Wetted Depth (m)	0.05	N/A	N/A

Riffle/Pool Spacing (m): N/A % Riffles: N/A % Pools: N/A Meander Amplitude: N/A

Pool Depth (m): N/A Riffle Length (m): N/A Undercuts (m): N/A

Velocity (m/s): 0 Wiffle ball / ADV / Estimated

Comments: Drainage feature from Ag. field

Bank Angle: ☐ 0 – 30 ☒ 30 – 60 ☒ 60 – 90 ☐ Undercut

Bank Erosion: ☒ < 5% ☐ 5 – 30% ☐ 30 – 60% ☐ 60 – 100%

Notes: Large Man-made WDJ halfway down reach. No riffles or pools

BFW and BFD taken at DS end of reach

Completed by: LG Checked by: ________

Reach Characteristics

Project Code: PN19033

GEO | MORPHIX Geomorphology Earth Science Observations

Date:	2019-05-10	**Stream/Reach:**	Wetland US Mayfield Rd. / EC-3
Weather:	Overcast 8°C	**Location:**	Mayfield Rd. @ Kennedy Road
Field Staff:	LG + WM	**Watershed/Subwatershed:**	Etobicoke Crk.
UTM (Upstream)	595371.06 mE 4844455.82 m N	**UTM (Downstream)**	596062.82 mE 4844847.98 m N

Land Use (Table 1): 3 **Valley Type** (Table 2): 3 **Channel Type** (Table 3): N/A **Channel Zone** (Table 4): N/A **Flow Type** (Table 5): N/A ☐ Groundwater Evidence: ______

Riparian Vegetation

Dominant Type: (Table 6) 3

Species: ______

Coverage: ☐ None ☐ Fragmented ☒ Continuous

Channel widths: ☒ 1-4 ☐ 4-10 ☐ > 10

Age Class (yrs): ☐ Immature (<5) ☒ Established (5-30) ☐ Mature (>30)

Encroachment: (Table 7) 1

Cattails, and deciduous trees in wetland.

Aquatic/Instream Vegetation

Type (Table8): 1 Coverage of Reach (%): 100

Woody Debris: ☐ Present in Cutbank ☒ Present in Channel ☐ Not Present

Density of WD: ☐ Low ☒ Moderate ☐ High

WDJ/50m: N/A

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 1

Channel Characteristics

Sinuosity (Type) (Table 9): N/A
Sinuosity (Degree) (Table 10): N/A
Gradient (Table 11): N/A
Number of Channels (Table 12): N/A

Entrenchment (Table 13): N/A
Type of Bank Failure (Table 14): N/A
Downs's Classification (Table 15): N/A

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	N/A ☐	☐	☐	☐	☐	☐	☐
Pool Substrate	N/A ☐	☐	☐	☐	☐	☐	☐
Bank Material	☒	☐	☐	☐	☐	☐	☐

Bankfull Width (m): N/A | |
Wetted Width (m): N/A | |
Bankfull Depth (m): N/A | |
Wetted Depth (m): N/A | |
Riffle/Pool Spacing (m): N/A % Riffles: N/A % Pools: N/A Meander Amplitude: N/A
Pool Depth (m): N/A Riffle Length (m): N/A Undercuts (m): N/A
Velocity (m/s): N/A | | Wiffle ball / ADV / Estimated

Bank Angle (Valley Slope): ☐ 0 – 30 ☒ 30 – 60 ☐ 60 – 90 ☐ Undercut

Bank Erosion (No erosion): ☒ < 5% ☐ 5 – 30% ☐ 30 – 60% ☐ 60 – 100%

Comments: BFW and BFD taken at North, South, and West inlet channels.

Notes: Wetland, no defined channel through wetland. Documented flow between wetland and small pond.

Completed by: LG Checked by: ______

- North inlet, South inlet, West inlet, and outlet channels have seperate XS surveys and velocity data during WQM visits.

GEO | MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics

Project Code: PN19033

Date:	2019-05-10	**Stream/Reach:**	W inlet of Wetland / EC-3a
Weather:	overcast 8°C	**Location:**	Mayfield Rd @ Kennedy Road
Field Staff:	LG + WM	**Watershed/Subwatershed:**	Etobicoke Crk.
UTM (Upstream)	595368.19 mE 4844529.9 mN	**UTM (Downstream)**	595431.33 mE 4844513.44 mN

Land Use (Table 1): 3 | Valley Type (Table 2): 3 | Channel Type (Table 3): 11 | Channel Zone (Table 4): 2 | Flow Type (Table 5): 1 | ☐ Groundwater | Evidence: ____

Riparian Vegetation

Dominant Type: (Table 6) 3

Species: ____

Coverage: ☐ None ☐ Fragmented ☒ Continuous

Channel widths: ☐ 1-4 ☒ 4-10 ☐ > 10

Age Class (yrs): ☒ Immature (<5) ☐ Established (5-30) ☐ Mature (>30)

Encroachment: (Table 7) 3

Aquatic/Instream Vegetation

Type (Table8): 1 Coverage of Reach (%): 100

Woody Debris: ☐ Present in Cutbank ☐ Present in Channel ☒ Not Present

Density of WD: ☒ Low ☐ Moderate ☐ High

WDJ/50m: 0

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 1

Channel Characteristics

Sinuosity (Type) (Table 9): 1

Sinuosity (Degree) (Table 10): 1

Gradient (Table 11): 1

Number of Channels (Table 12): 1

Entrenchment (Table 13): 2

Type of Bank Failure (Table 14): 1

Downs's Classification (Table 15): d

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	☐	☒	☒	☐	☐	☐	☐
Pool Substrate	☒	☒	☐	☐	☐	☐	☐
Bank Material	☒	☒	☐	☐	☐	☐	☐

Bankfull Width (m)	1.4	—	→
Bankfull Depth (m)	0.3	—	→
Wetted Width (m)	0.5	—	→
Wetted Depth (m)	0.05	—	→

Riffle/Pool Spacing (m): N/A | % Riffles: N/A | % Pools: N/A | Meander Amplitude: N/A

Pool Depth (m): N/A | Riffle Length (m): N/A | Undercuts (m): N/A | Comments: ____

Velocity (m/s): 0.1 | — | → | Wiffle ball / ADV / Estimated

Bank Angle: ☐ 0 – 30 ☐ 30 – 60 ☒ 60 – 90 ☐ Undercut

Bank Erosion: ☒ < 5% ☐ 5 – 30% ☐ 30 – 60% ☐ 60 – 100%

Notes: Ditch w/ sand / fine sediment deposition

- XS surveyed w/ RTK unit at pressure logger
- velocity and wetted measurements will be taken during each WQM visit

Completed by: LG

Checked by: ____

Reach Characteristics Key

Table 1 Land Use

1. Forest
2. Pasture
3. Agricultural
4. Industrial
5. Park
6. Institutional
7. Residential
8. Golf Course
9. Commercial

Table 2 Valley Type

1. Unconfined
2. Confined
3. Partially Confined

Table 3 Channel Type

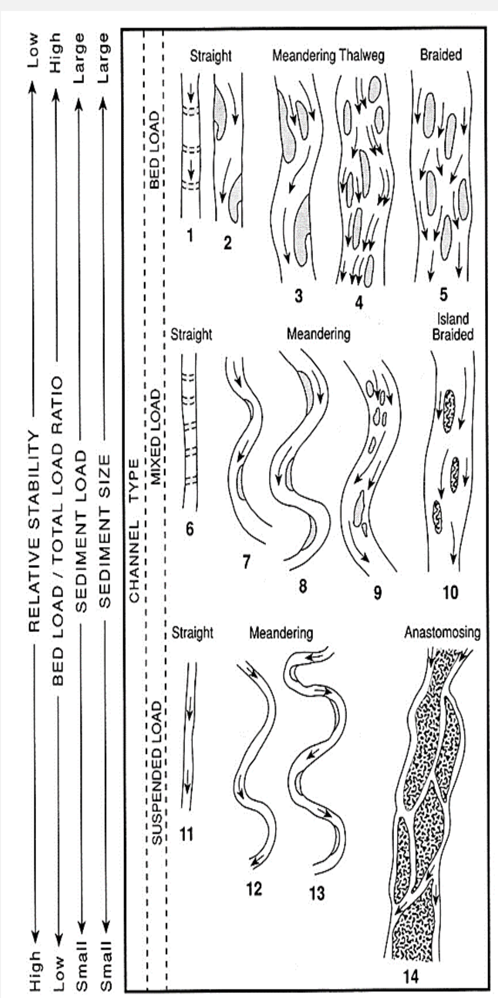


Table 4 Channel Zone

1. Headwater zone
2. Transfer zone
3. Deposition zone

Table 5 Flow Type

1. Perennial
2. Intermittent
3. Ephemeral

Table 6 Dominant Vegetation Type

1. Trees
2. Shrubs
3. Grasses
4. Herbaceous

Table 7 Extent of Encroachment into Channel

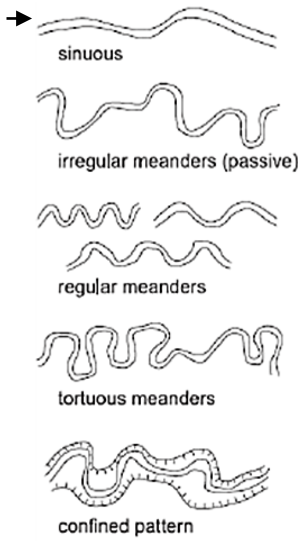
1. None
2. Minimal
3. Moderate
4. Heavy
5. Extreme

Table 8 Type of Aquatic Vegetation

1. Rooted Emergent
2. Rooted Submergent
3. Rooted Floating
4. Free Floating Roots
5. Floating Algae
6. Attached Algae

Table 9 Type of Sinuosity

1. Sinuous
2. Irregular Meanders
3. Regular Meanders
4. Tortuous Meanders
5. Confined pattern (within valley)



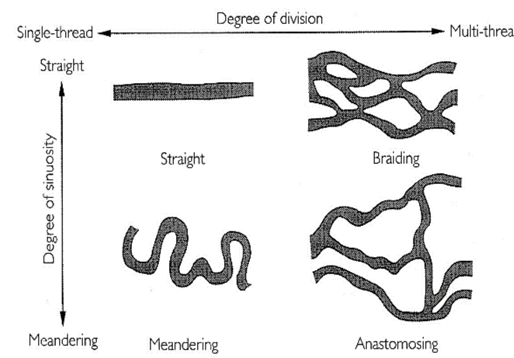


Table 10 Degree of Sinuosity

1. Straight (1 – 1.05)
2. Low sinuosity (1.06–1.30)
3. Meandering (1.31 - 3.0)

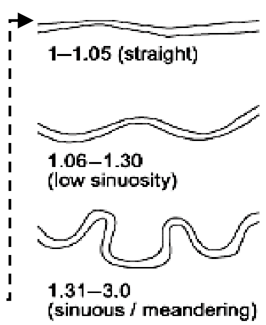


Table 11 Gradient

1. Low
2. Moderate
3. High

Table 12 Number of Channels

1. Single
2. Up to 3 (Wandering)
3. >3 (Braided)
4. >3 (Anastamosing or Anabranching)
5. Discontinuous or Absent

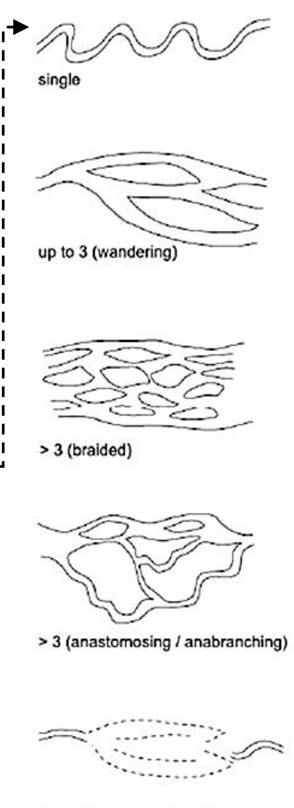
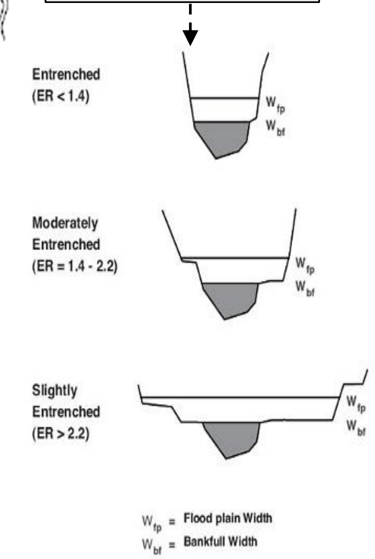


Table 13 Entrenchment

1. Low (>2.2)
2. Moderate (1.4 – 2.2)
3. High (<1.4)



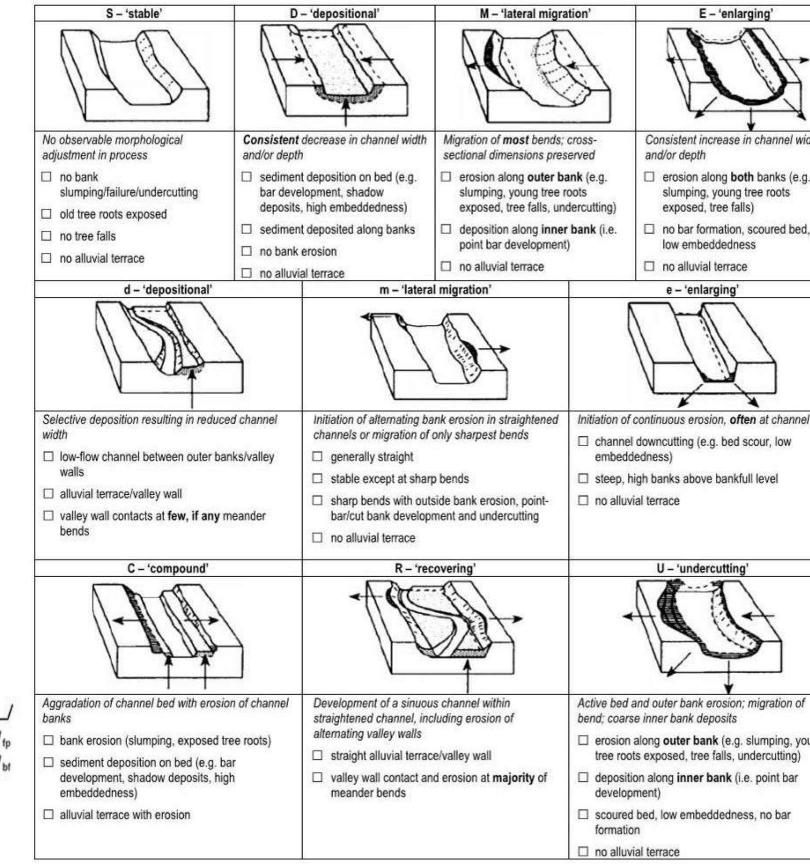


Table 14 Type of Bank Failure

1. Fluvial Entrainment (Hydraulic action)
2. Undercutting (Hydraulic action)
3. Slab Failure (Mass failure)
4. Parallel slide (Mass failure)
5. Fall/Sloughing (Mass failure)
6. Rotational slip and slump (Mass failure)

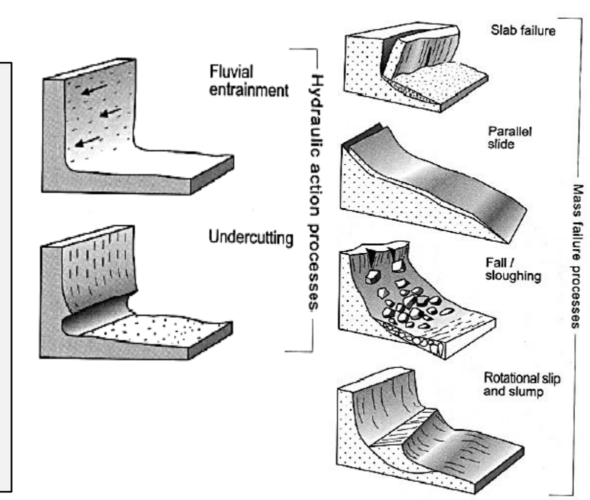


Table 15 Downs's Model of Channel Classification

S – Stable
D or d – Depositional
M or m – Lateral Migration
E or e – Enlarging
C – Compound
R – Recovering
U – Undercutting

Table 16 Odours

1. None
2. Fishy
3. Petroleum
4. Sewage
5. Chemical
6. Other

Table 17 Turbidity

1. Clear
2. Slightly turbid
3. Turbid
4. Opaque
5. Stained
6. Other

Appendix E
Detailed Geomorphological Assessment Summary

Detailed Geomorphological Assessment Summary

Reach EC-1

Project Number:	PN19033	**Date:**	May 10, 2019
Client:	Snell's Hollow Landowner Group	**Length Surveyed (m):**	105.6
Location:	Heart Lake Conservation Area	**# of Cross-Sections:**	6

Reach Characteristics

Drainage Area:	Not measured	**Dominant Riparian Vegetation Type:**	Trees
Geology/Soils:	Clay to silt-textured till	**Extent of Riparian Cover:**	Continuous
Surrounding Land Use:	Forest	**Width of Riparian Cover:**	>10 channel widths
Valley Type:	Confined	**Age Class of Riparian Vegetation:**	Mature (>30 years)
Dominant Instream Vegetation Type:	Rooted submergent	**Extent of Encroachment into Channel:**	Minimal
Portion of Reach with Vegetation:	20%	**Density of Woody Debris:**	Moderate

Hydrology

Measured Discharge (m^3/s):	Not measured	**Calculated Bankfull Discharge (m^3/s):**	4.30
Modelled 2-year Discharge (m^3/s):	Not modelled	**Calculated Bankfull Velocity (m/s):**	0.76
Modelled 2-year Velocity (m/s):	Not modelled		

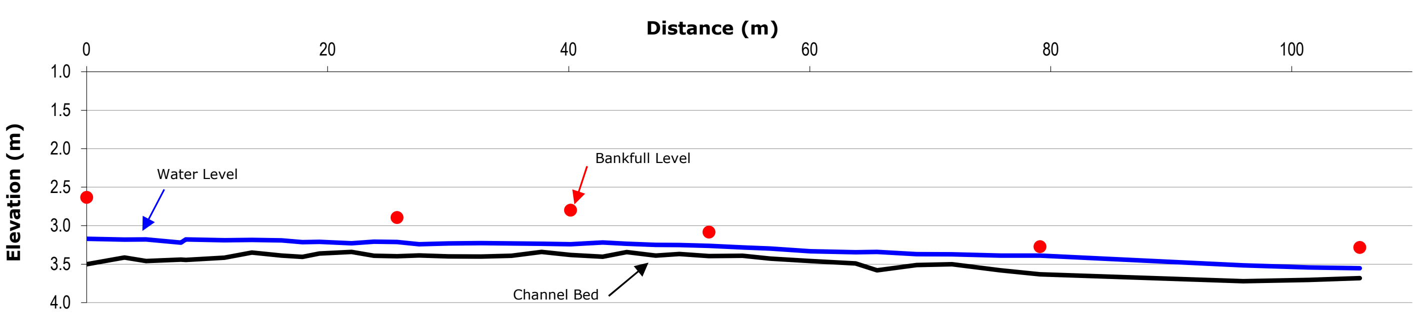
Profile Characteristics

Bankfull Gradient (%):	0.66
Channel Bed Gradient (%):	0.26
Riffle Gradient (%):	N/A: no riffles
Riffle Length (m):	N/A: no riffles
Riffle-Pool Spacing (m):	N/A: no riffle and pools

Planform Characteristics

Sinuosity:	1.13
Meander Belt Width (m):	Not measured
Radius of Curvature (m):	Not measured
Meander Amplitude (m):	Not measured
Meander wavelength (m):	Not measured

Longitudinal Profile



Bank Characteristics

	Minimum	Maximum	Average
Bank Height (m):	0.2	0.70	0.45
Bank Angle (deg):	10	45	24
Root Depth (m):	0.05	0.20	0.10
Root Density (%):	10	70	42
Bank Undercut (m):		No undercuts	

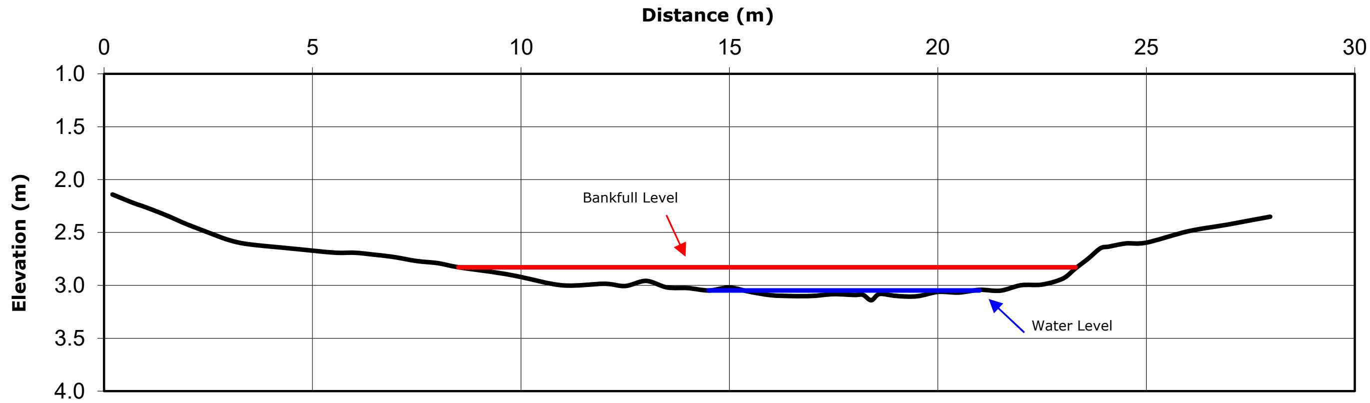
	Minimum	Maximum	Average
Torvane Value (kg/cm^2):		Not measured	
Penetrometer Value (kg/cm^3):		Not measured	
Bank Material (range):		Clay, silt, sand	

Cross-Sectional Characteristics

	Minimum	Maximum	Average
Bankfull Width (m):	12.70	27.90	17.95
Average Bankfull Depth (m):	0.18	0.49	0.32
Bankfull Width/Depth (m/m):	29	108	61
Wetted Width (m):	4.90	18.50	11.95
Average Water Depth (m):	0.04	0.25	0.13
Wetted Width/Depth (m/m):	48	175	108
Entrenchment (m):		Not measured	
Entrenchment Ratio (m/m):		Not measured	
Maximum Water Depth (m):	0.09	0.54	0.26
Manning's *n* :		0.050	

Photograph at cross section 4 (left bank)

Representative Cross-Section 4

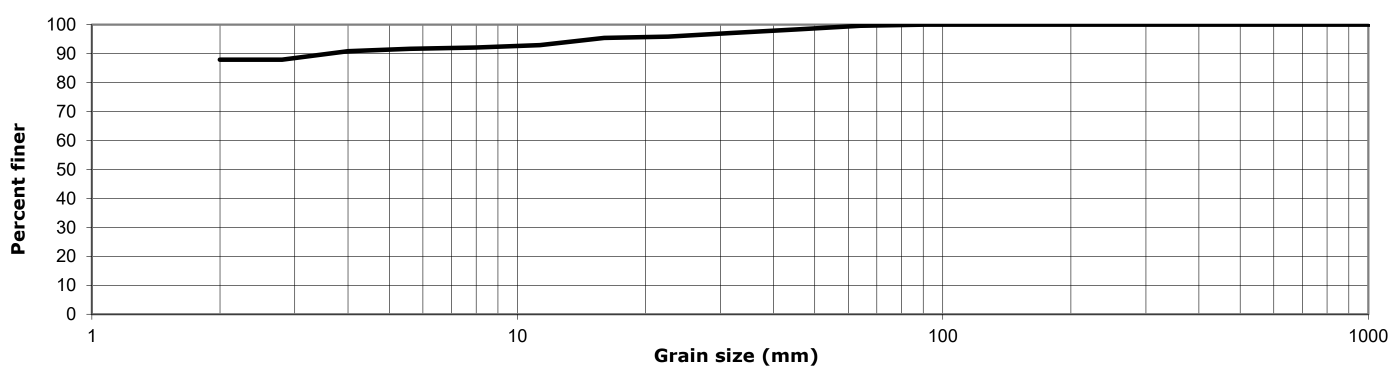


Substrate Characteristics

Particle Size (mm)		
D_{10} :	<	2.0
D_{50} :	<	2.0
D_{84} :	<	2.0

Subpavement:	Clay, silt, sand
Particle shape:	N/A: fine graind materials
Embeddedness (%):	N/A: fine grained materials
Particle range (riffle):	N/A: no riffles
Particle Range (pool):	N/A: no pools

Cumulative Particle Size Distribution



Channel Thresholds

Flow Competency (m/s):		**Tractive Force at Bankfull (N/m^2):**	20.53
for D_{50}:	0.00	**Tractive Force at 2-year flow (N/m^2):**	Not modelled
for D_{84}:	0.00	**Critical Shear Stress (D_{50}) (N/m^2):**	0.00
Unit Stream Power at Bankfull (W/m^2):	15.50		

General Field Observations

Channel Description

Reach EC-1 consisted of a fairly straight and low gradient channel through a confined valley. The continuous and wide riparian buffer zone consisted of mature trees. The average bankfull width and depth were 17.95 m and 0.32 m. Bank materials ranged from clay to sand. Little to no bank erosion was observed. There were no riffles or pools. Bed materials consisted of organic material, clay, silt, and fine sand. Two trail crossings were present across the channel and valley. Woody debris was present within the channel but not due to the channel widening.

Cross Section 4 - Facing Downstream

Appendix F
Flow Monitoring Data

2019 W Inlet Water Temperature

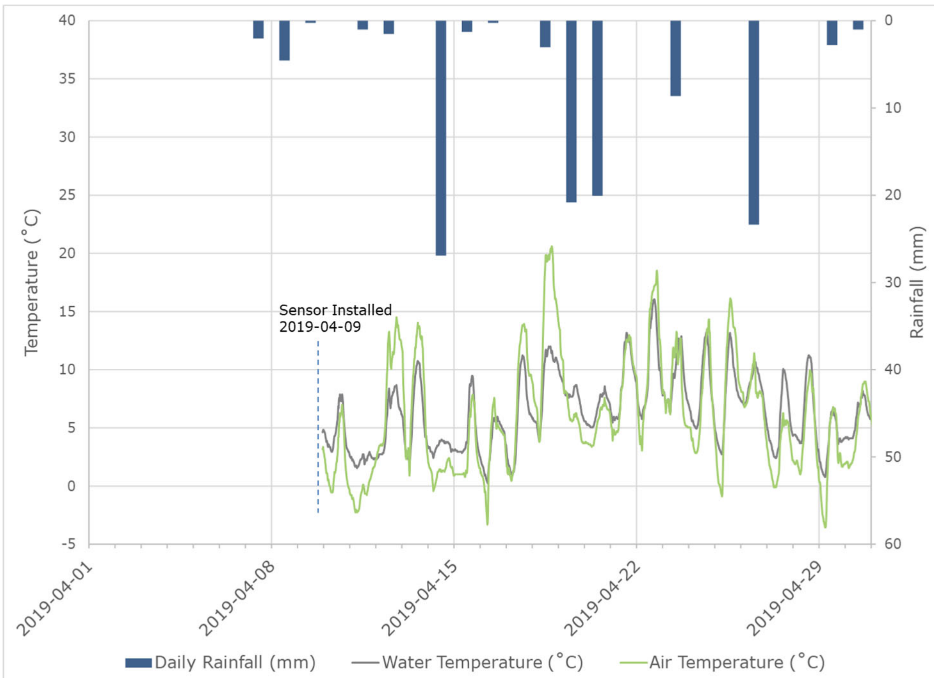
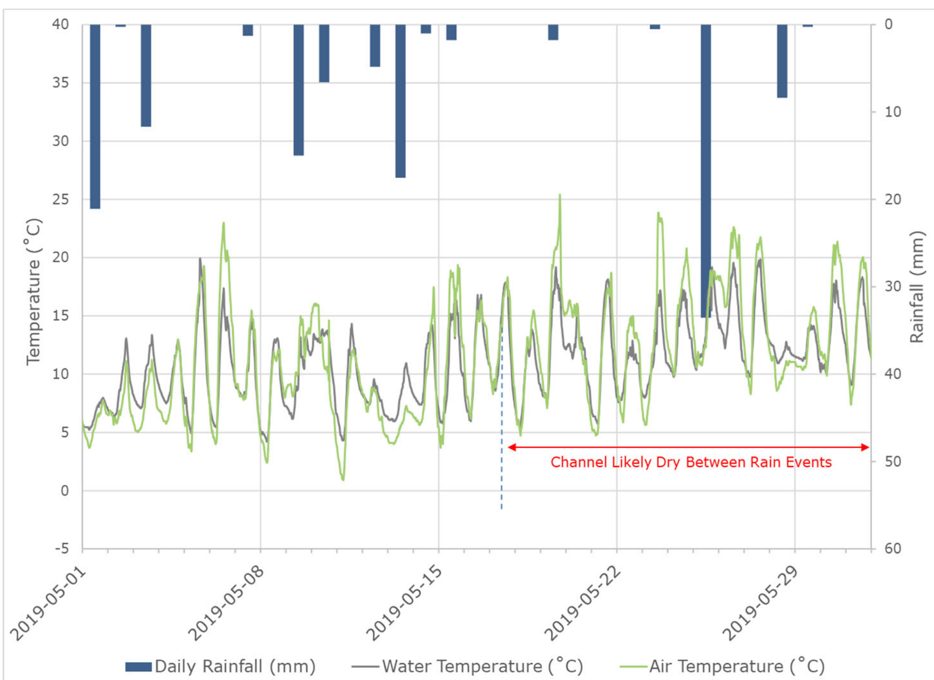
<table>
<tr><td rowspan="2">Figure 1</td><td>
</td></tr>
<tr><td>Water temperature, air temperature and daily rainfall at W Inlet for April 2019.</td></tr>
<tr><td rowspan="2">Figure 2</td><td>
</td></tr>
<tr><td>Water temperature, air temperature and daily rainfall at W Inlet for May 2019.</td></tr>
</table>

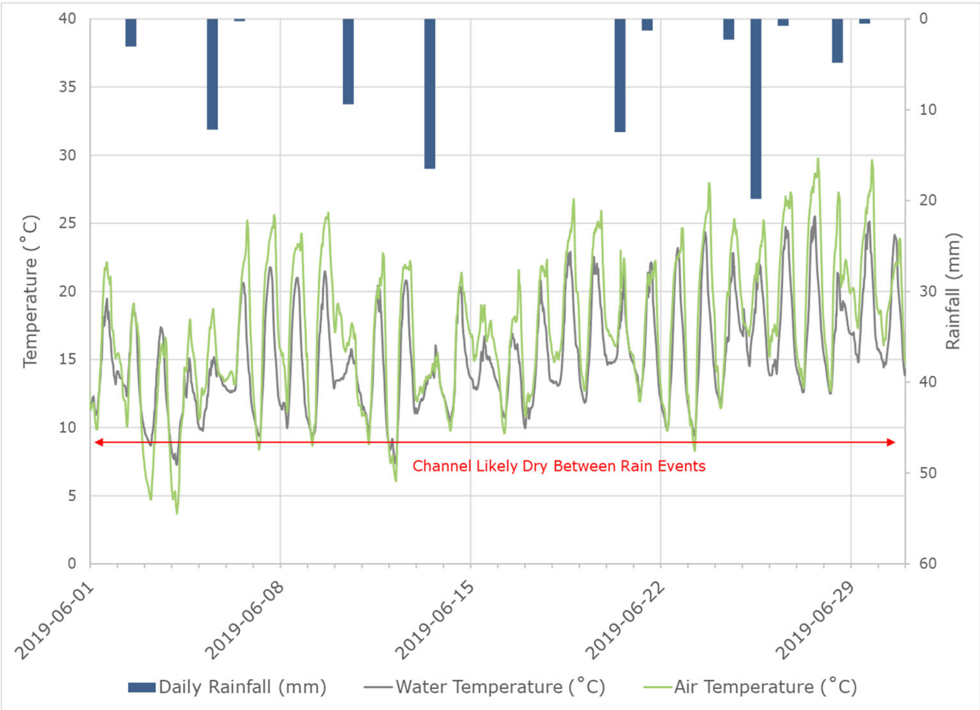
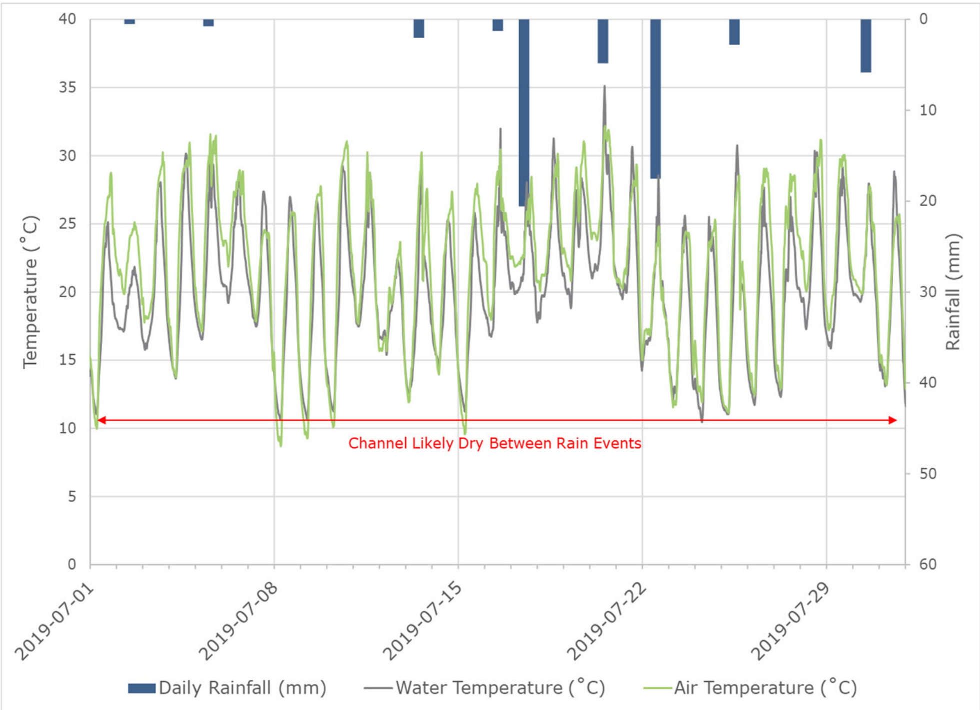
Figure 3	
	Water temperature, air temperature and daily rainfall at **W Inlet** for June 2019.
Figure 4	
	Water temperature, air temperature and daily rainfall at **W Inlet** for July 2019.

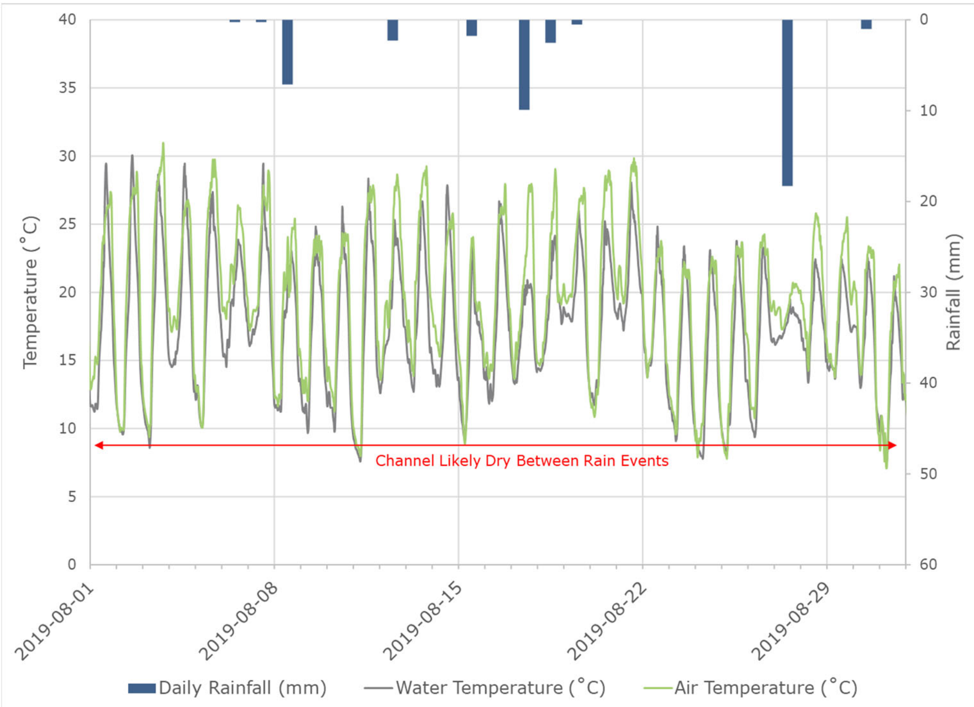
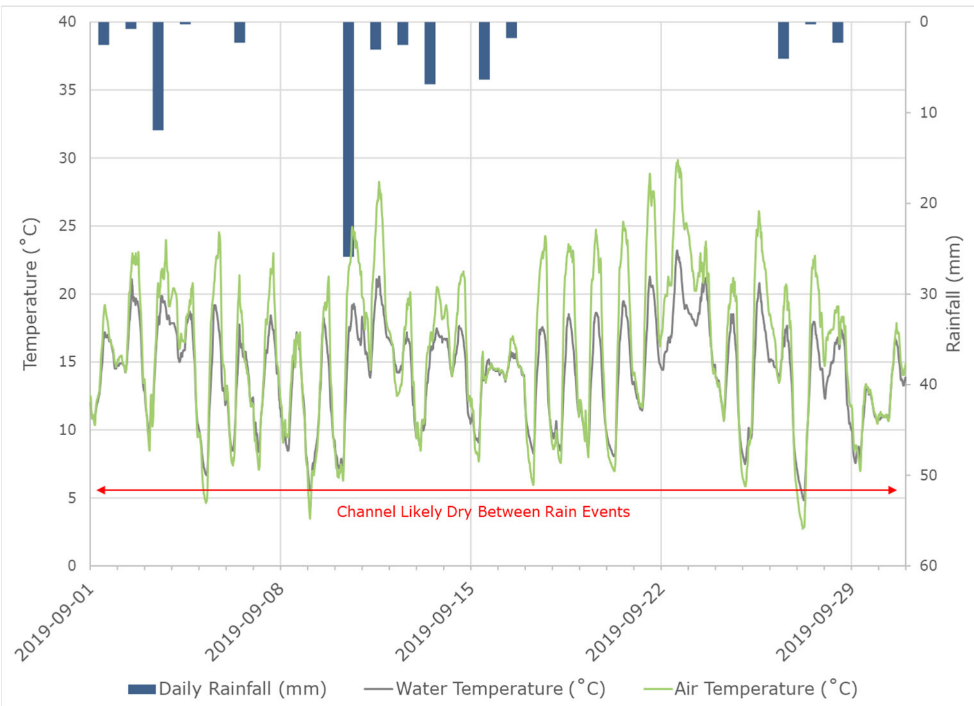
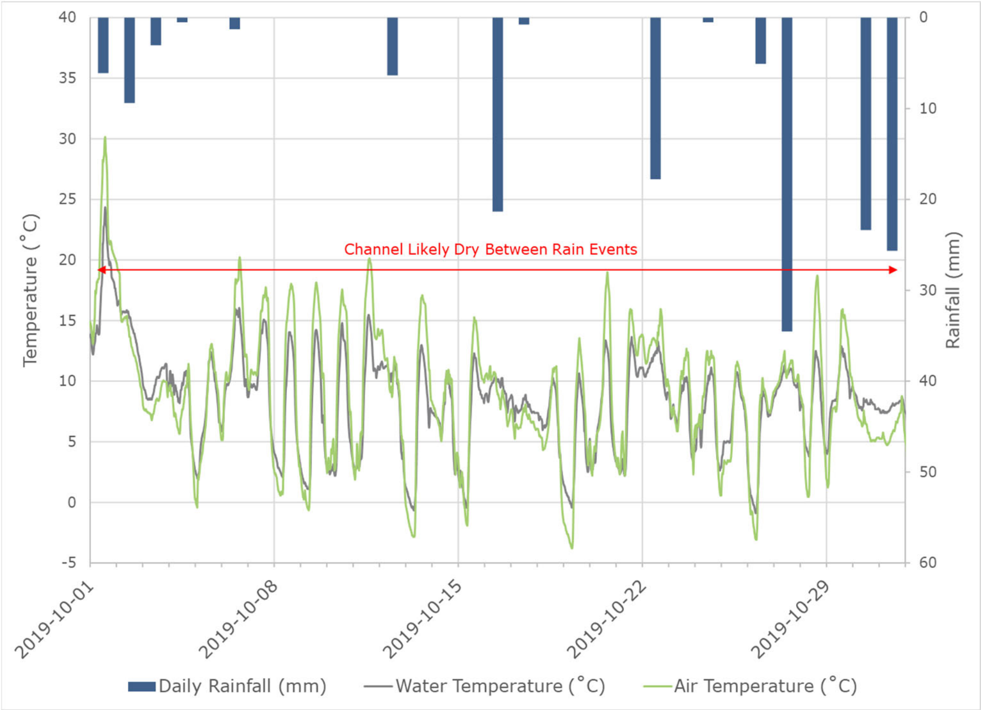
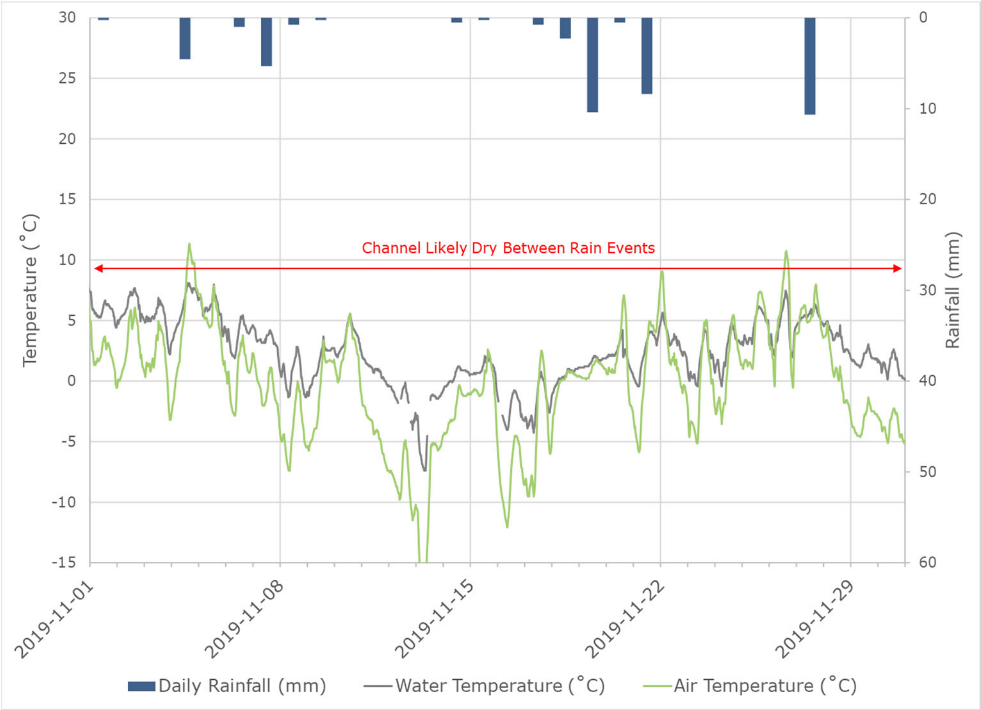
Figure 5	
	Water temperature, air temperature and daily rainfall at **W Inlet** for August 2019.
Figure 6	
	Water temperature, air temperature and daily rainfall at **W Inlet** for September 2019.

Figure 7	
	Water temperature, air temperature and daily rainfall at **W Inlet** for October 2019.
Figure 8	
	Water temperature, air temperature and daily rainfall at **W Inlet** for November 2019.

2019 S Inlet Water Temperature

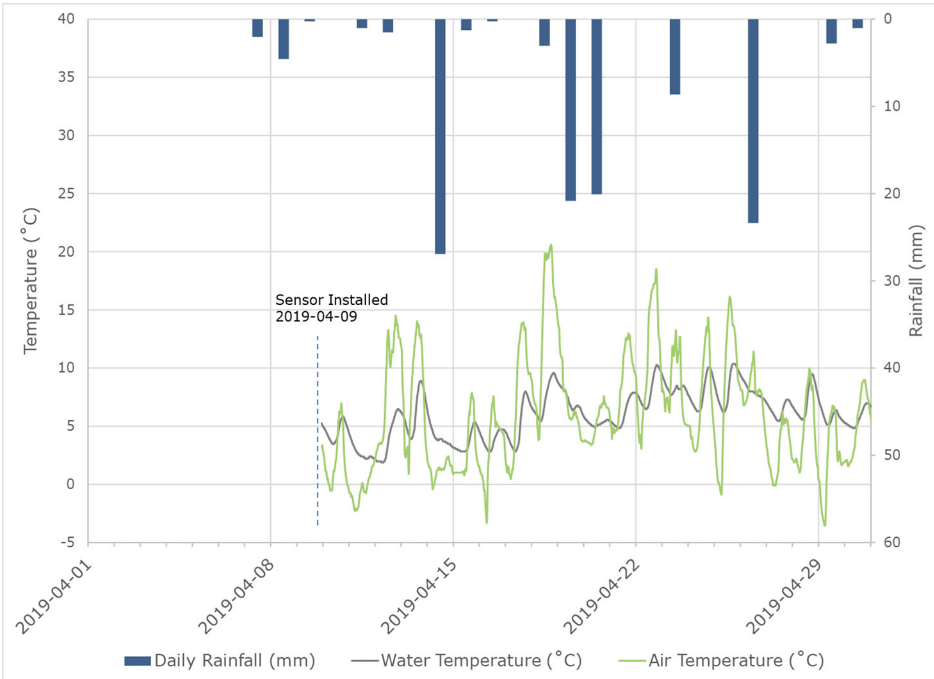
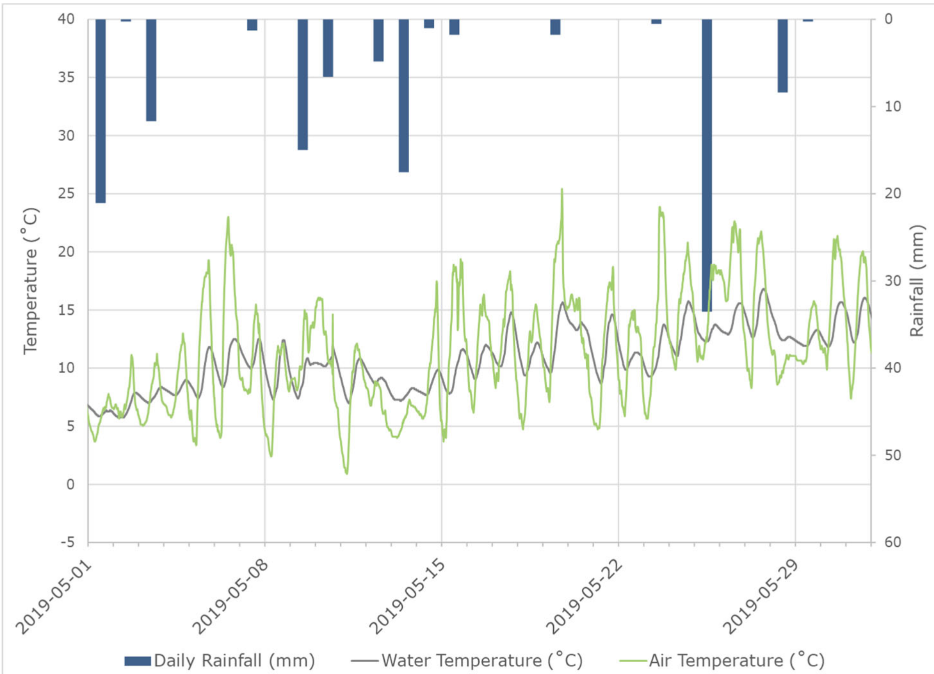
Figure 9	 Water temperature, air temperature and daily rainfall at **S Inlet** for April 2019.
Figure 10	 Water temperature, air temperature and daily rainfall at **S Inlet** for May 2019.

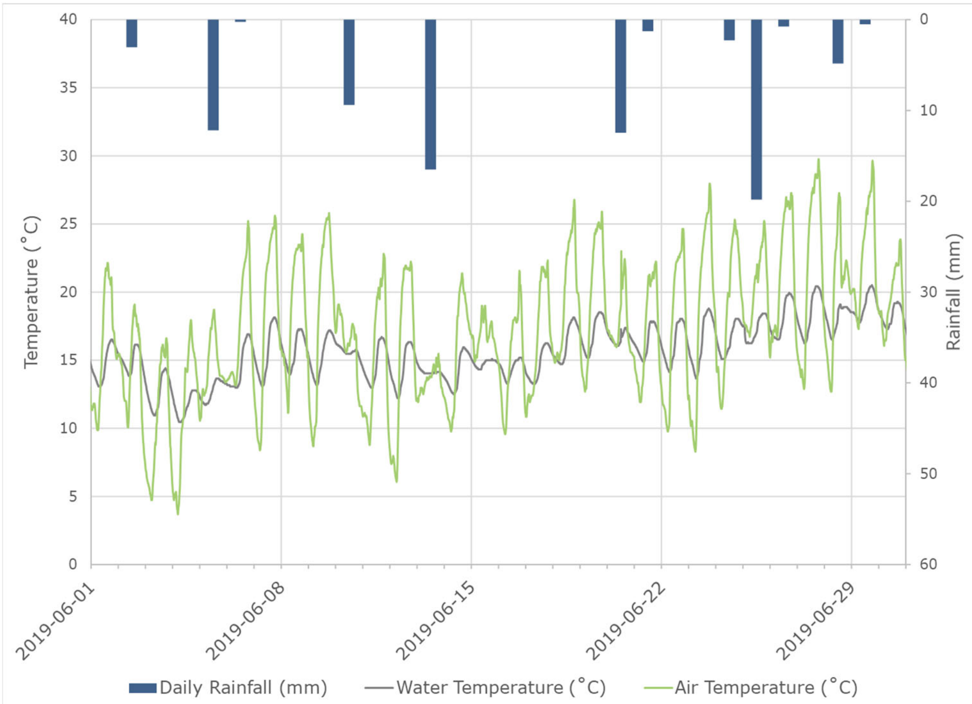
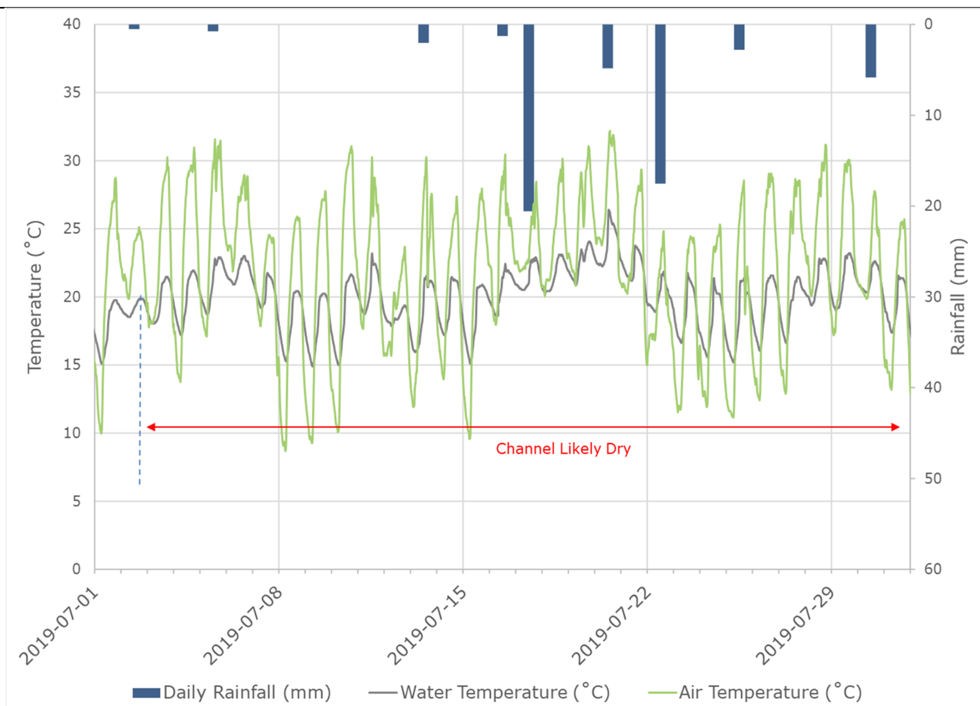
Figure 11	
	Water temperature, air temperature and daily rainfall at **S Inlet** for June 2019.
Figure 12	
	Water temperature, air temperature and daily rainfall at **S Inlet** for July 2019.

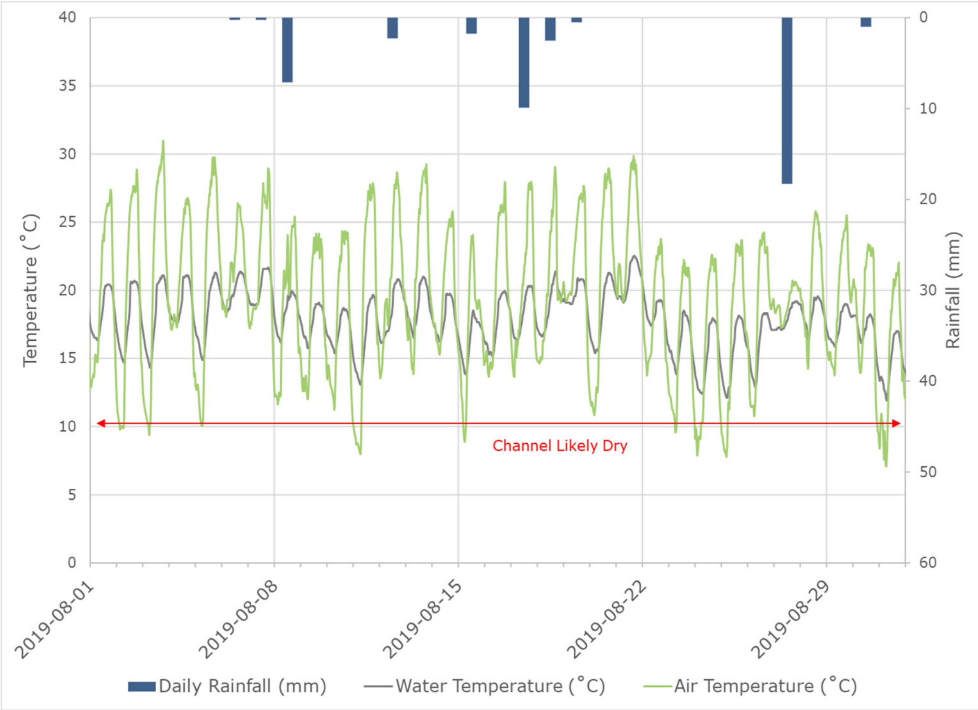
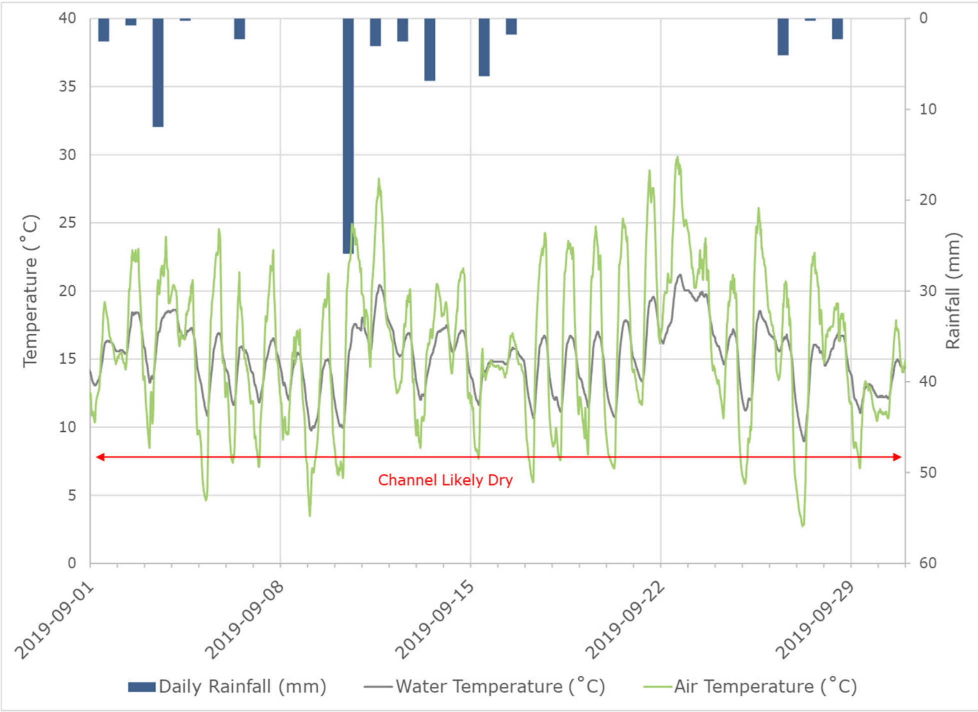
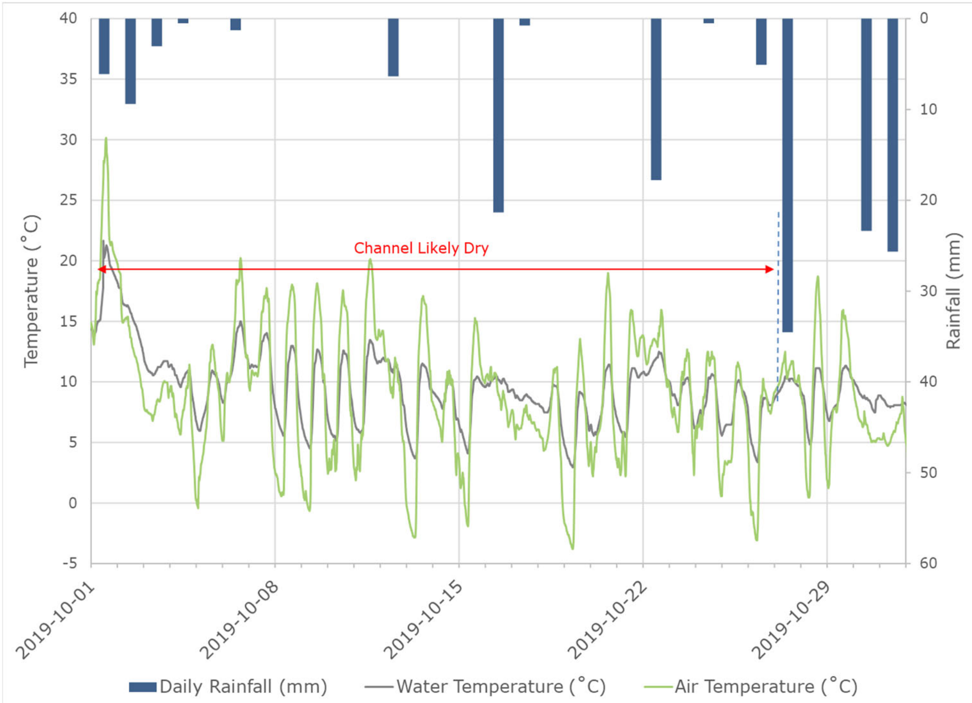
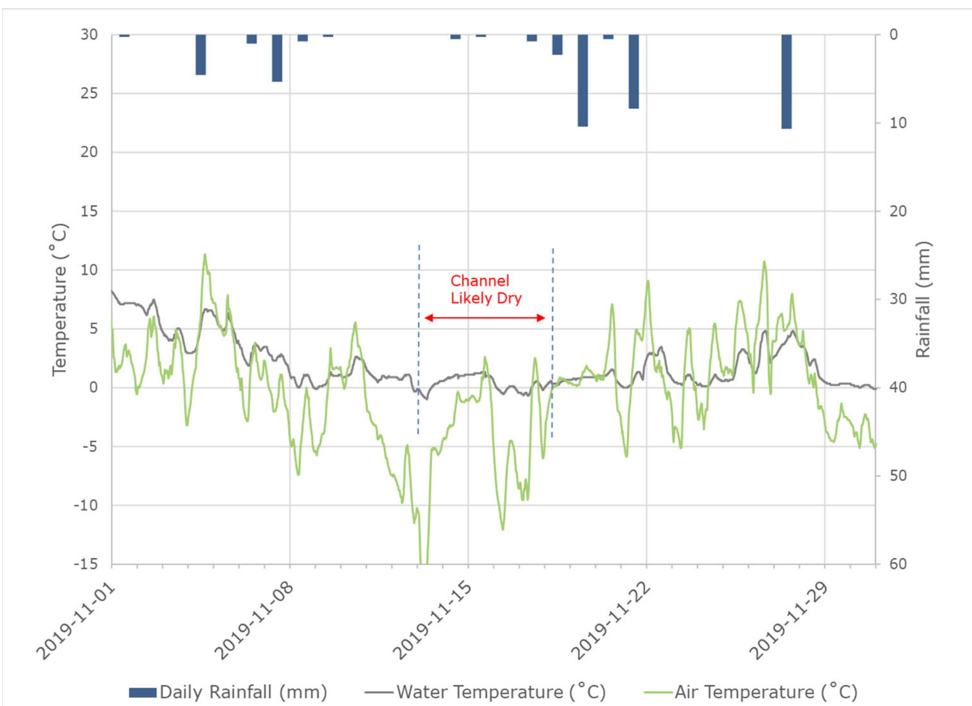
Photo 13	
	Water temperature, air temperature and daily rainfall at **S Inlet** for August 2019.
Figure 14	
	Water temperature, air temperature and daily rainfall at **S Inlet** for September 2019.

Figure 15	
	Water temperature, air temperature and daily rainfall at **S Inlet** for October 2019.
Figure 16	
	Water temperature, air temperature and daily rainfall at **S Inlet** for November 2019.

2019 Bridge Water Temperature

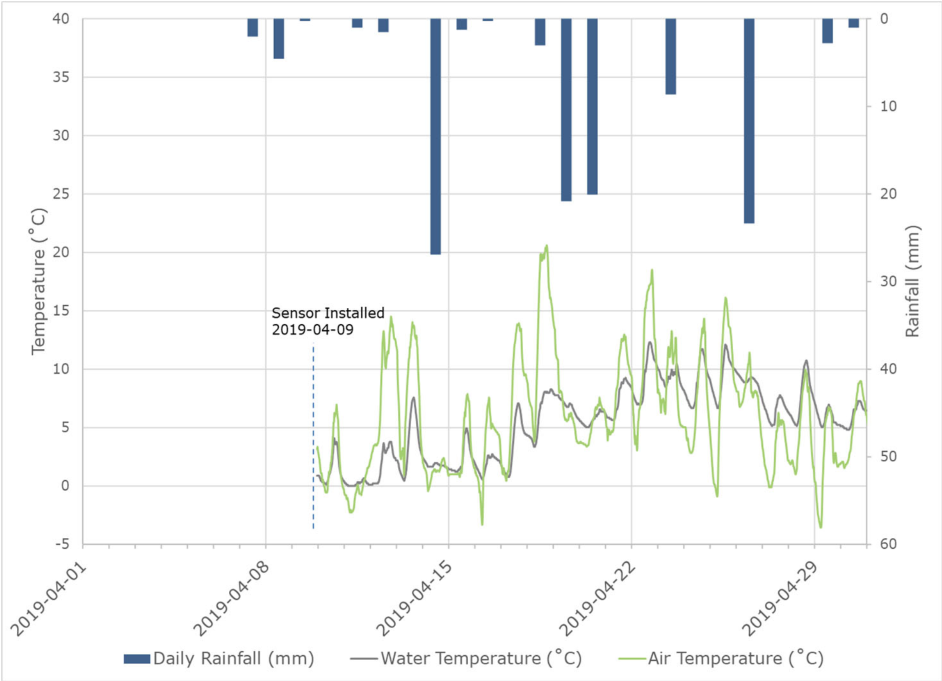
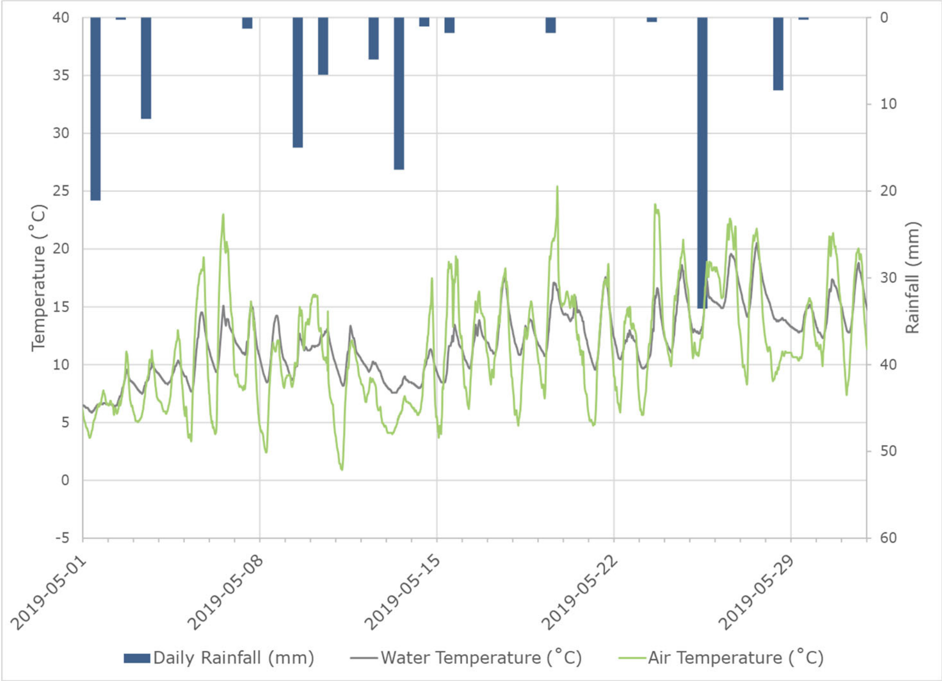
Figure 17	
	Water temperature, air temperature and daily rainfall at **Bridge** for April 2019.
Figure 18	
	Water temperature, air temperature and daily rainfall at **Bridge** for May 2019.

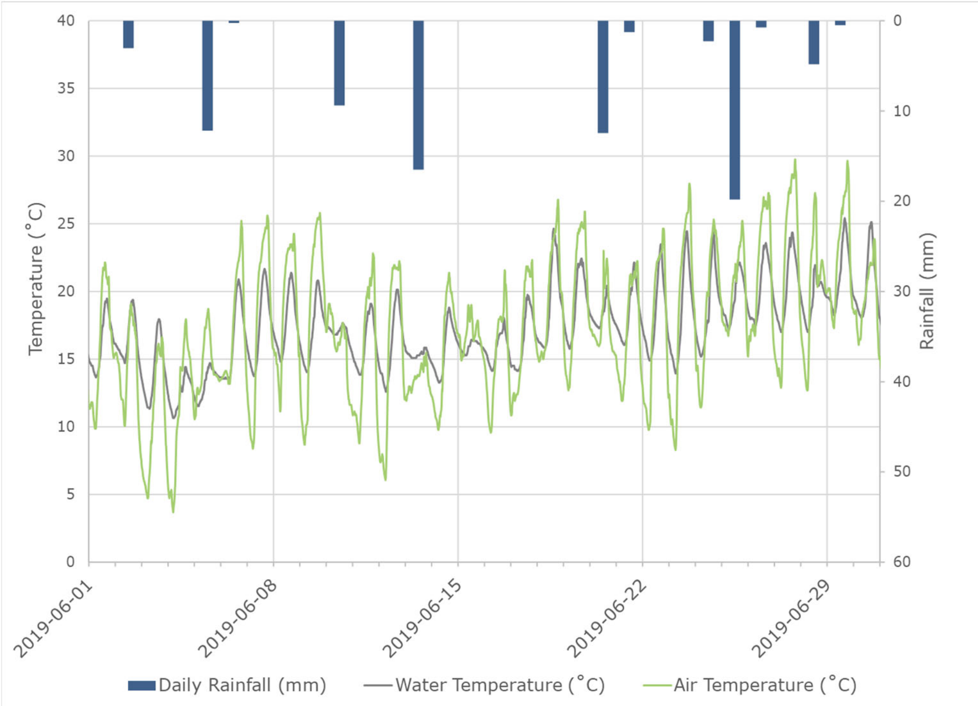
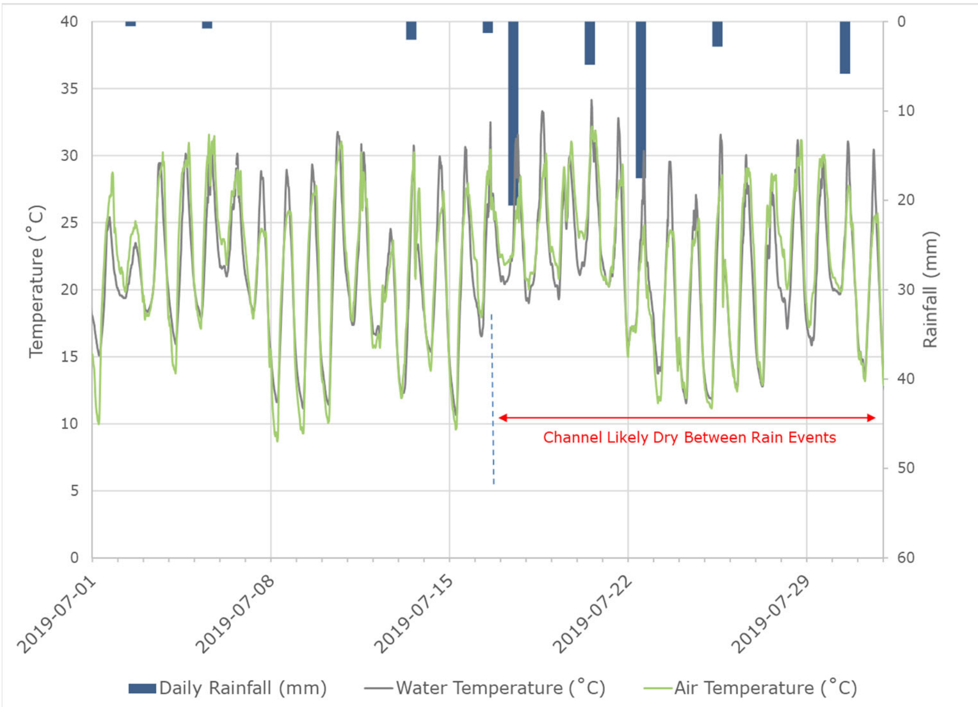
Figure 19	
	Water temperature, air temperature and daily rainfall at **Bridge** for June 2019.
Figure 20	
	Water temperature, air temperature and daily rainfall at **Bridge** for July 2019.

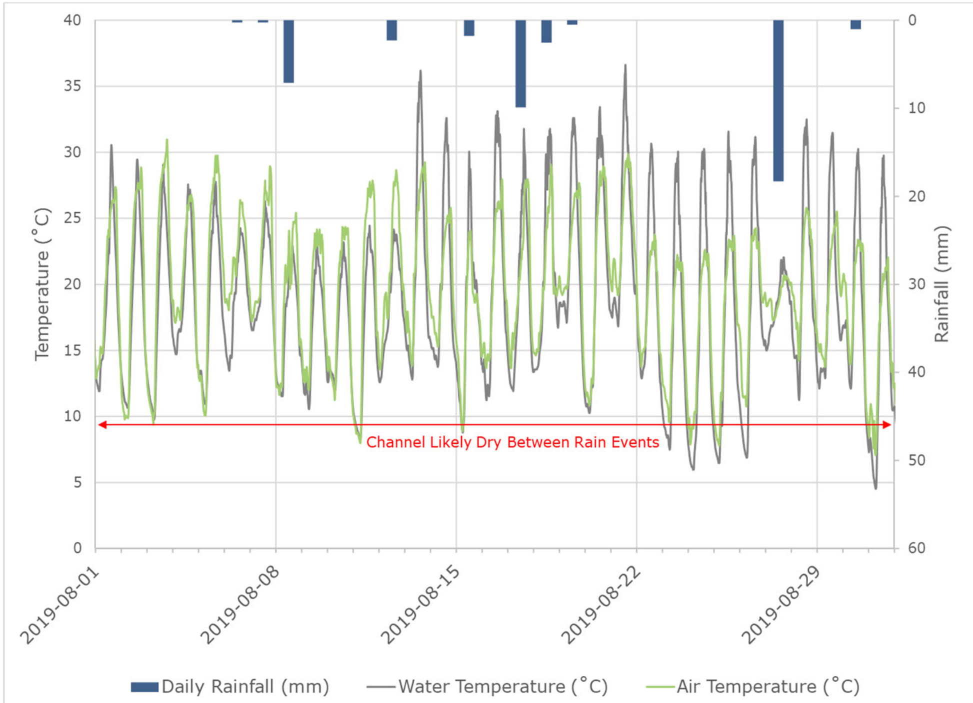
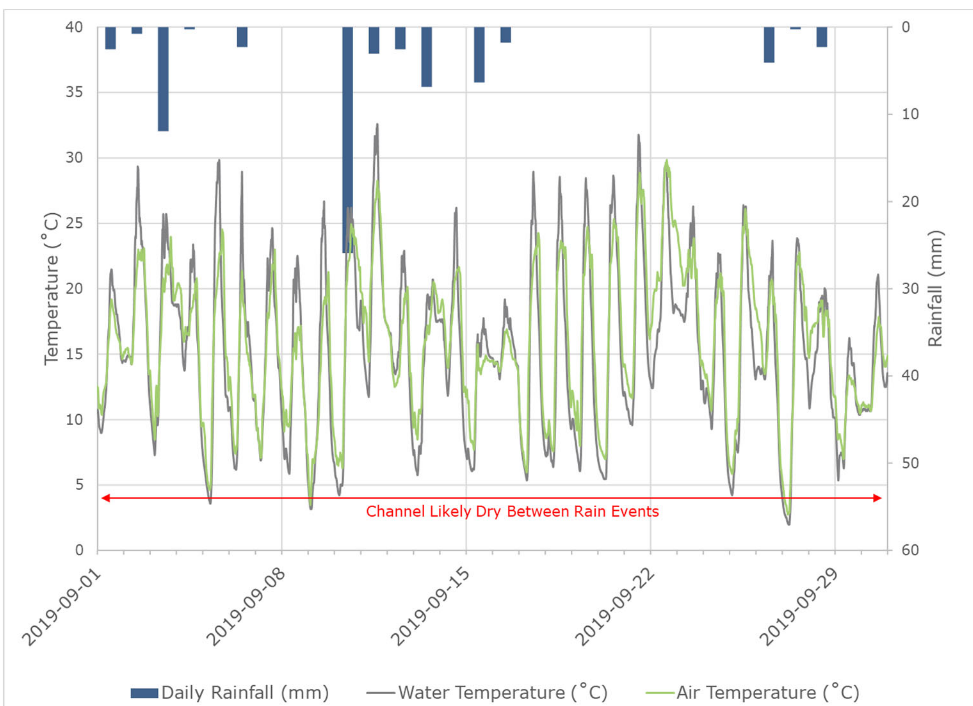
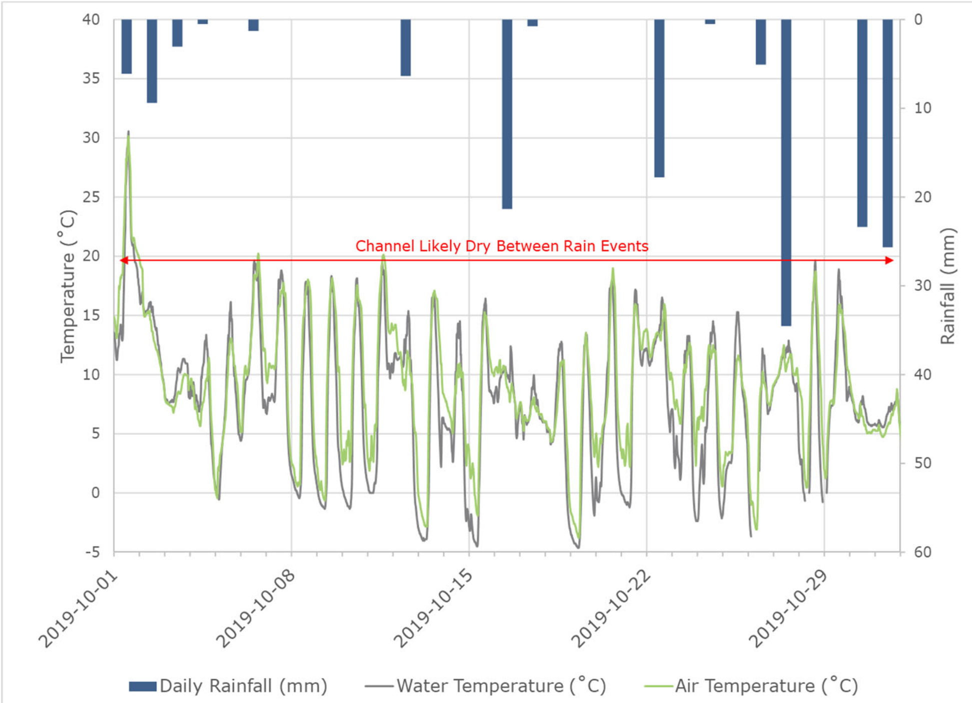
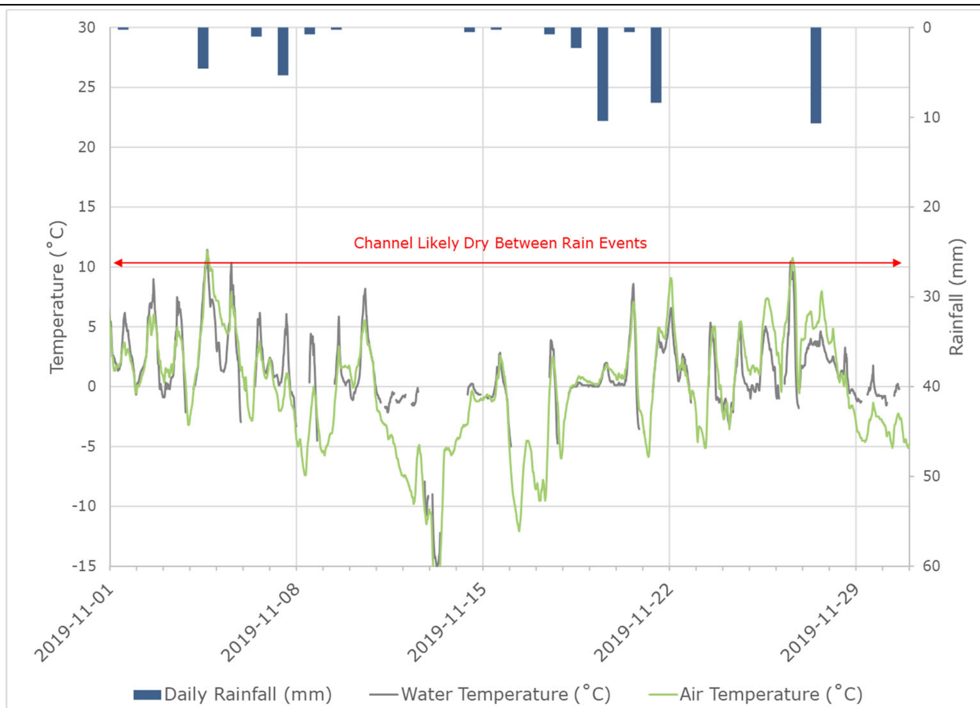
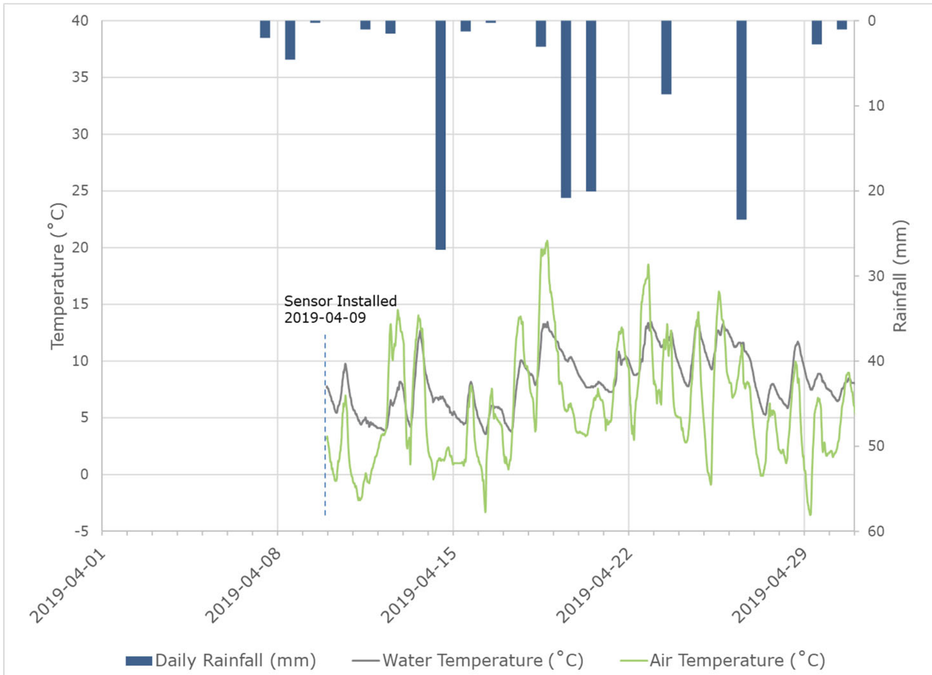
Figure 21	
	Water temperature, air temperature and daily rainfall at **Bridge** for August 2019.
Figure 22	
	Water temperature, air temperature and daily rainfall at **Bridge** for September 2019.

Figure 23	
	Water temperature, air temperature and daily rainfall at **Bridge** for October 2019.
Figure 24	
	Water temperature, air temperature and daily rainfall at **Bridge** for November 2019.

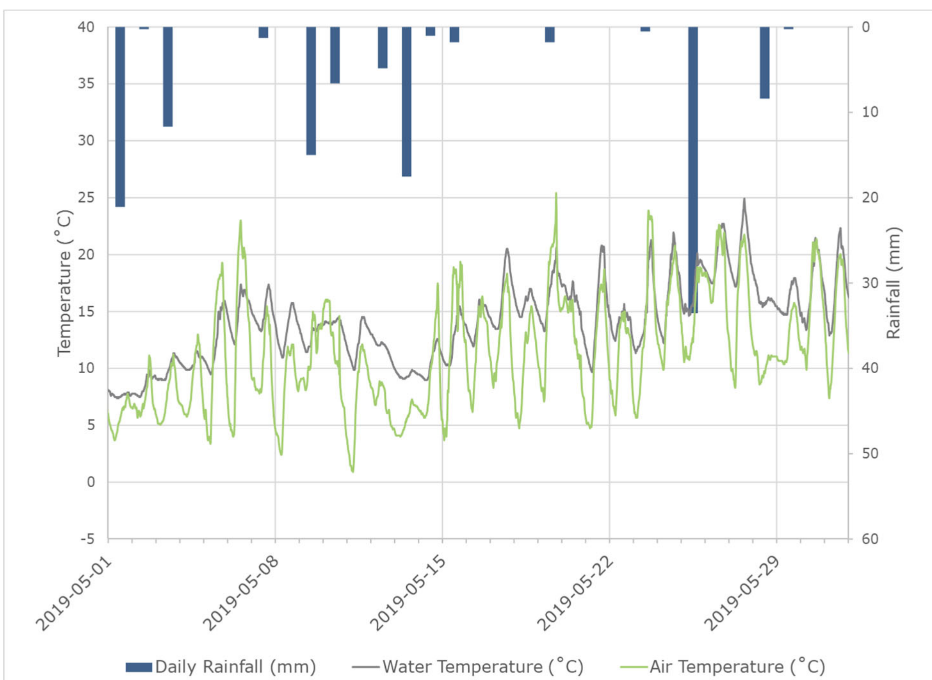
2019 Outlet Water Temperature

Figure 25



Water temperature, air temperature and daily rainfall at **Outlet** for April 2019.

Figure 26



Water temperature, air temperature and daily rainfall at **Outlet** for May 2019.

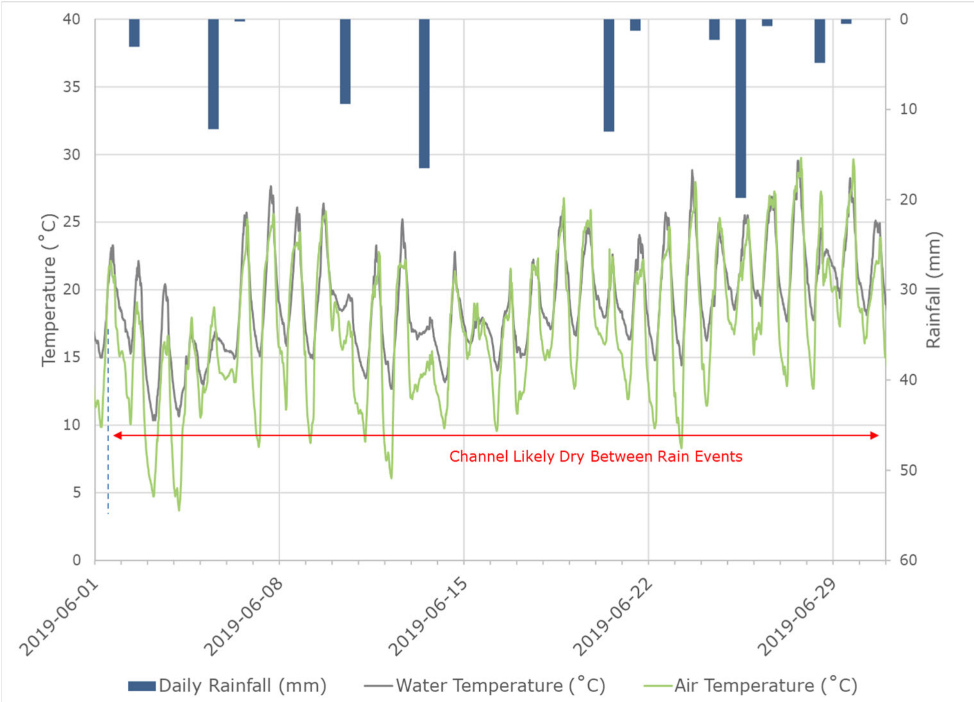
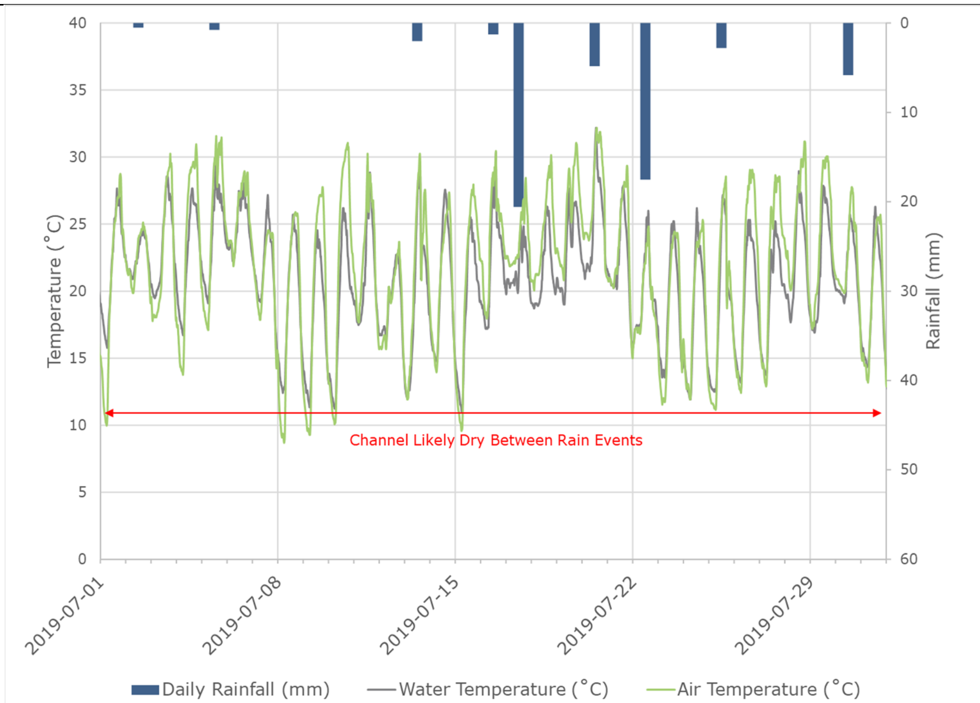
Figure 27	
	Water temperature, air temperature and daily rainfall at **Outlet** for June 2019.
Figure 28	
	Water temperature, air temperature and daily rainfall at **Outlet** for July 2019.

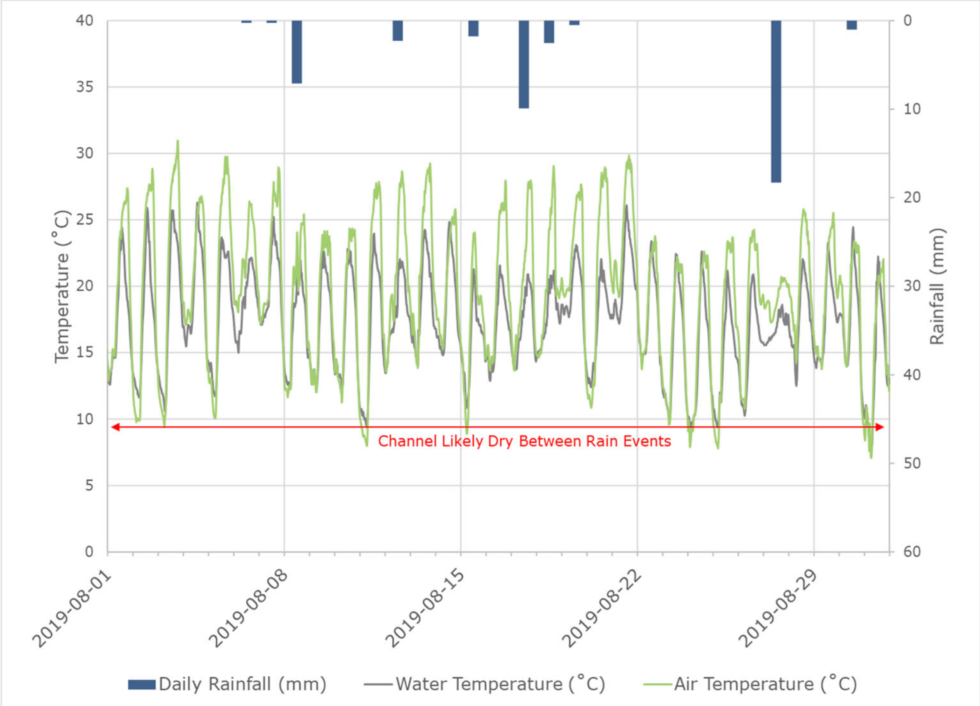
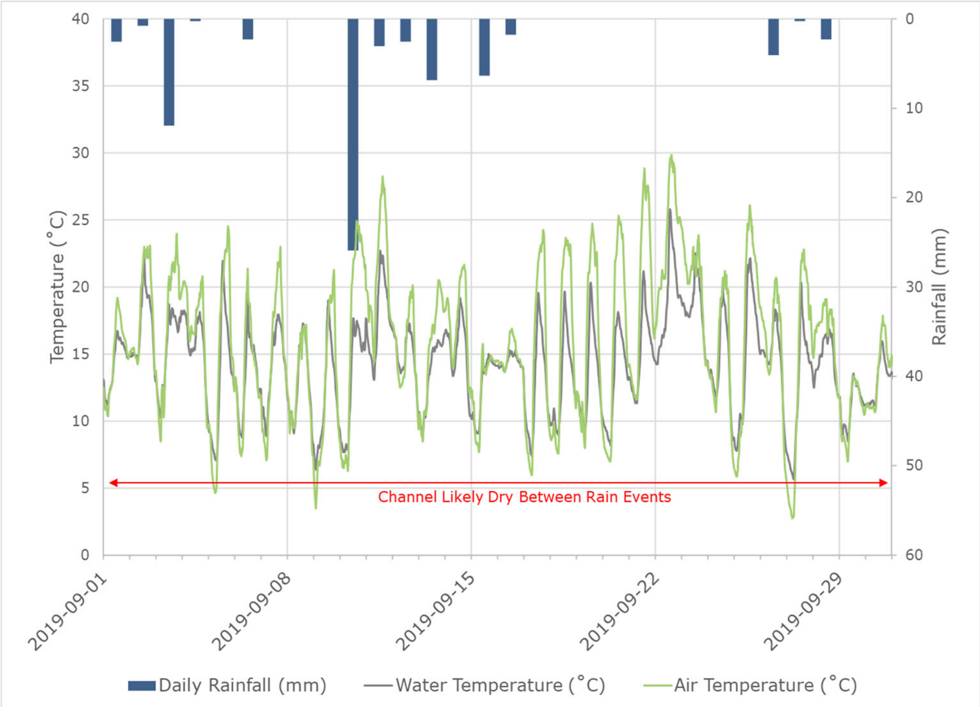
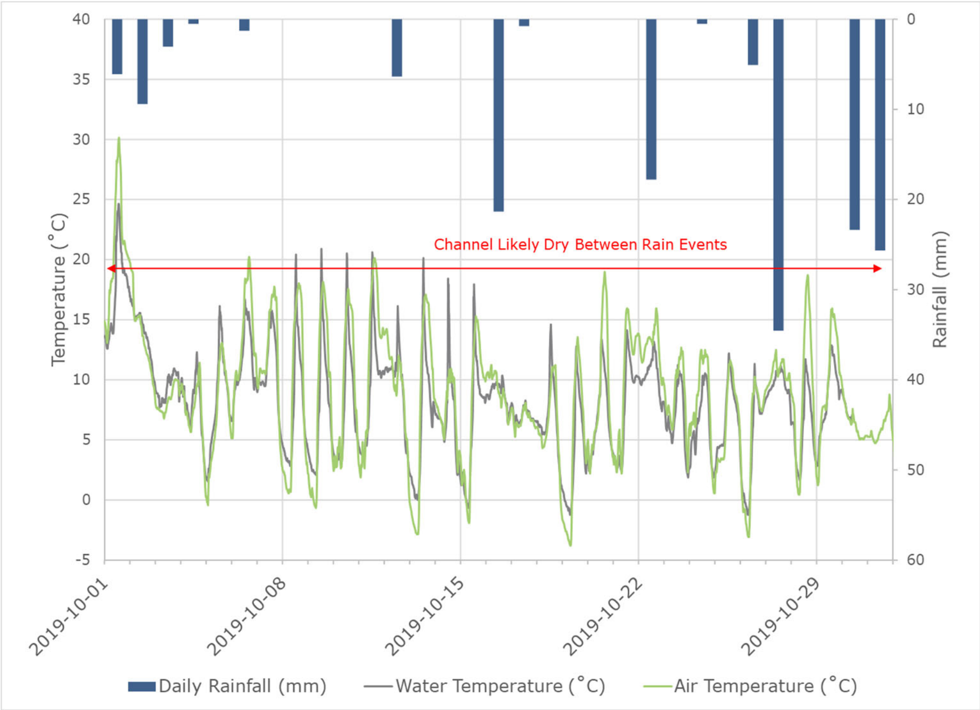
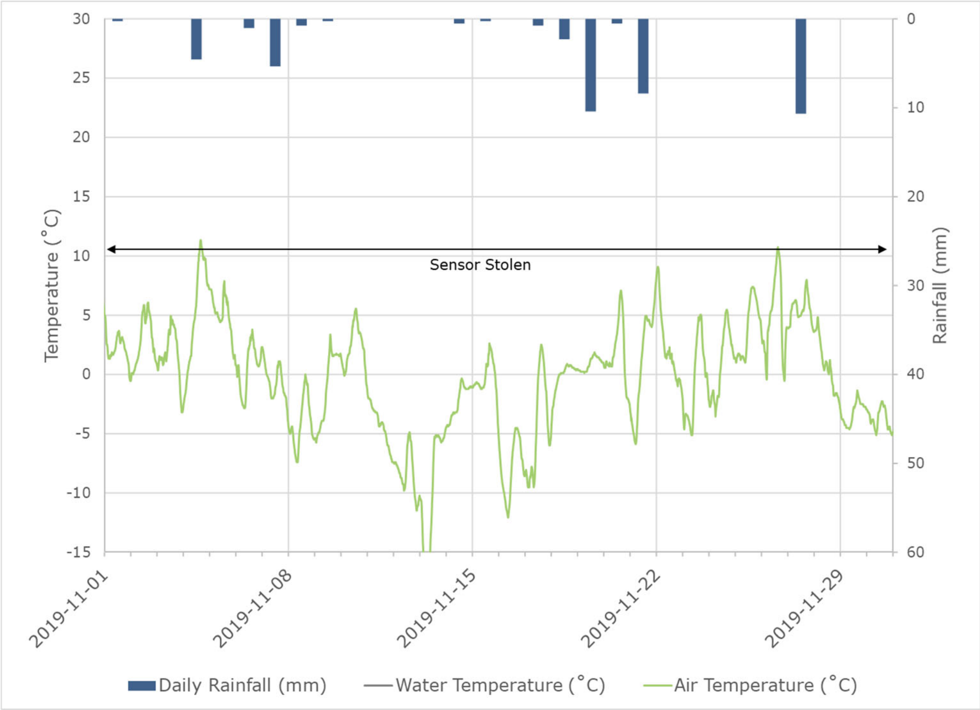
Figure 29	
	Water temperature, air temperature and daily rainfall at **Outlet** for August 2019.
Figure 30	
	Water temperature, air temperature and daily rainfall at **Outlet** for September 2019.

Figure 31	
	Water temperature, air temperature and daily rainfall at **Outlet** for October 2019.
Figure 32	
	Water temperature, air temperature and daily rainfall at **Outlet** for November 2019.

2019 W Inlet Water Level

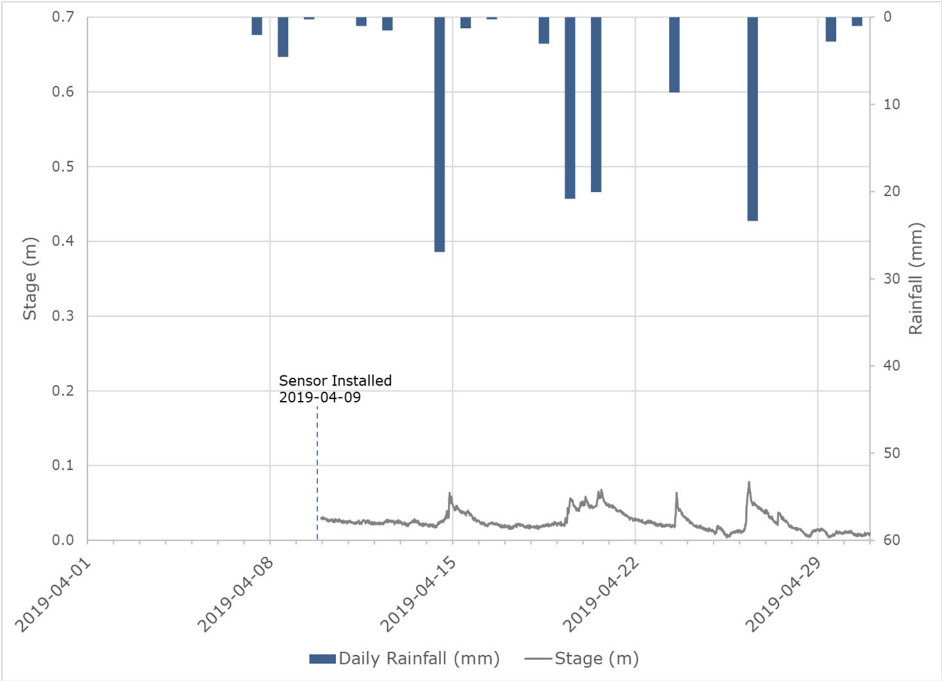
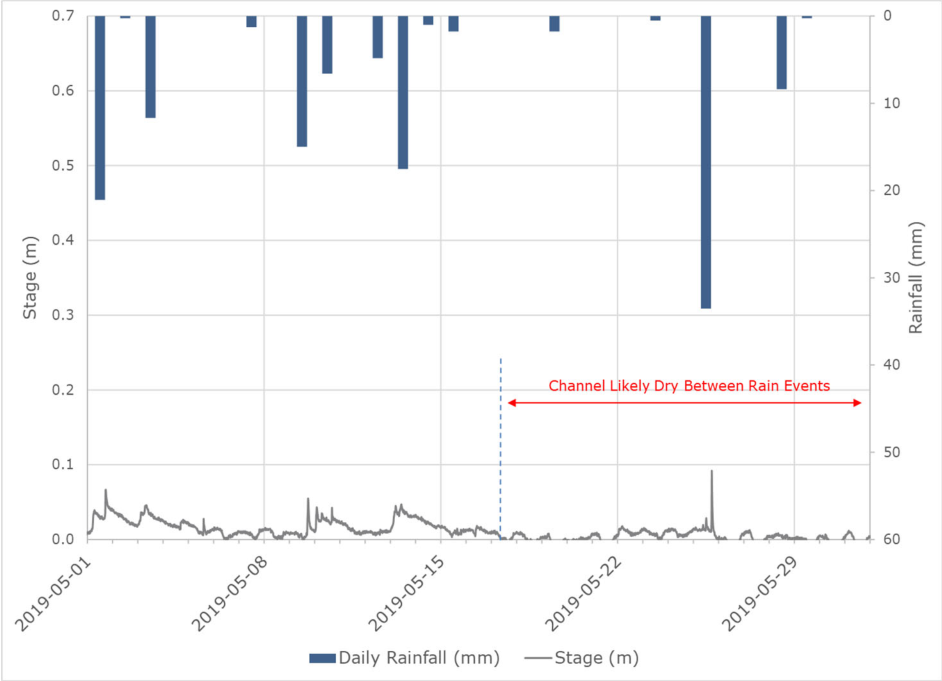
Figure 33	
	Water level and daily rainfall at **W Inlet** for April 2019.
Figure 34	
	Water level and daily rainfall at **W Inlet** for May 2019.

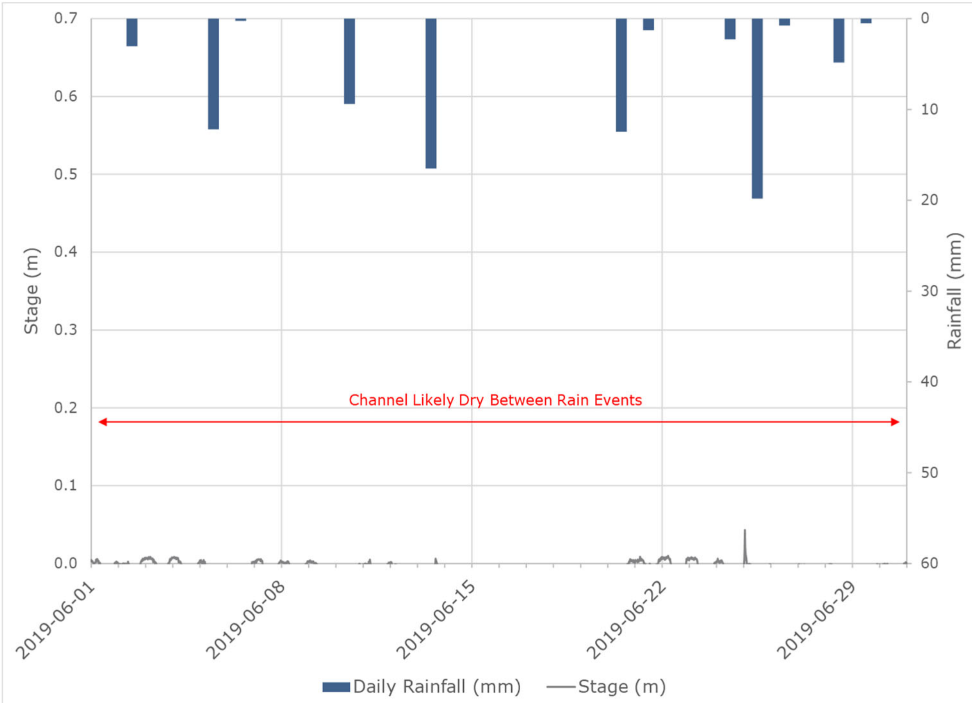
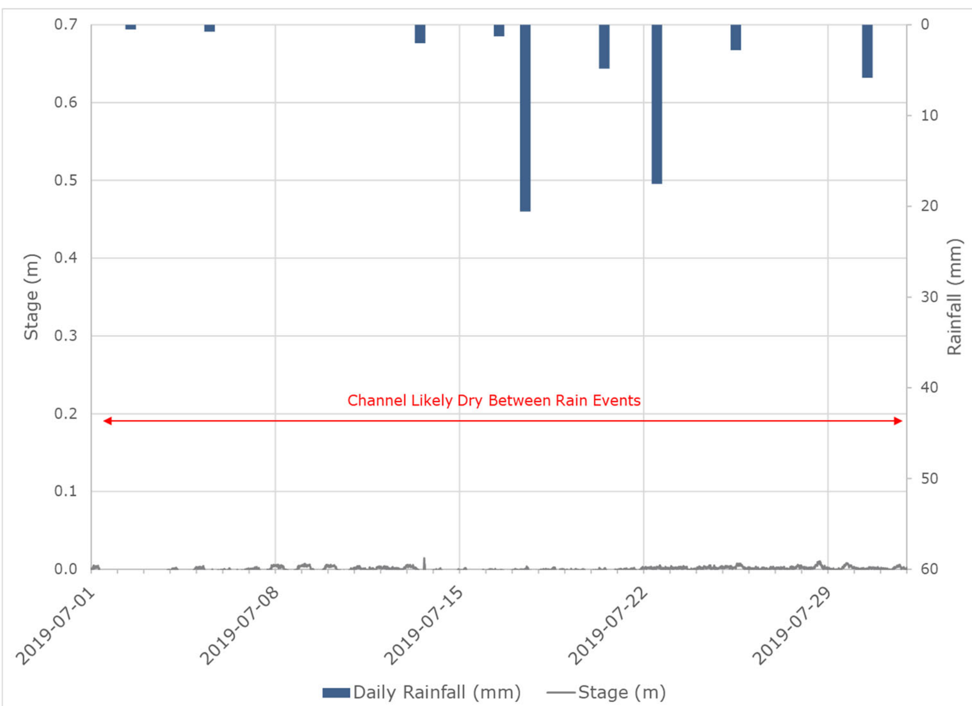
Figure 35	
	Water level and daily rainfall at **W Inlet** for June 2019.
Figure 36	
	Water level and daily rainfall at **W Inlet** for July 2019.

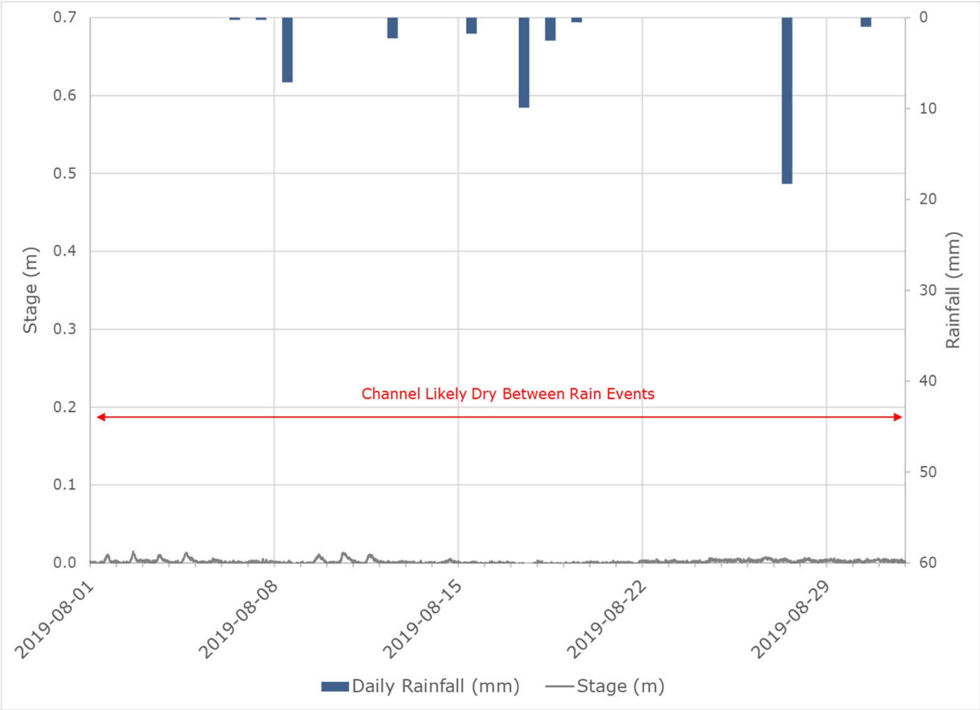
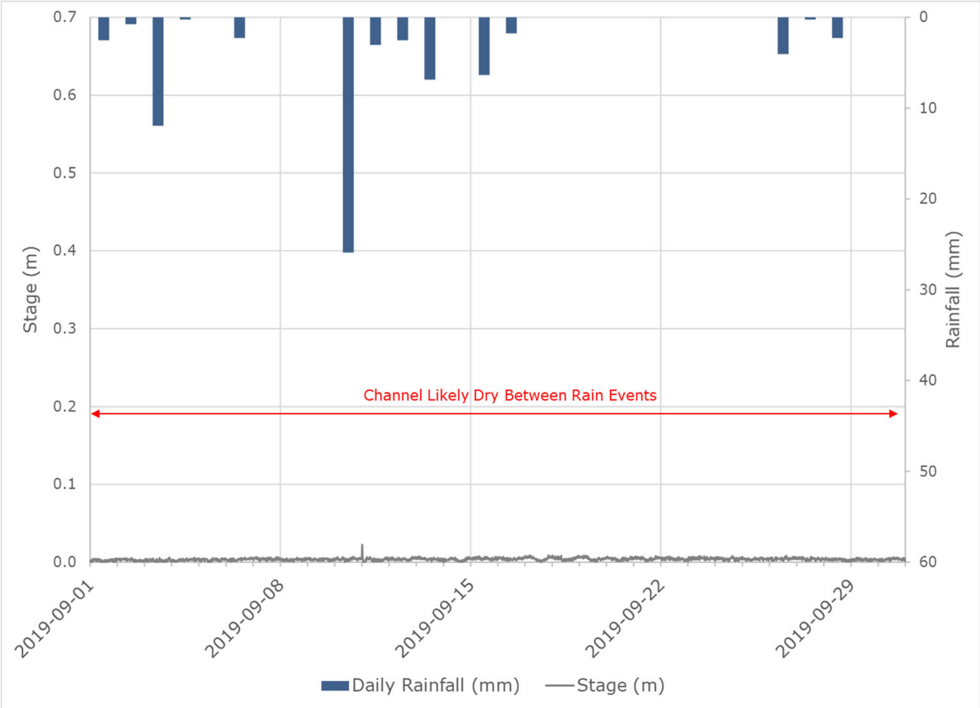
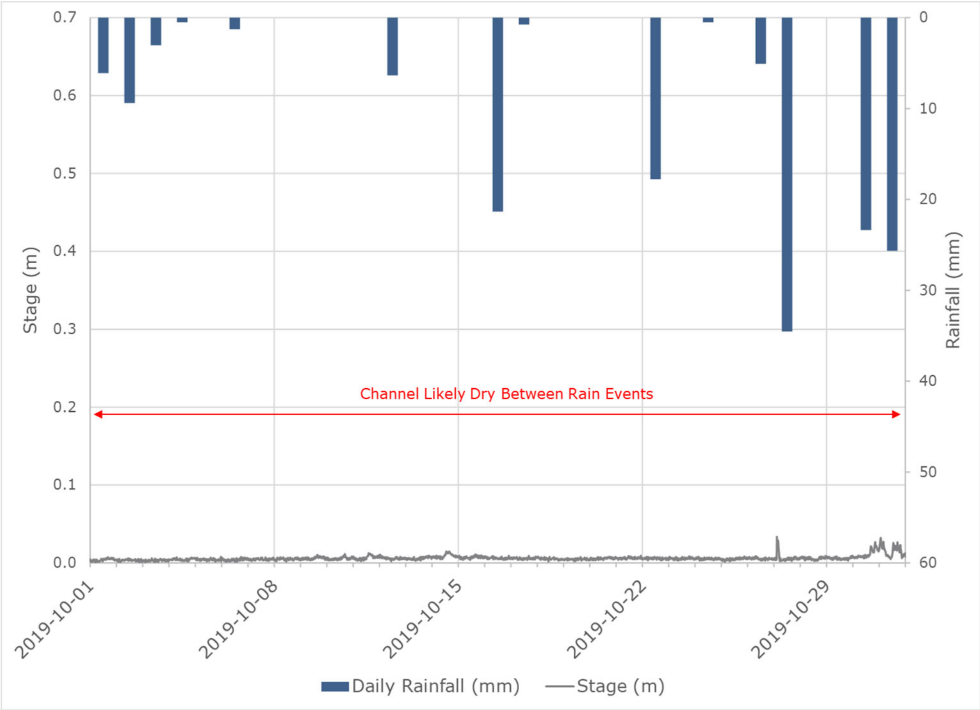
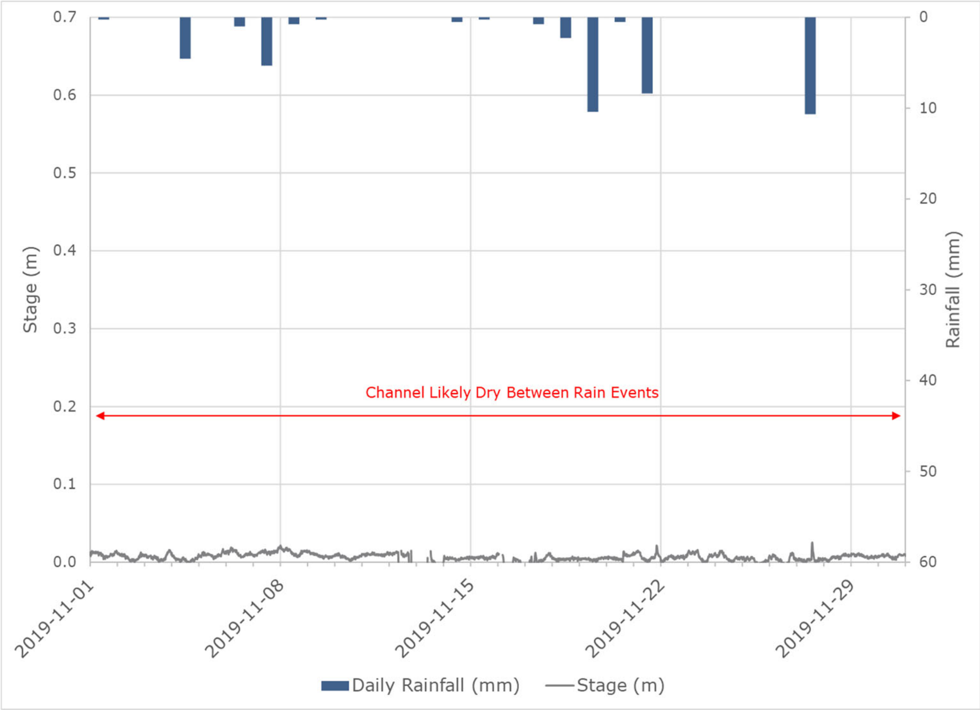
Figure 37	
	Water level and daily rainfall at **W Inlet** for August 2019.
Figure 38	
	Water level and daily rainfall at **W Inlet** for September 2019.

Figure 39	
	Water level and daily rainfall at **W Inlet** for October 2019.
Figure 40	
	Water level and daily rainfall at **W Inlet** for November 2019.

2019 S Inlet Water Level

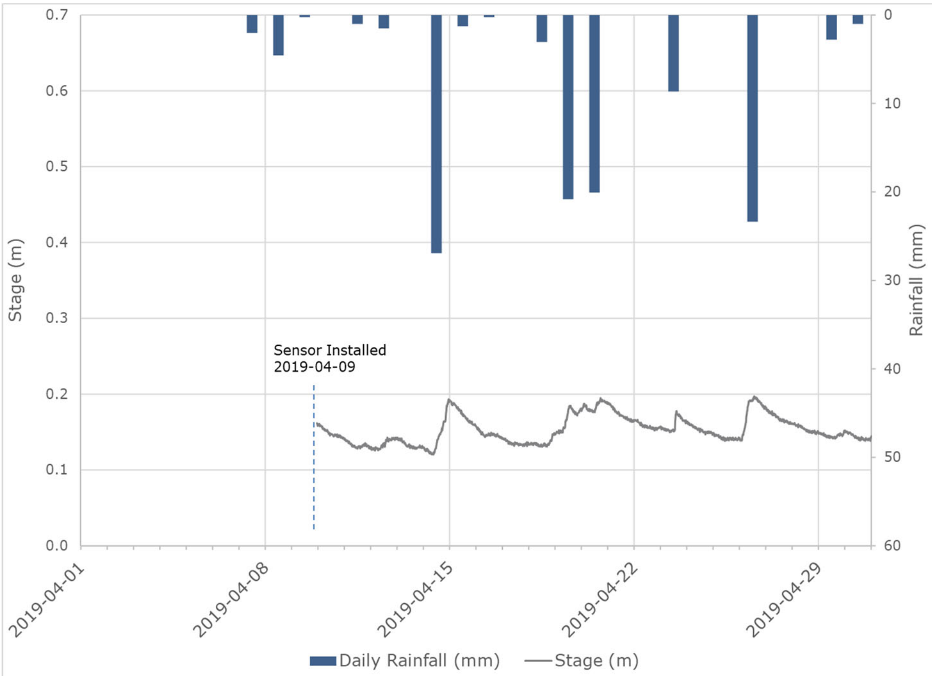
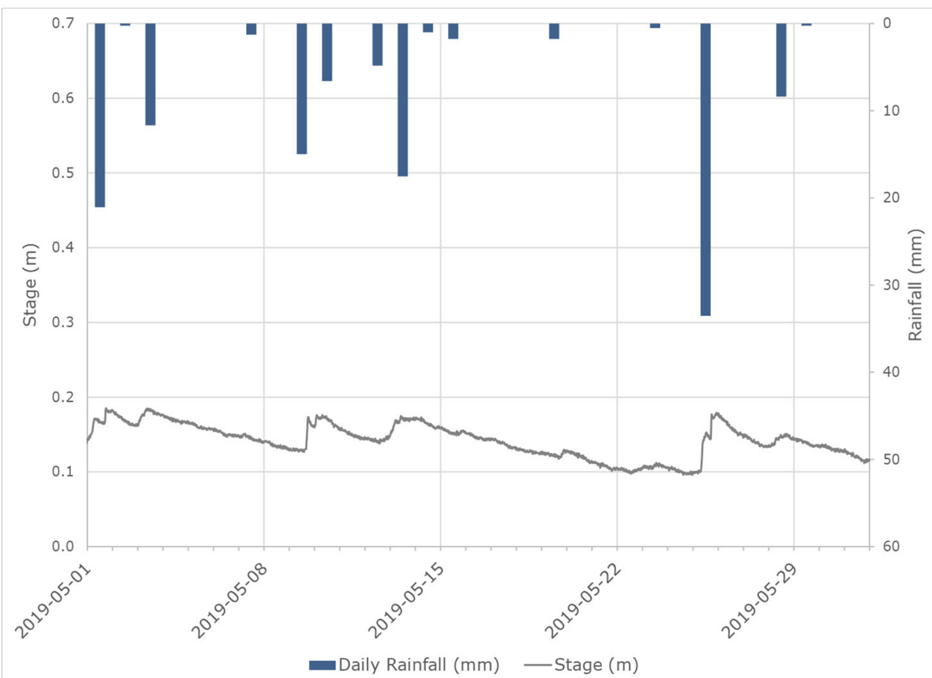
Figure 41	 Water level and daily rainfall at **S Inlet** for April 2019.
Figure 42	 Water level and daily rainfall at **S Inlet** for May 2019.

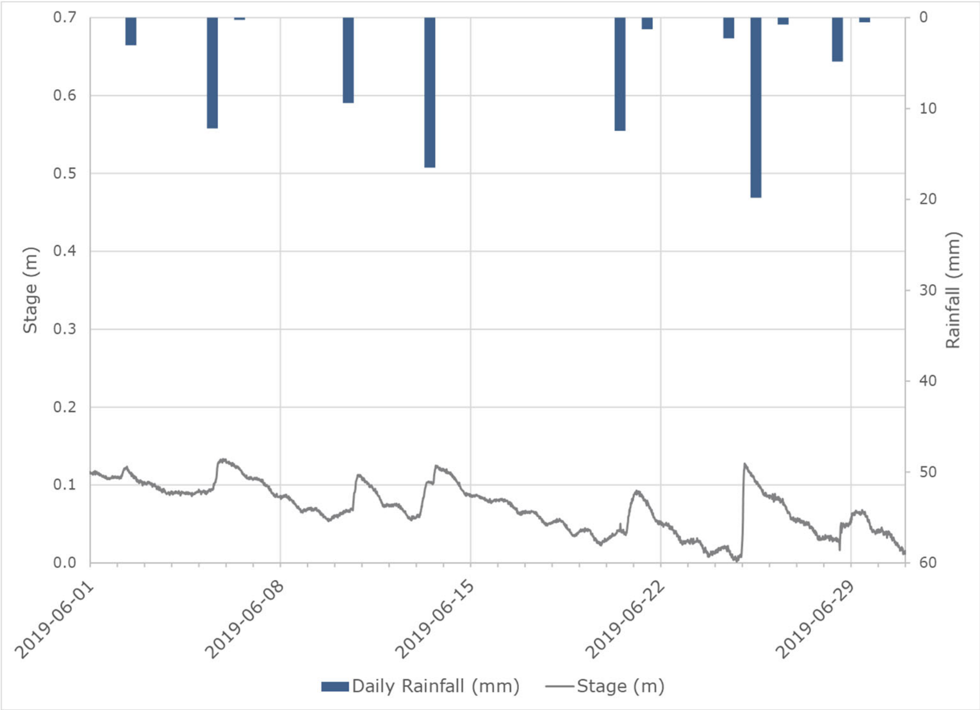
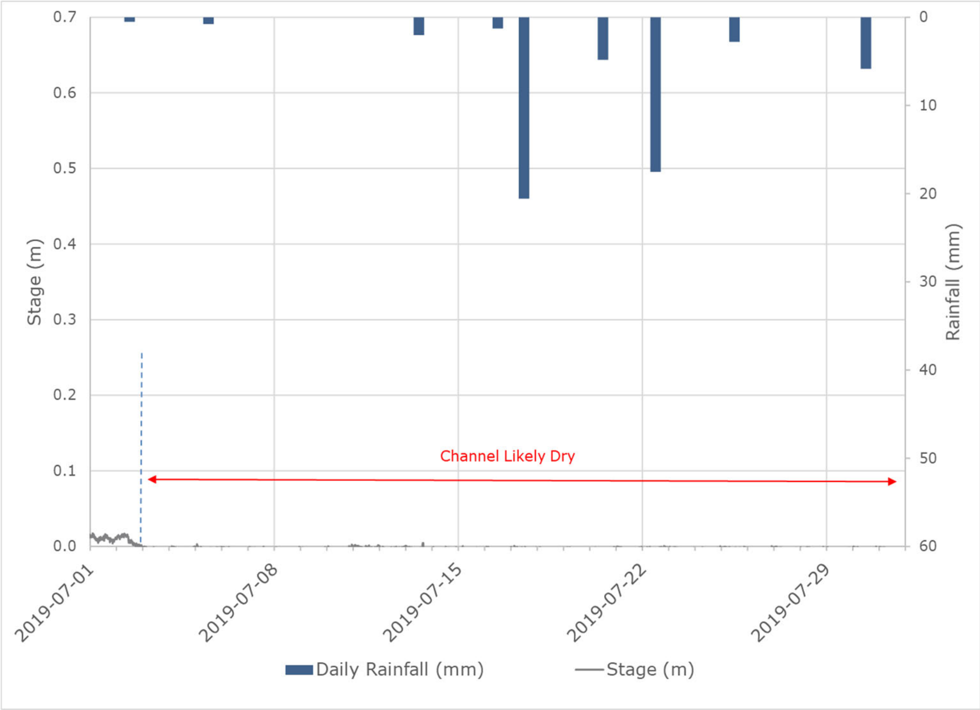
Figure 43	
	Water level and daily rainfall at **S Inlet** for June 2019.
Figure 44	
	Water level and daily rainfall at **S Inlet** for July 2019.

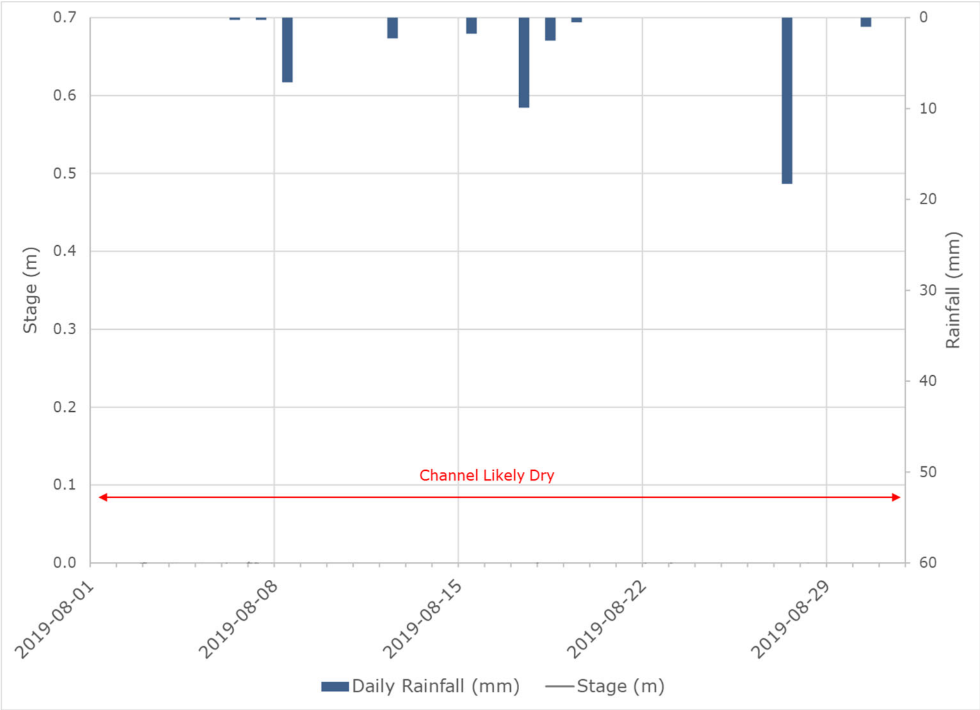
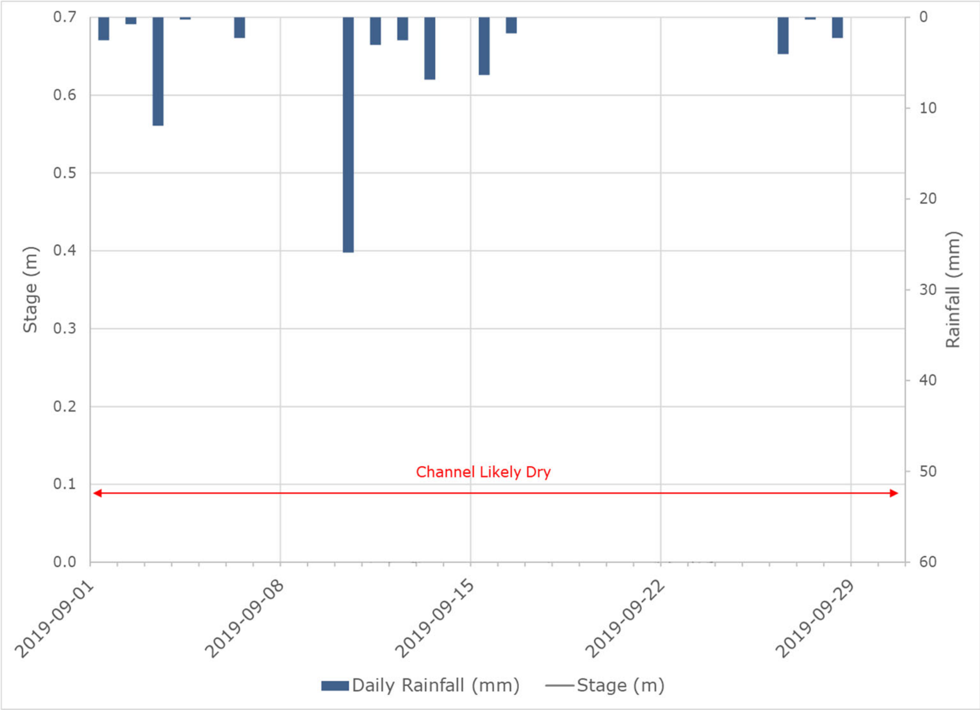
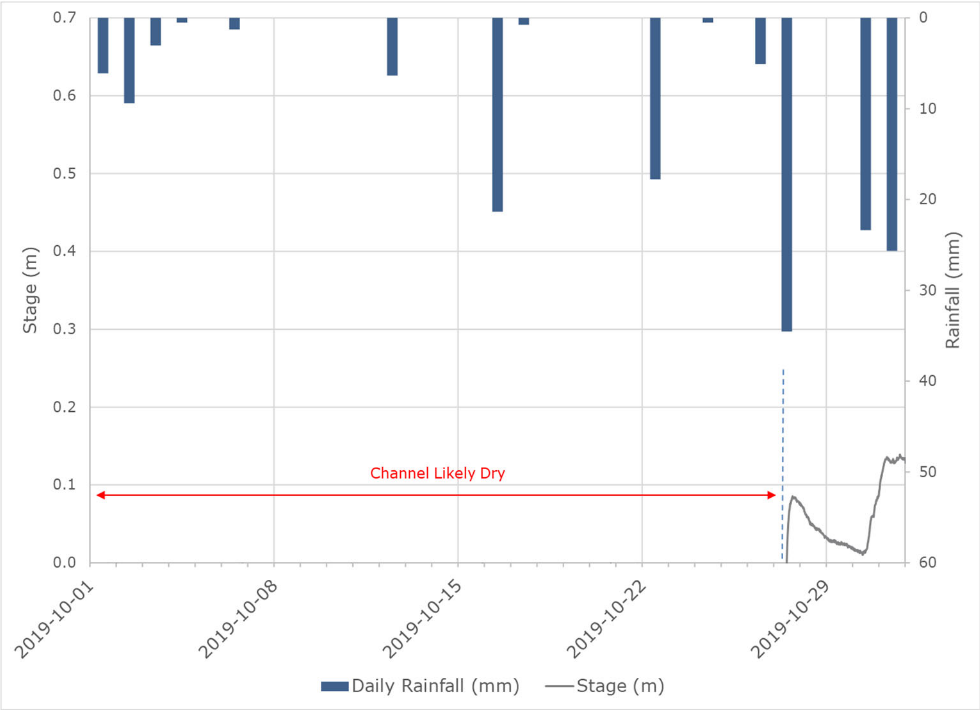
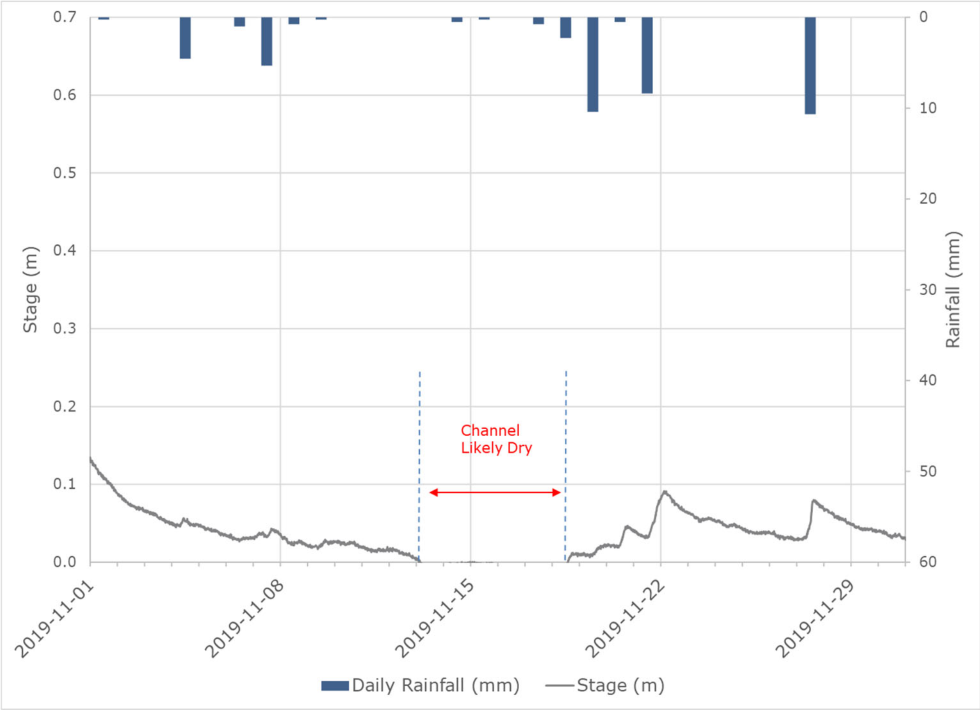
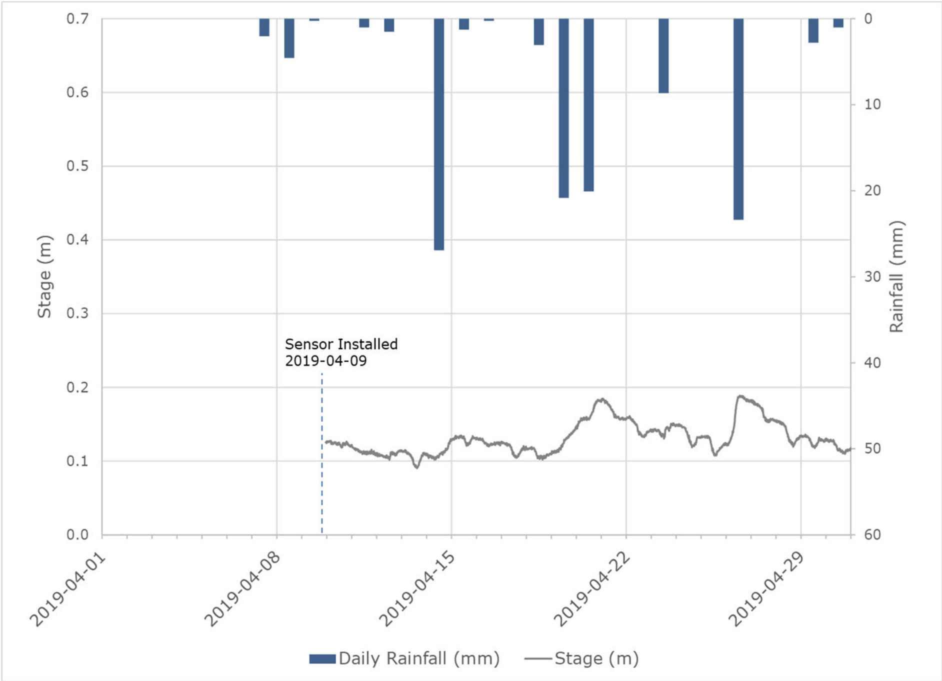
Figure 45	
	Water level and daily rainfall at **S Inlet** for August 2019.
Figure 46	
	Water level and daily rainfall at **S Inlet** for September 2019.

Figure 47	
	Water level and daily rainfall at **S Inlet** for October 2019.
Figure 48	
	Water level and daily rainfall at **S Inlet** for November 2019.

2019 Bridge Water Level

<table>
<tr><td>Figure 49</td><td>
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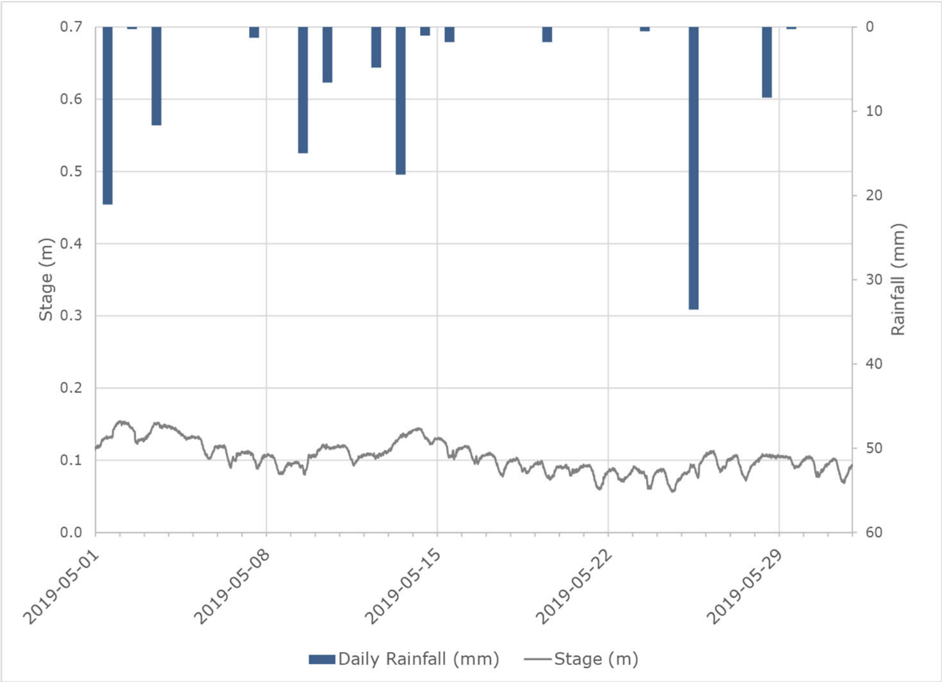
<tr><td></td><td>Water level and daily rainfall at Bridge for April 2019.</td></tr>
<tr><td>Figure 50</td><td>
</td></tr>
<tr><td></td><td>Water level and daily rainfall at Bridge for May 2019.</td></tr>
</table>

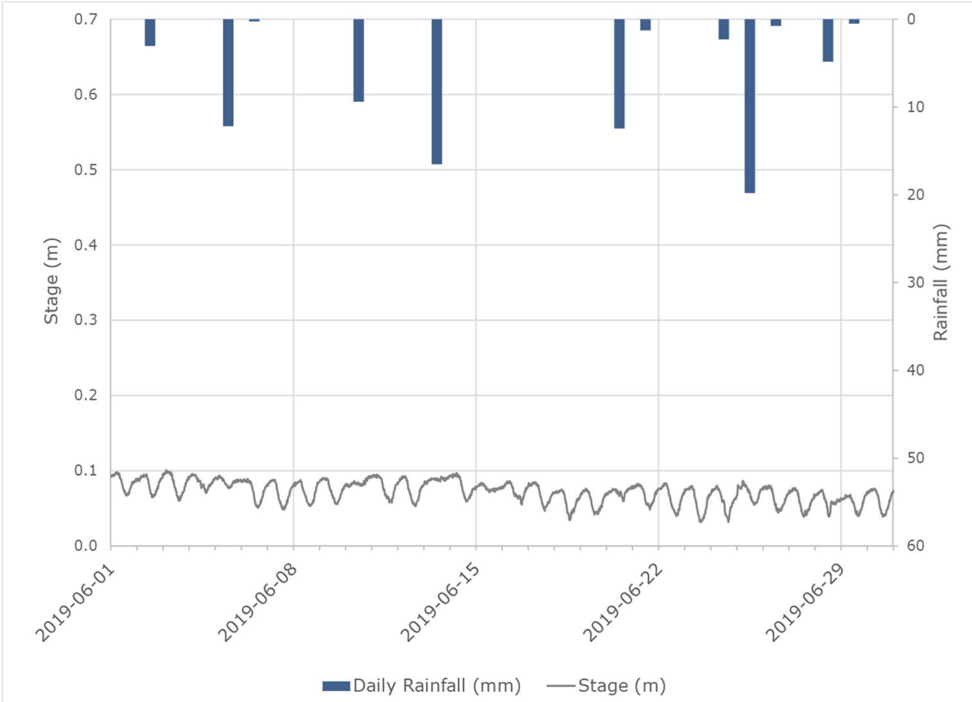
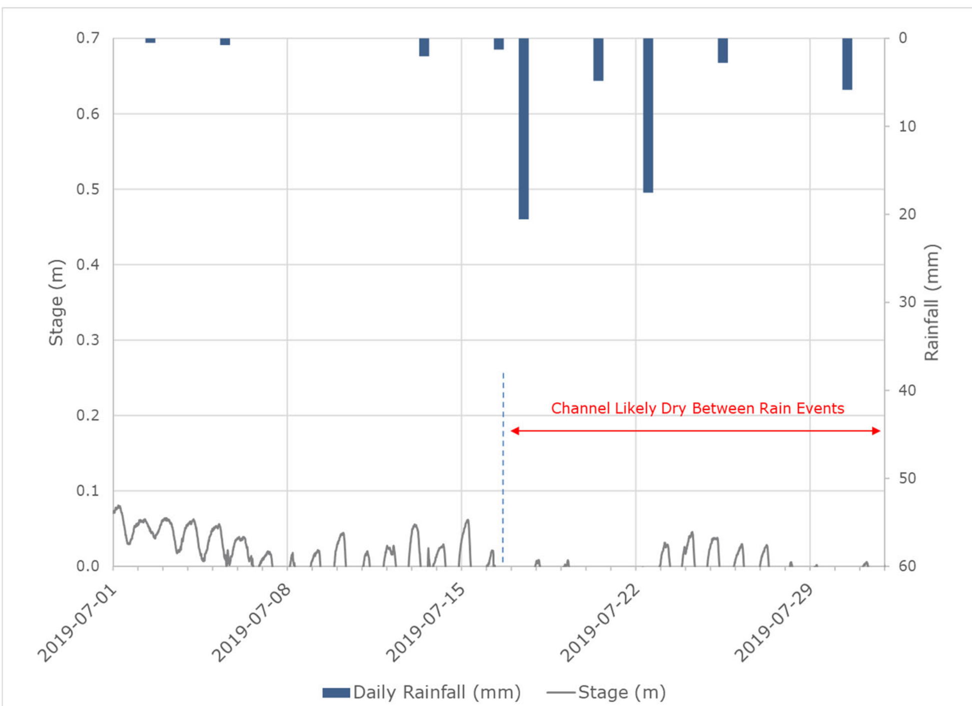
Figure 51	
	Water level and daily rainfall at **Bridge** for June 2019.
Figure 52	
	Water level and daily rainfall at **Bridge** for July 2019.

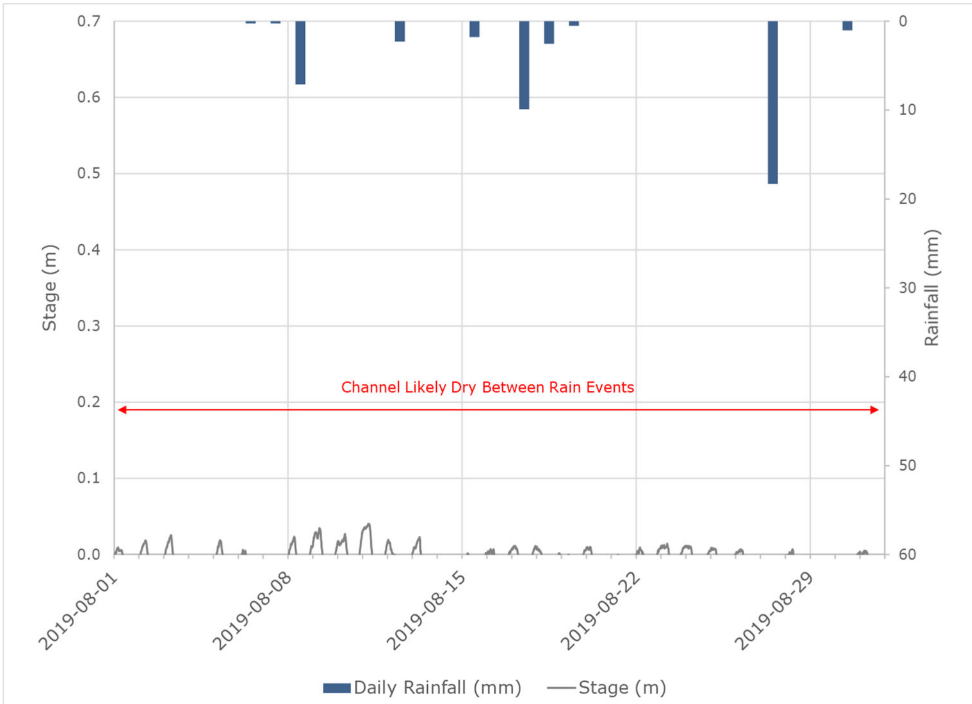
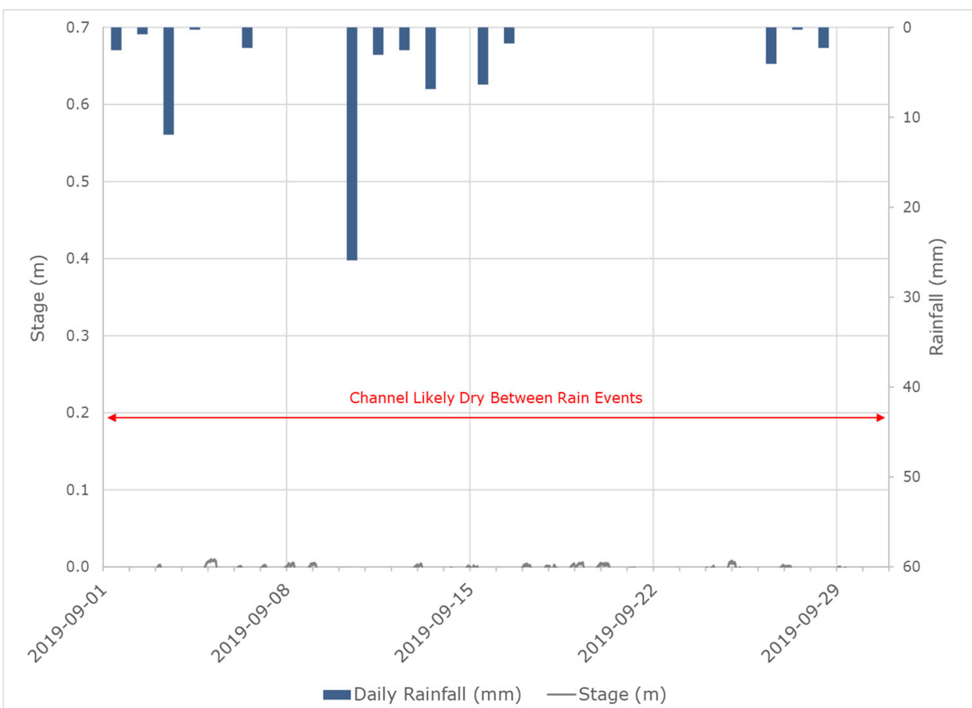
Figure 53	
	Water level and daily rainfall at **Bridge** for August 2019.
Figure 54	
	Water level and daily rainfall at **Bridge** for September 2019.

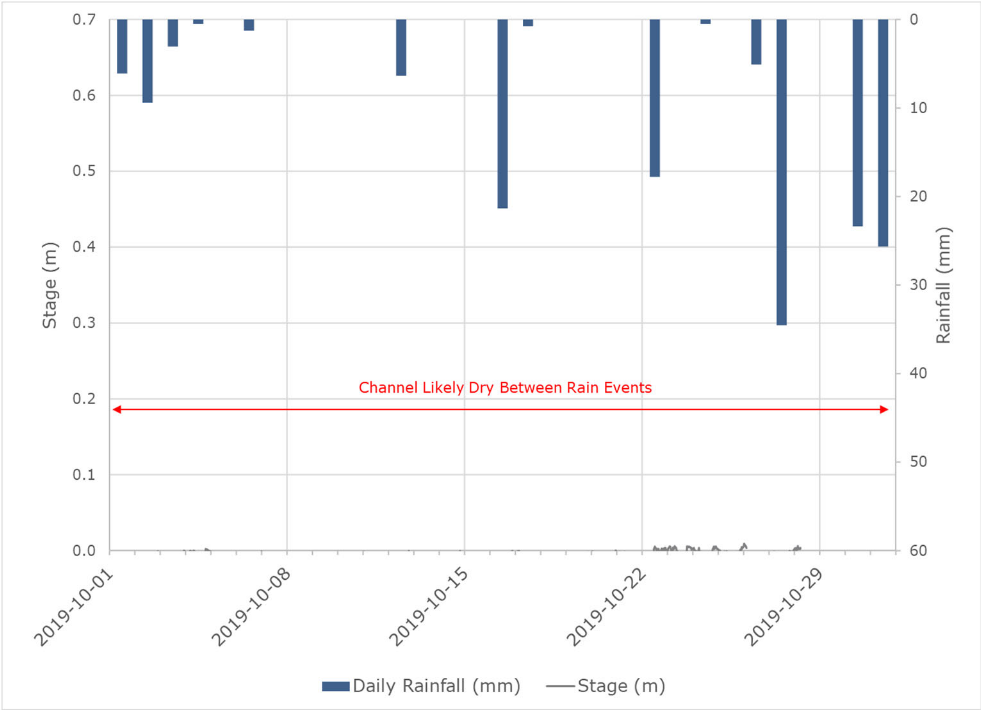
Figure 55	
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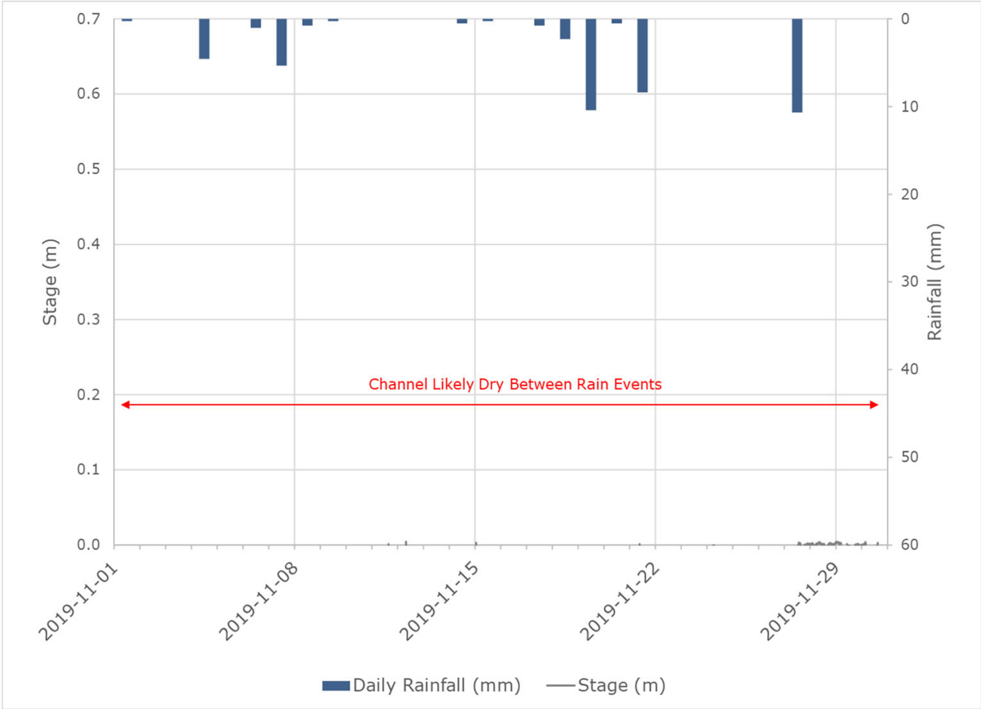
Figure 56	
	Water level and daily rainfall at **Bridge** for November 2019.

2019 Outlet Water Level

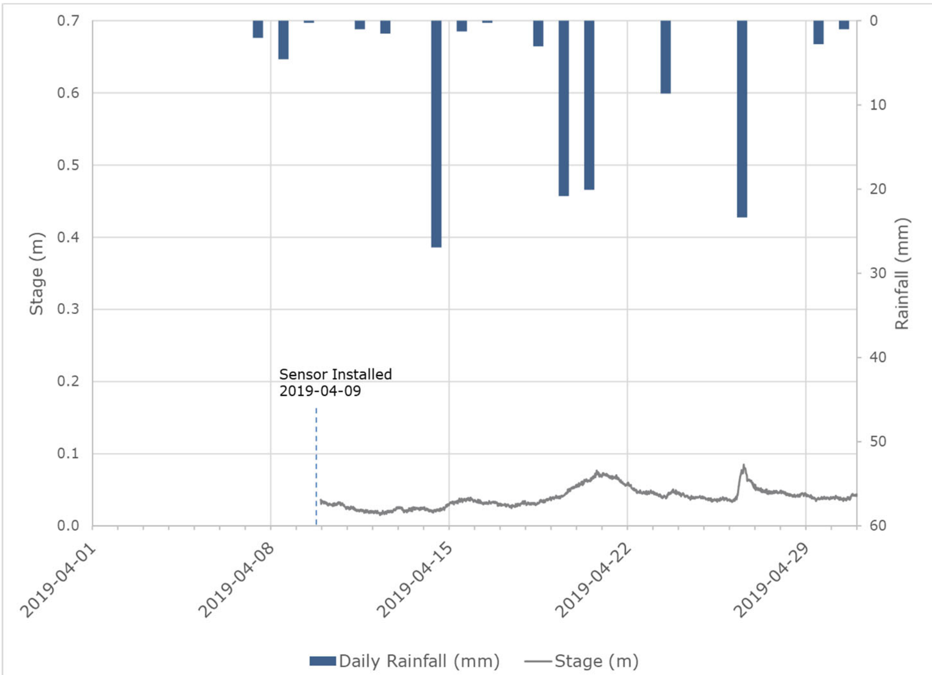
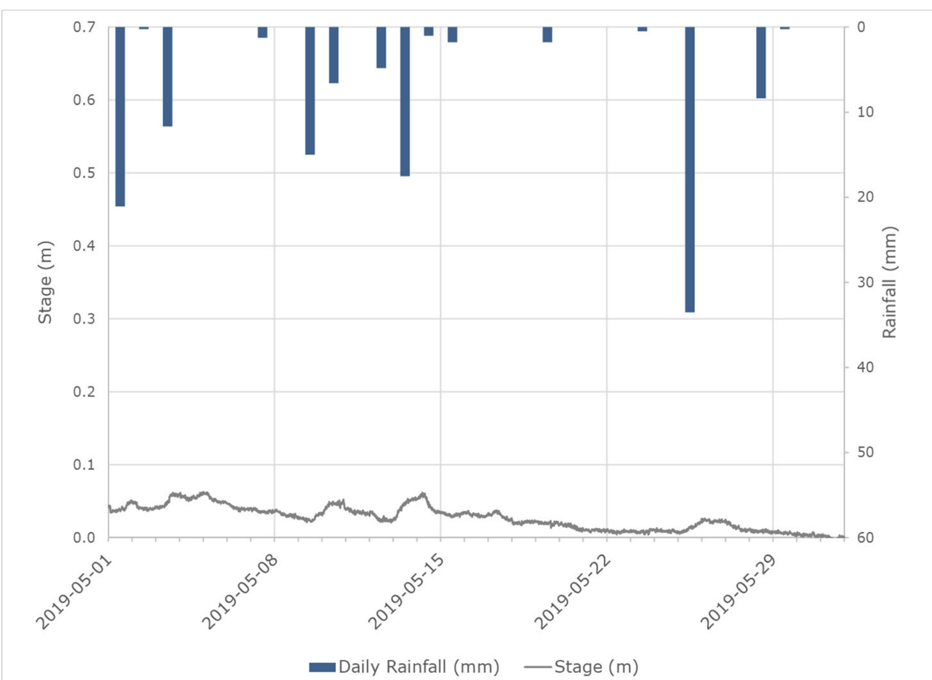
Figure 57	
	Water level and daily rainfall at **Outlet** for April 2019.
Figure 58	
	Water level and daily rainfall at **Outlet** for May 2019.

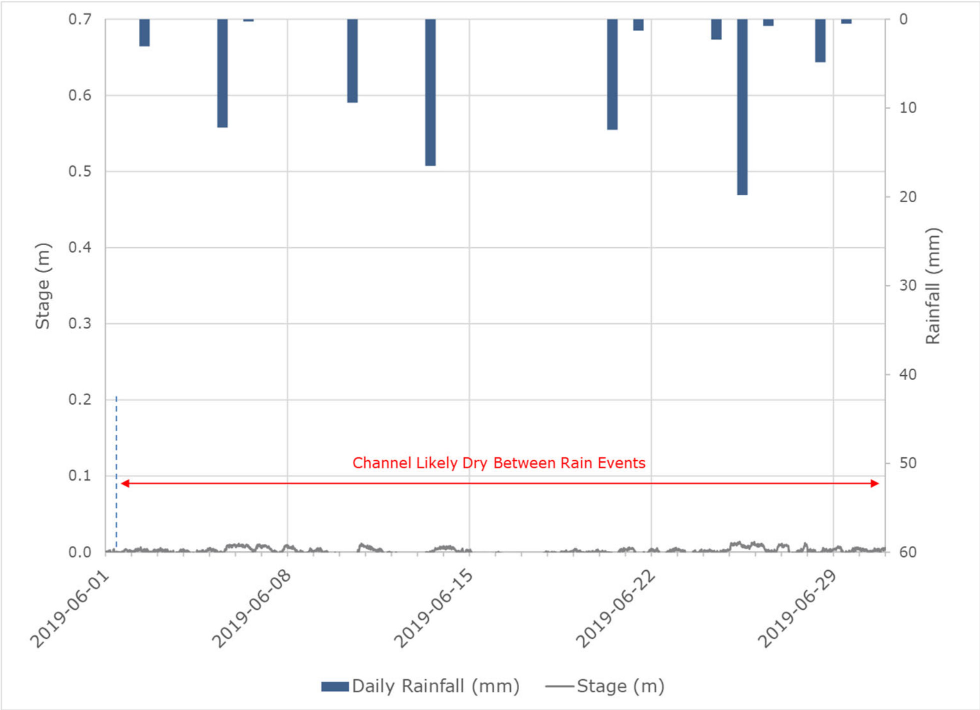
Figure 59	
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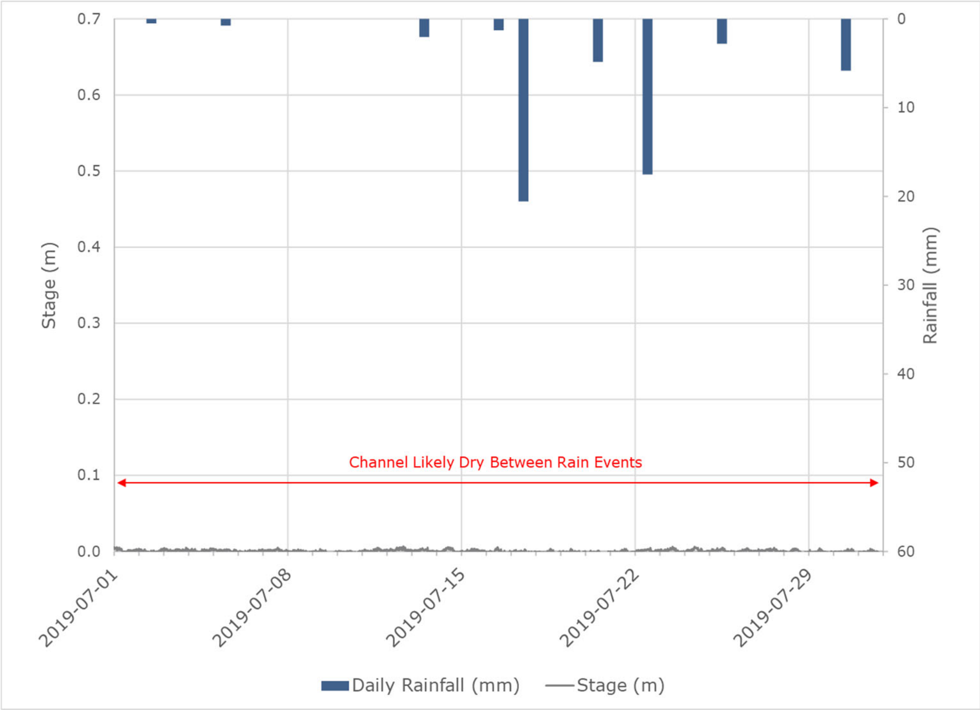
Figure 60	
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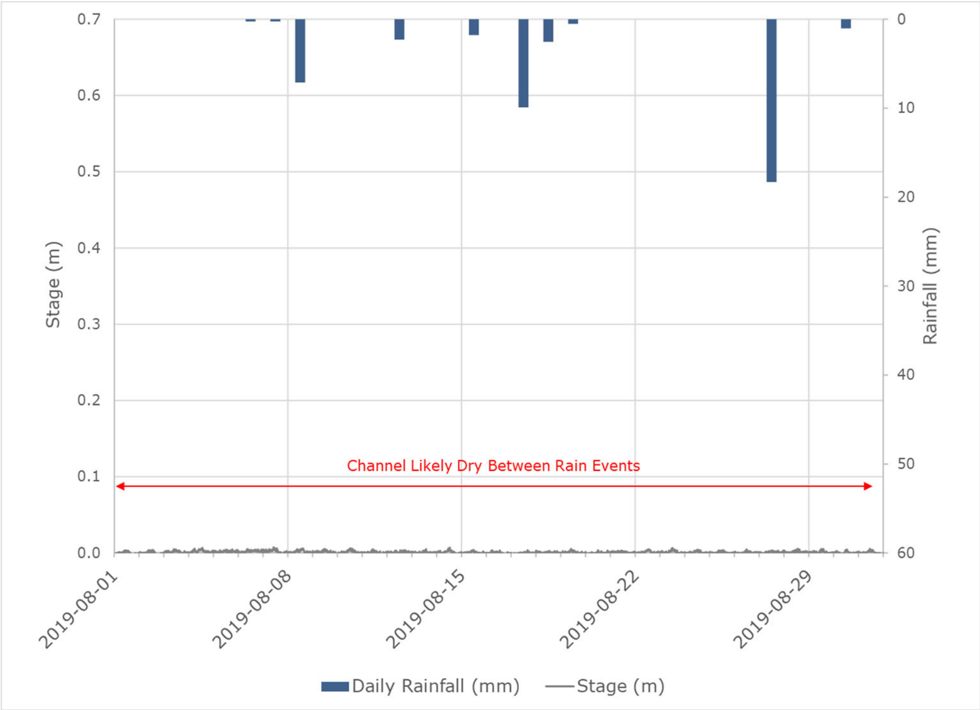
Figure 61	
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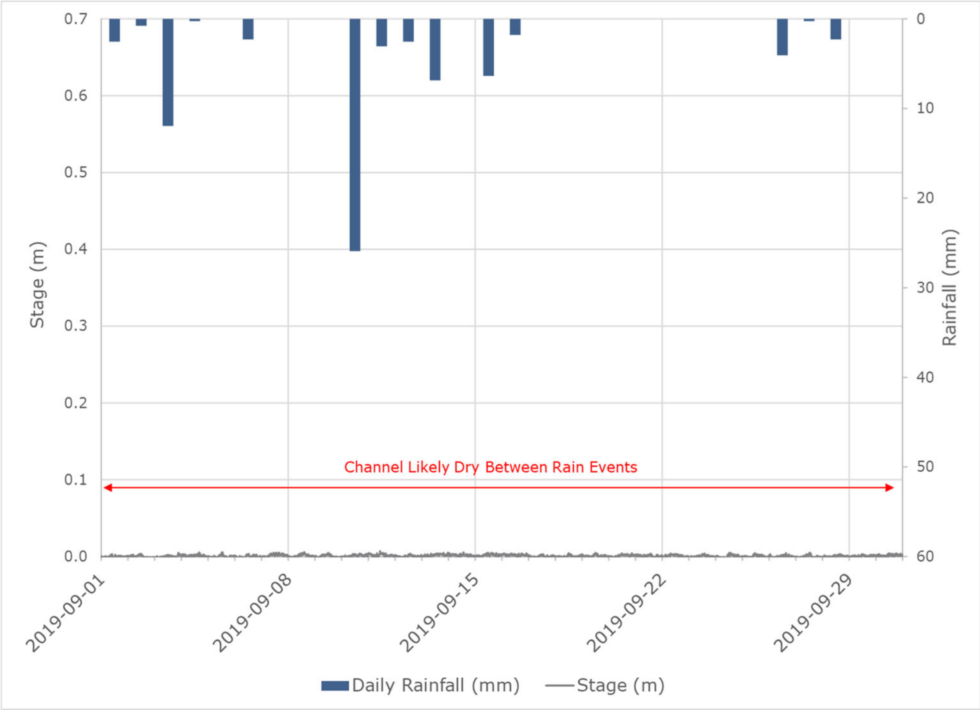
Figure 62	
	Water level and daily rainfall at **Outlet** for September 2019.

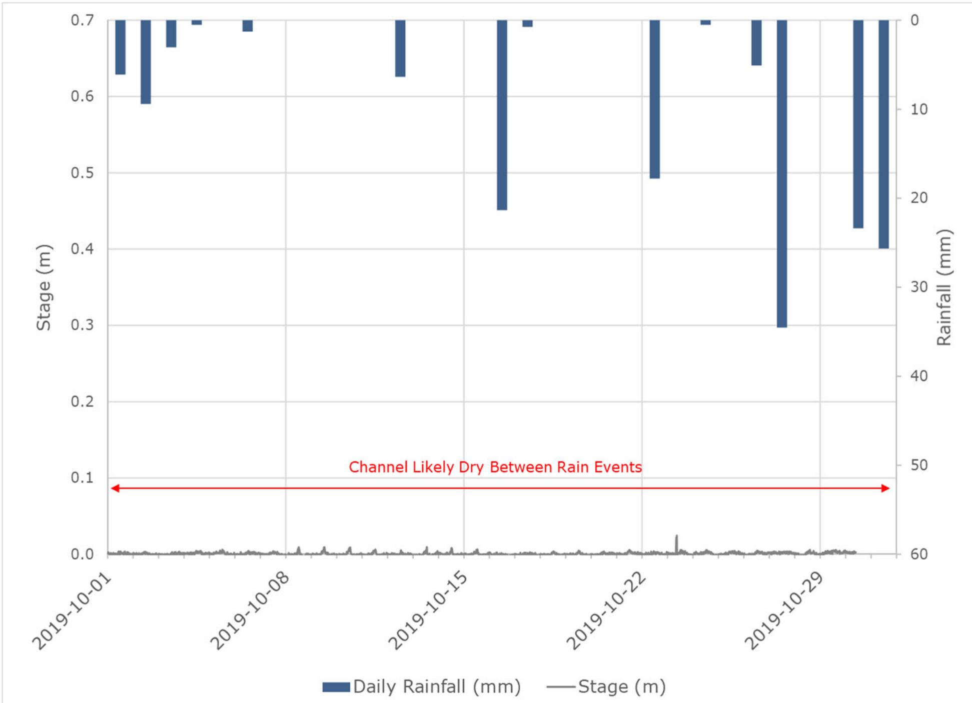
Figure 63	
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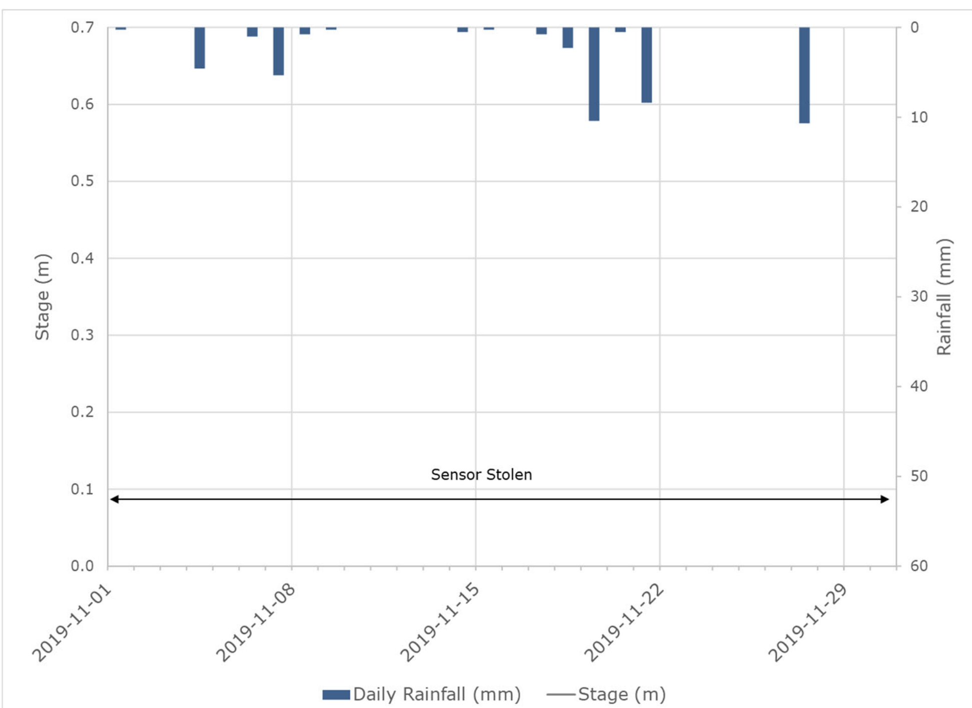
Figure 64	
	Water level and daily rainfall at **Outlet** for November 2019.

2020 W Inlet Water Temperature

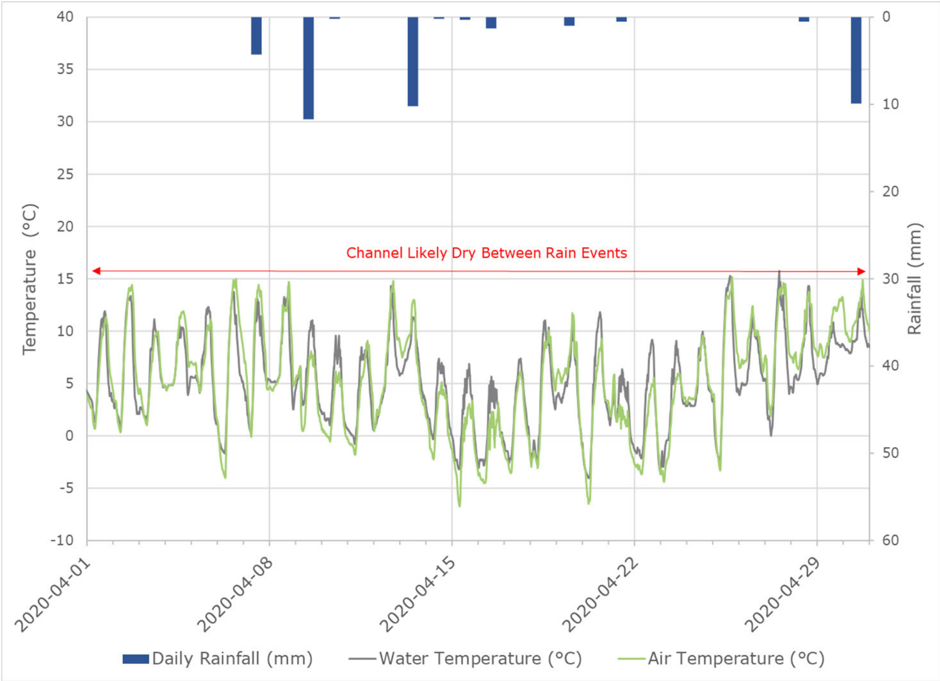
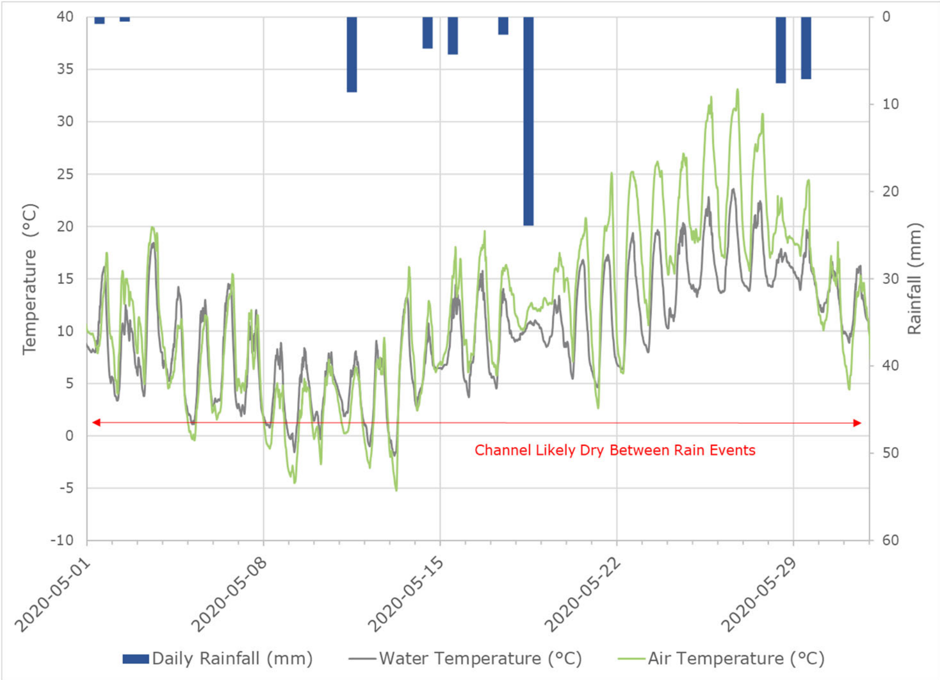
Figure 65	
	Water temperature, air temperature and daily rainfall at **W Inlet** for April 2020.
Figure 66	
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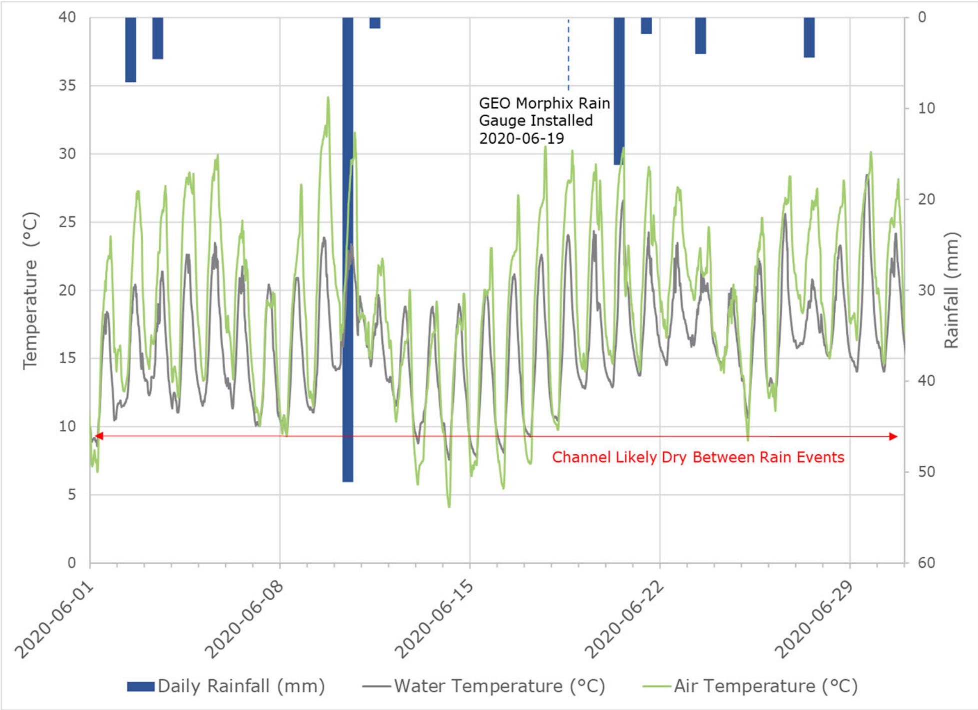
Figure 67	
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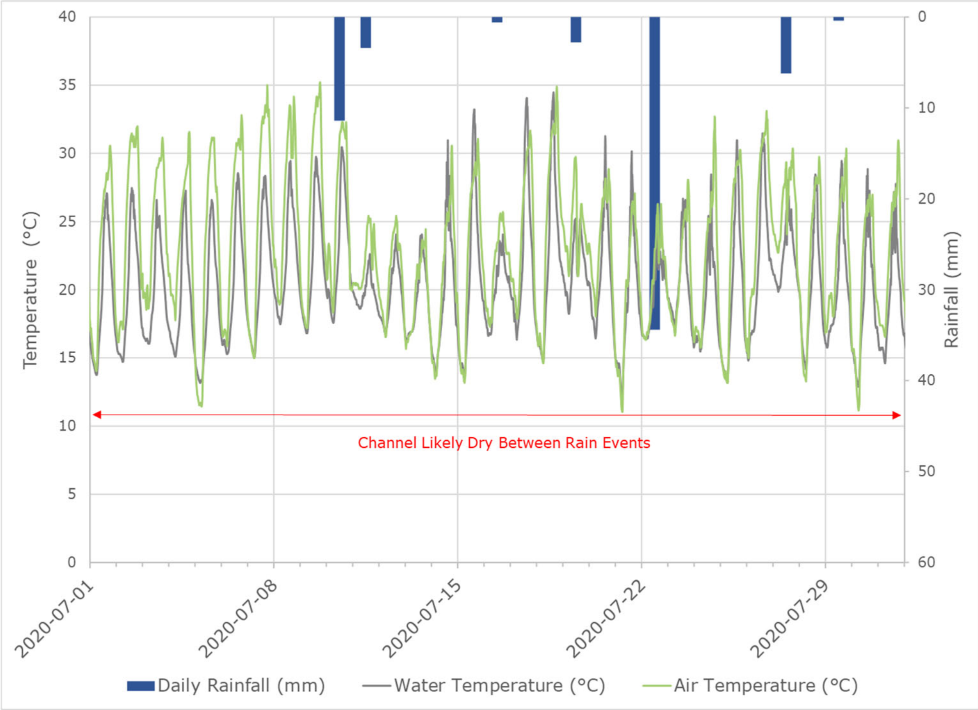
Figure 68	
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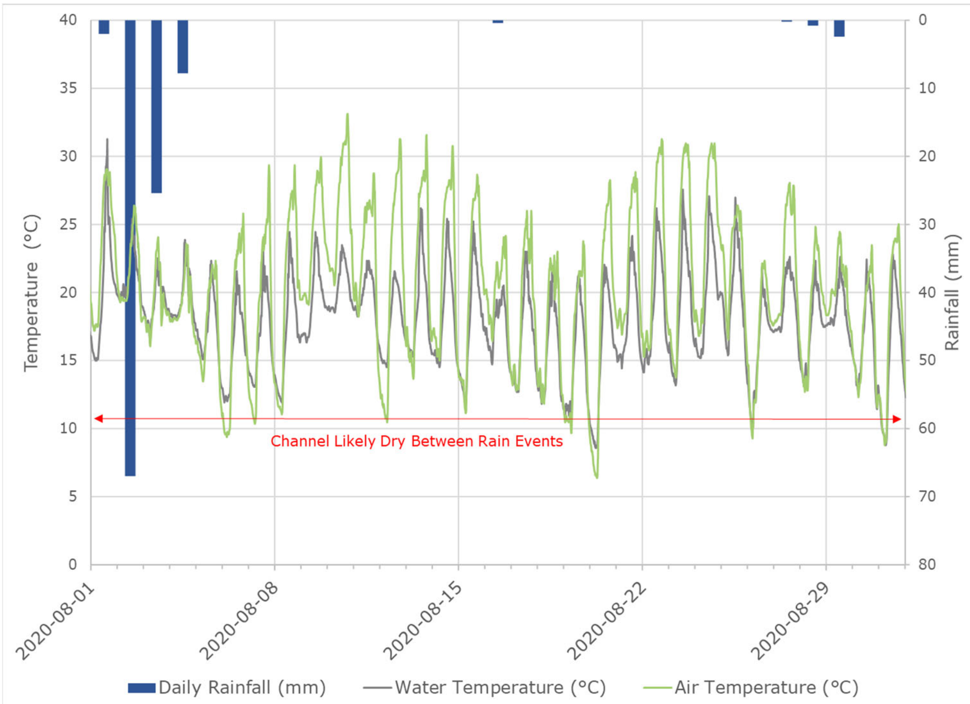
Figure 69	
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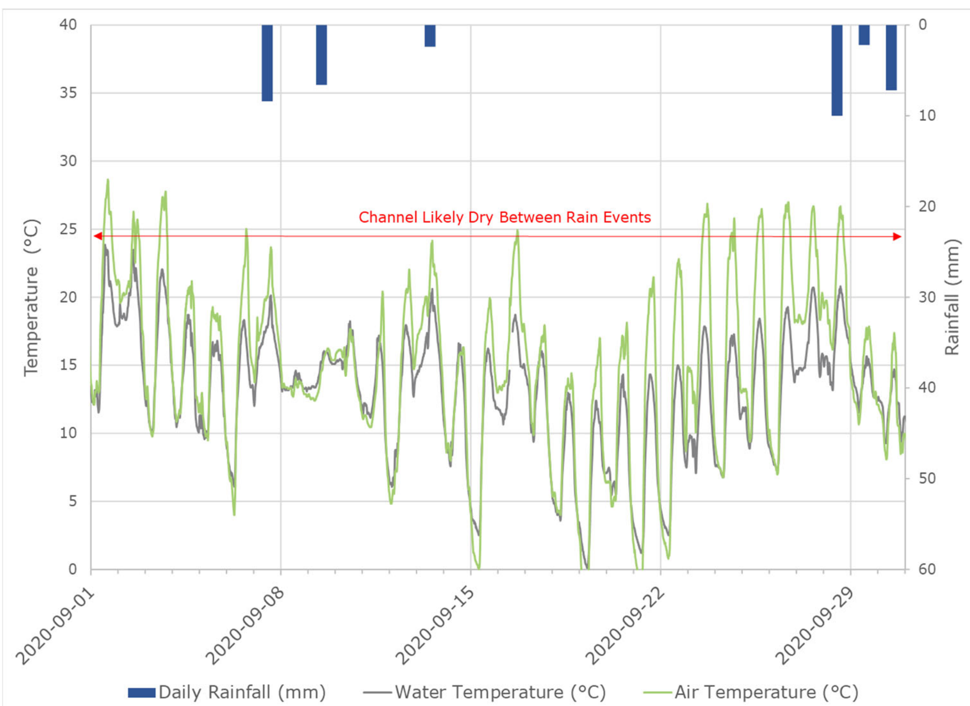
Figure 70	
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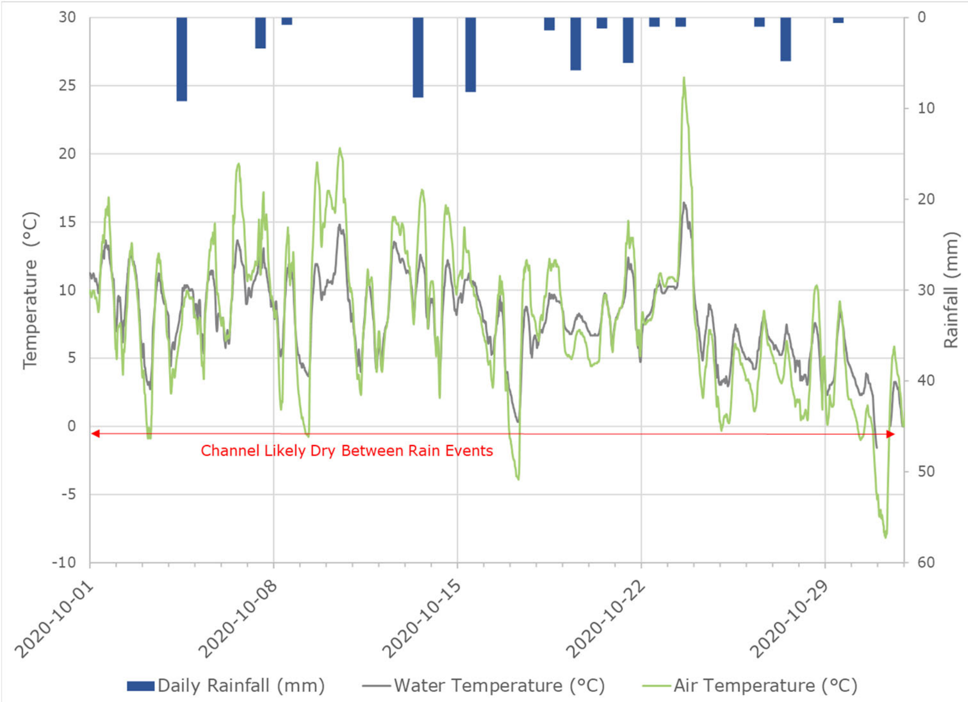
Figure 71	
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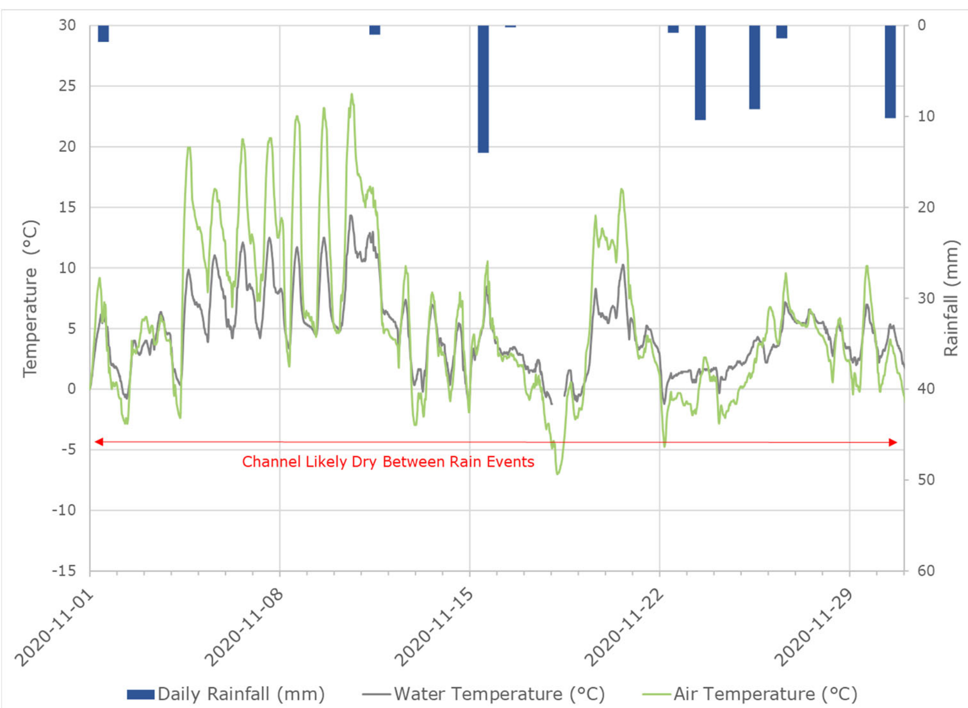
Figure 72	
	Water temperature, air temperature and daily rainfall at **W Inlet** for November 2020.

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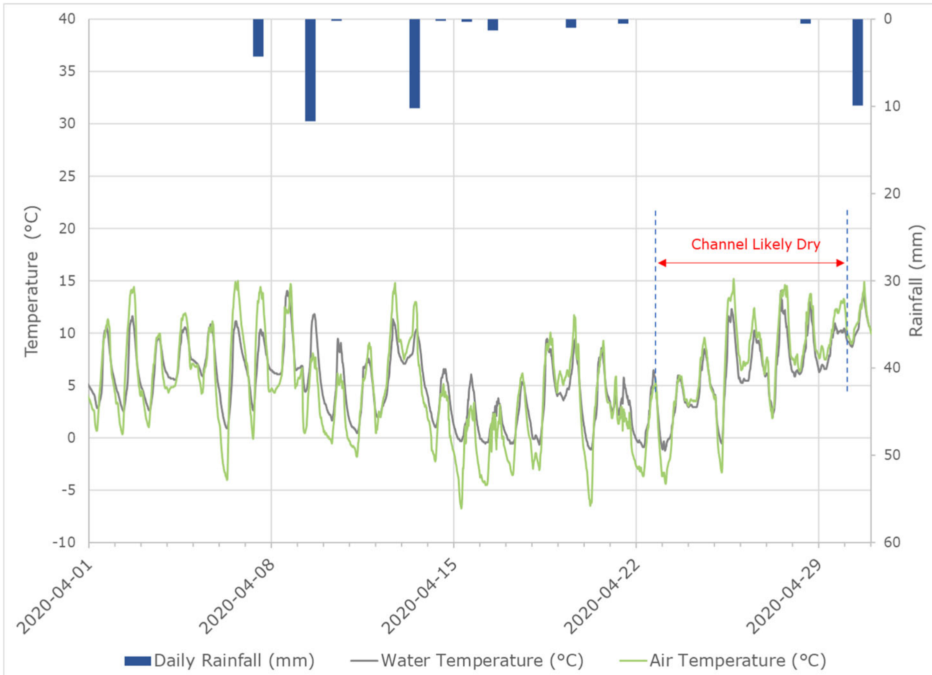
Figure 73	
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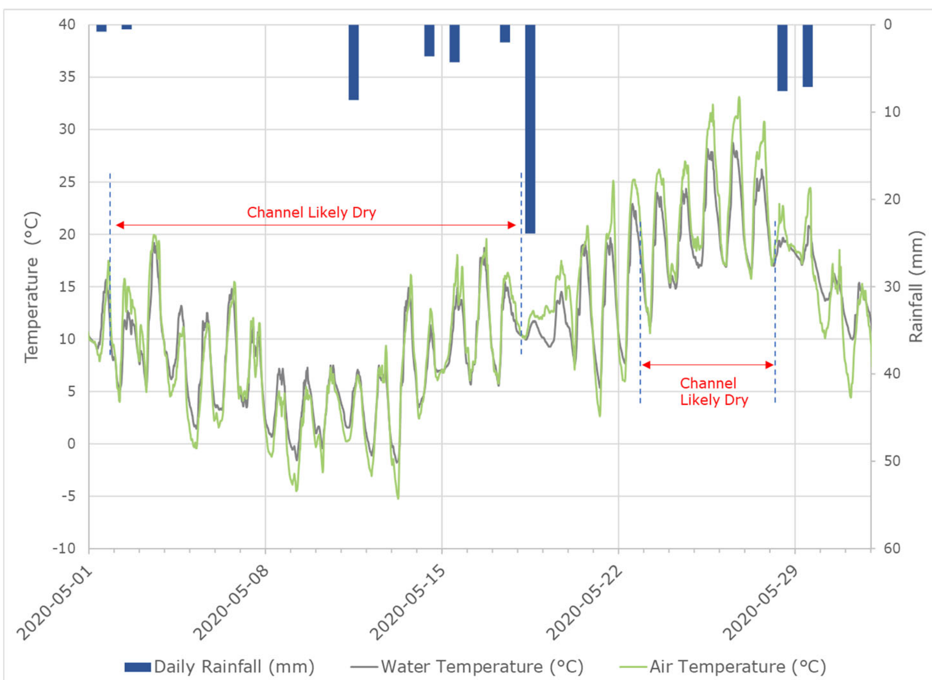
Figure 74	
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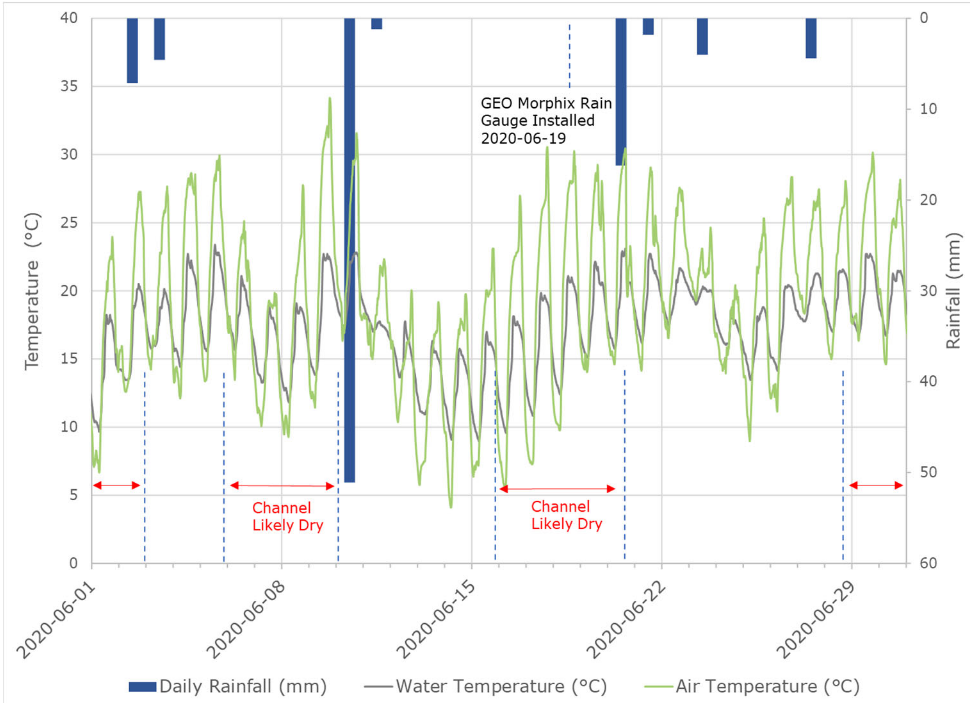
Figure 75	
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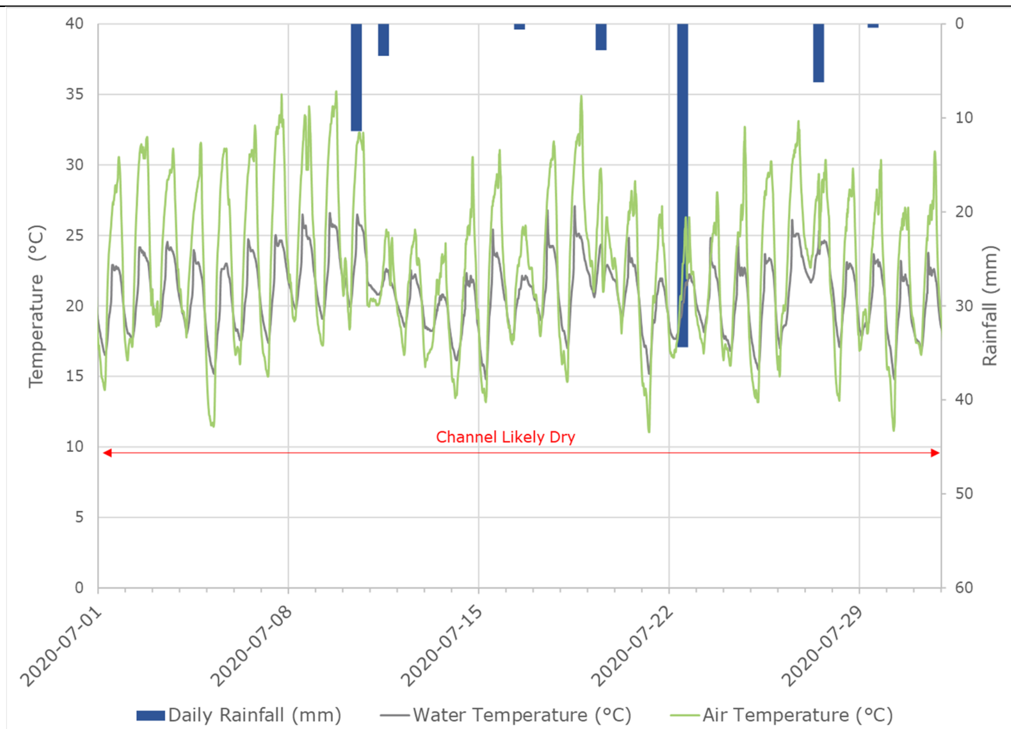
Figure 76	
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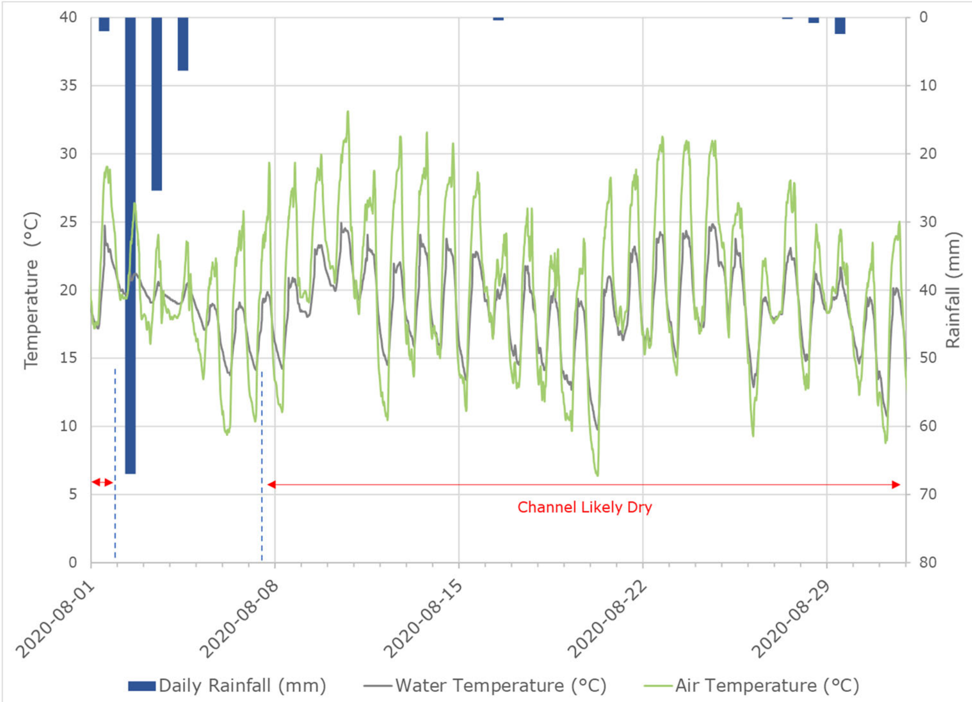
<tr><td rowspan="2">Photo 77</td><td>
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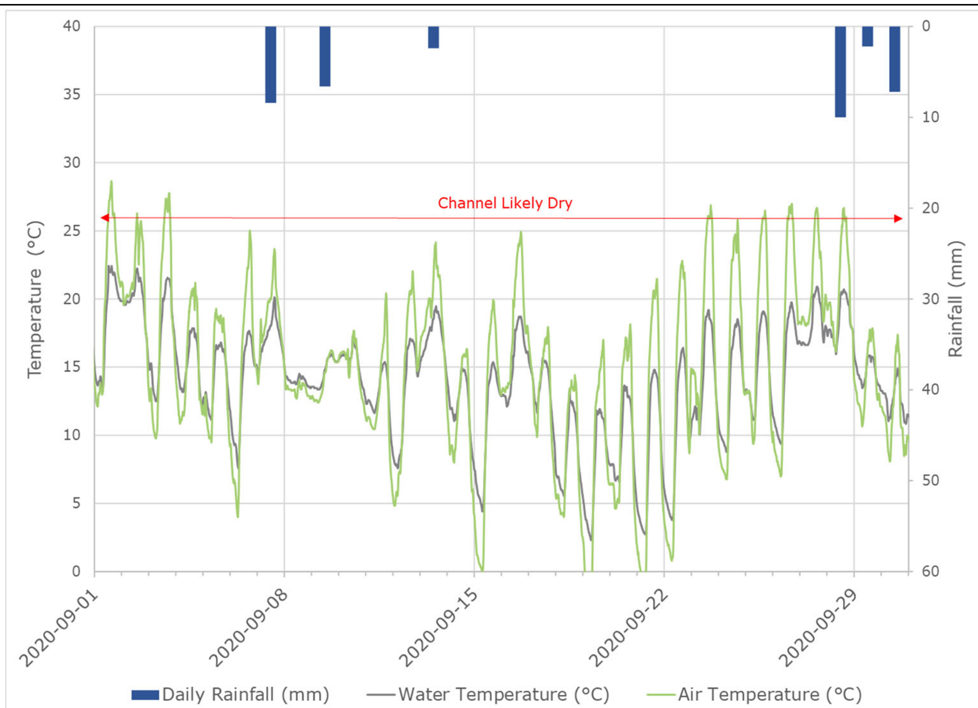
<tr><td rowspan="2">Figure 78</td><td>
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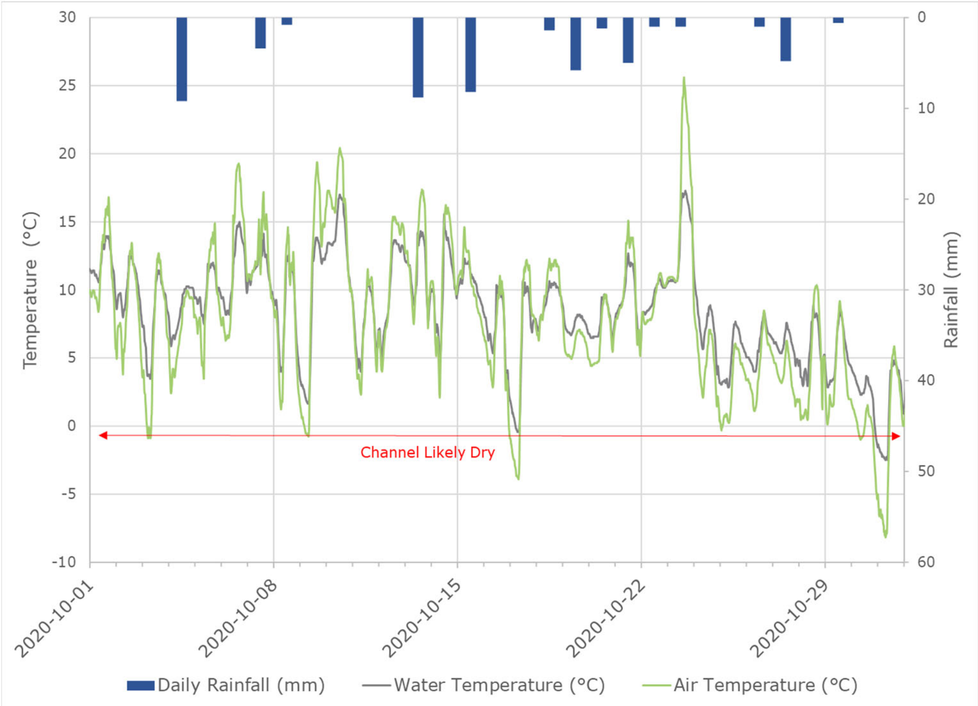
Figure 79	
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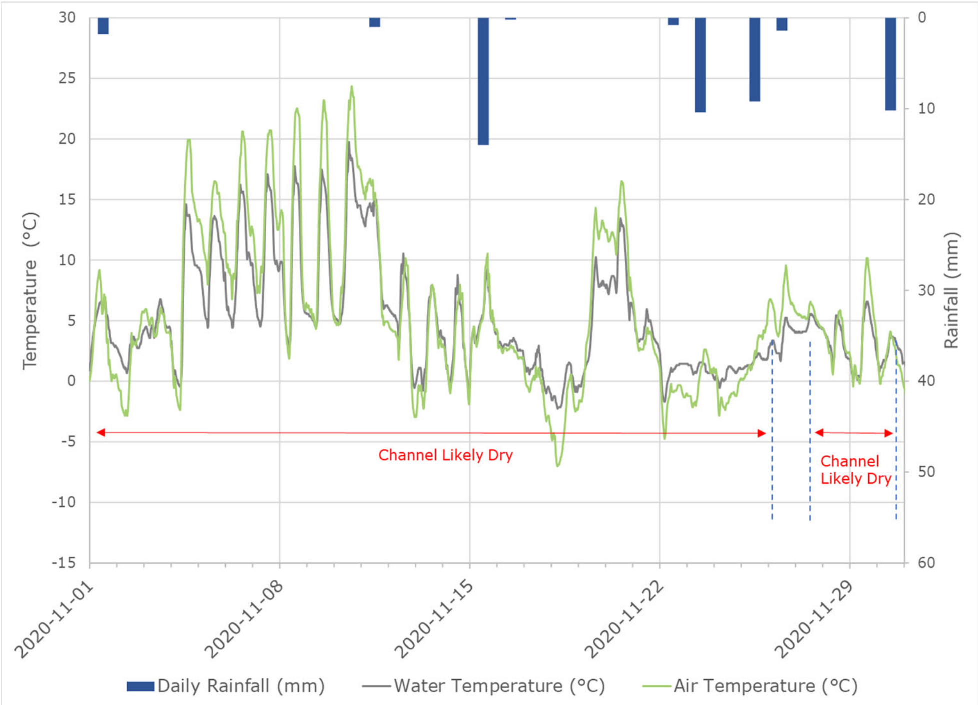
Figure 80	
	Water temperature, air temperature and daily rainfall at **S Inlet** for November 2020.

2020 Bridge Water Temperature

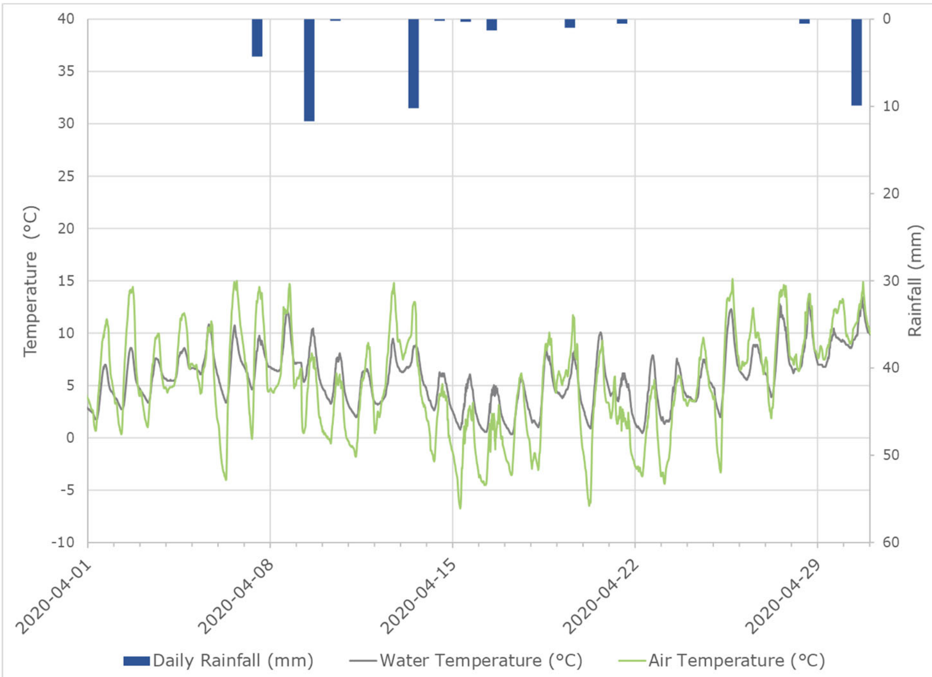
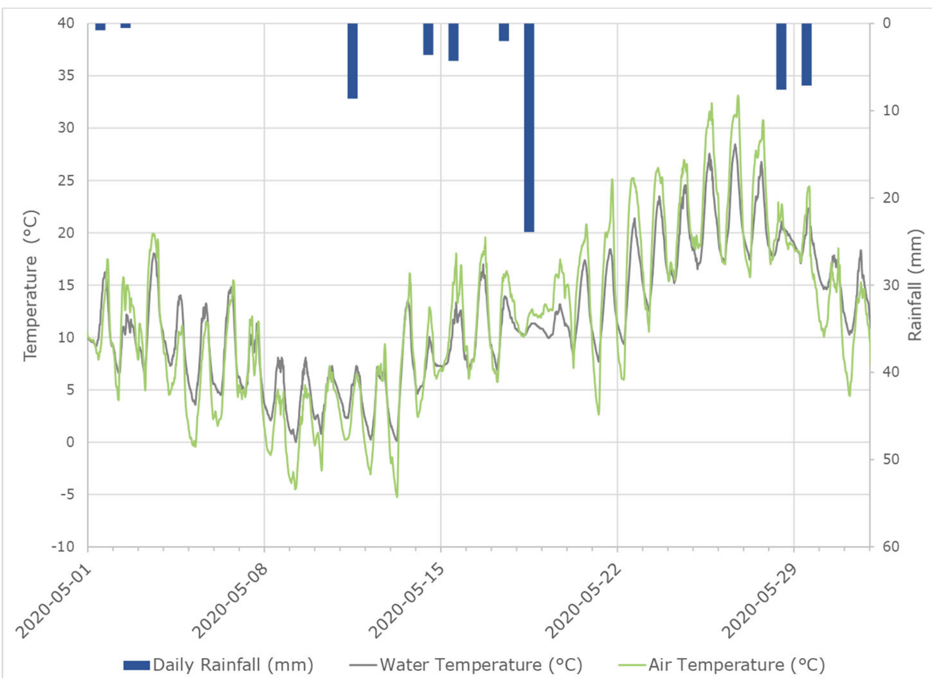
Figure 81	 Water temperature, air temperature and daily rainfall at **Bridge** for April 2020.
Figure 82	 Water temperature, air temperature and daily rainfall at **Bridge** for May 2020.

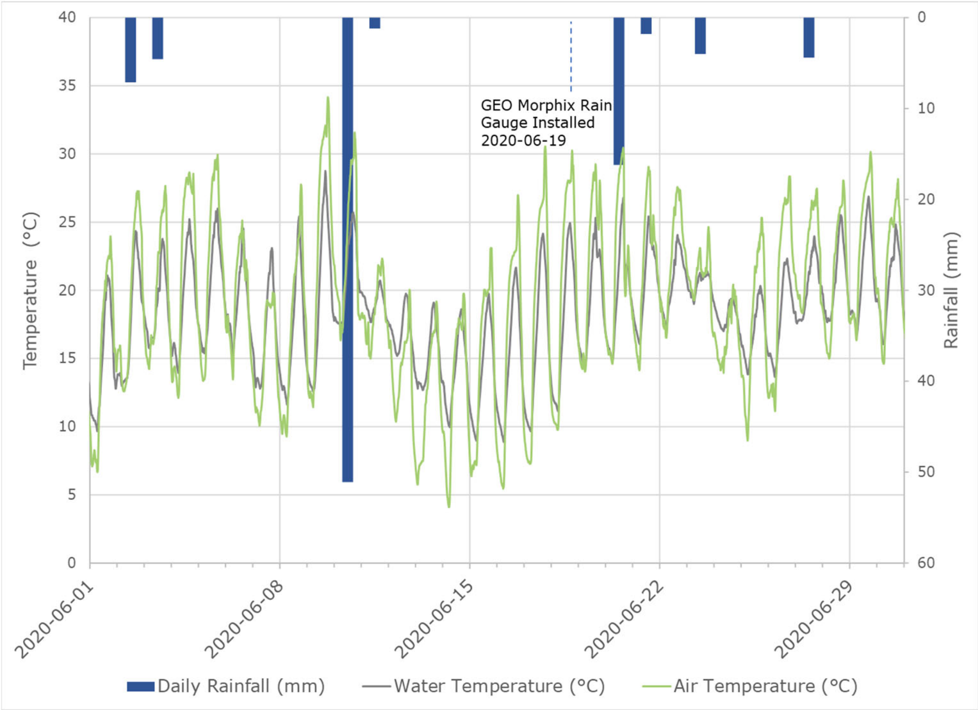
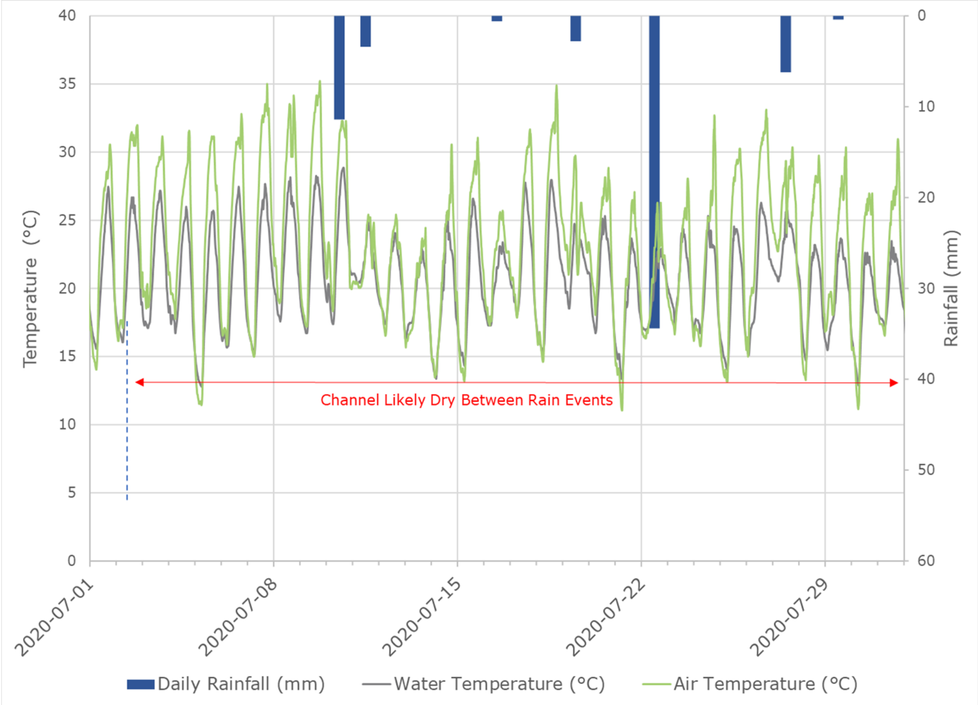
Figure 83	
	Water temperature, air temperature and daily rainfall at **Bridge** for June 2020.
Figure 84	
	Water temperature, air temperature and daily rainfall at **Bridge** for July 2020.

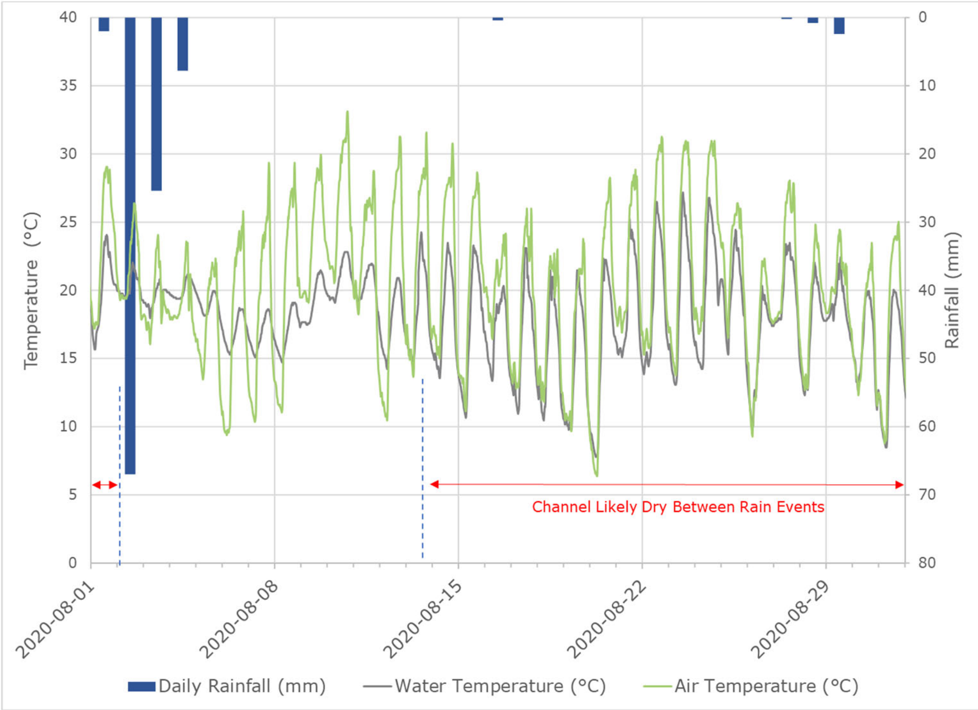
Figure 85	
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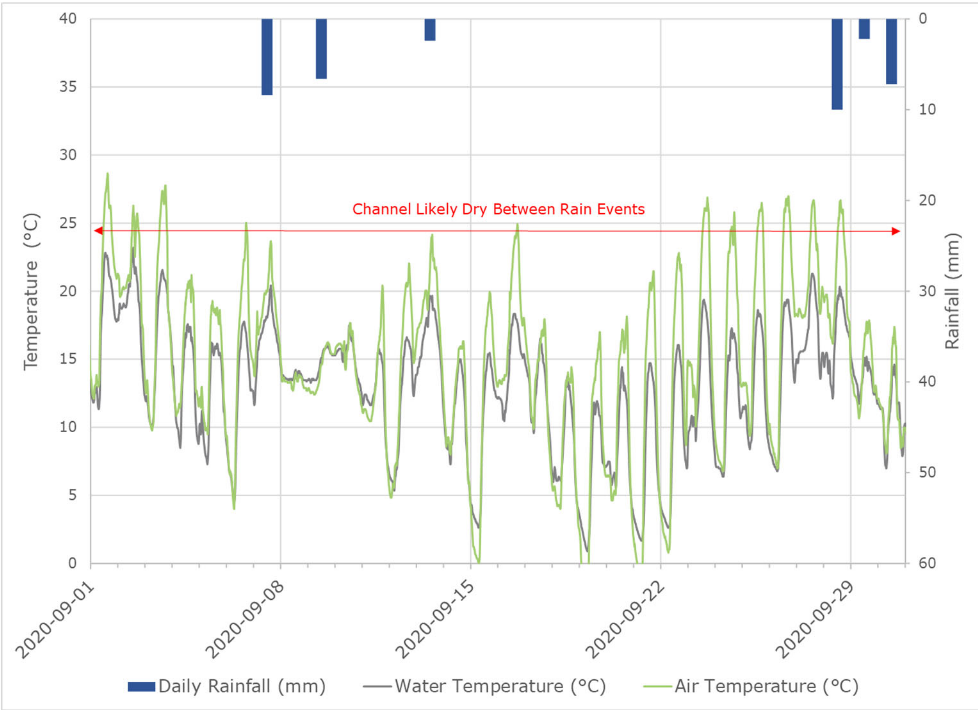
Figure 86	
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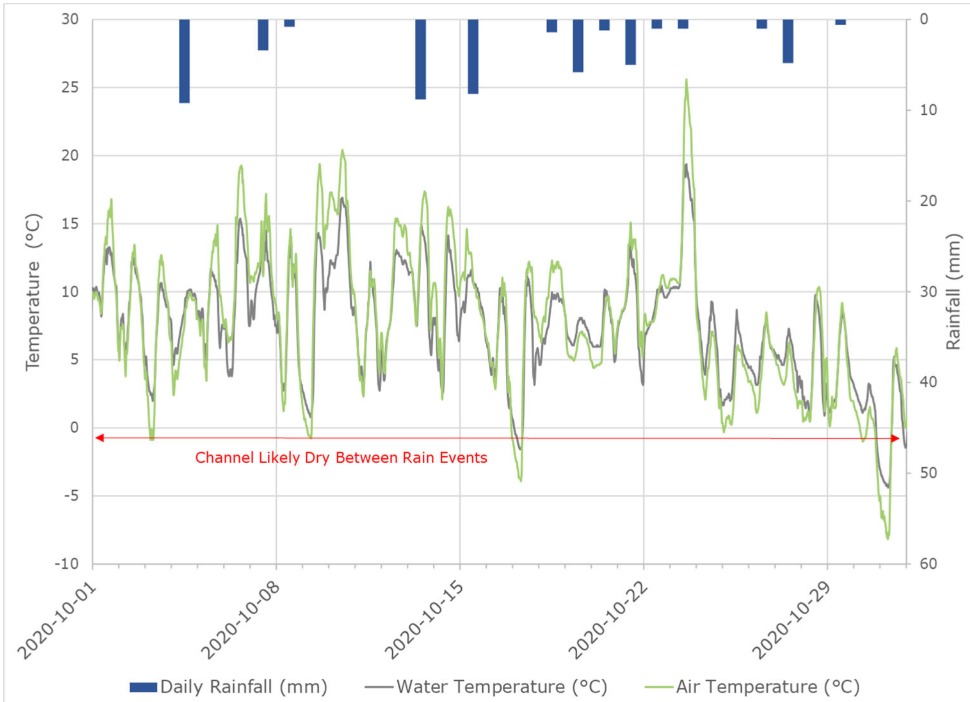
<tr><td rowspan="2">Figure 87</td><td>
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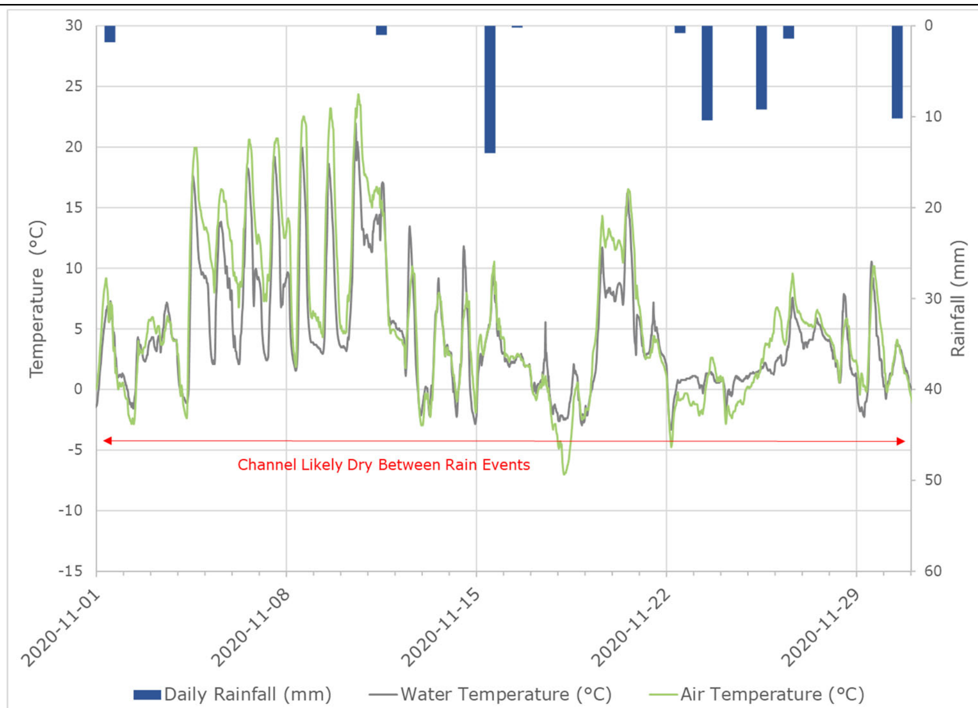
<tr><td rowspan="2">Figure 88</td><td>
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2020 Outlet Water Temperature

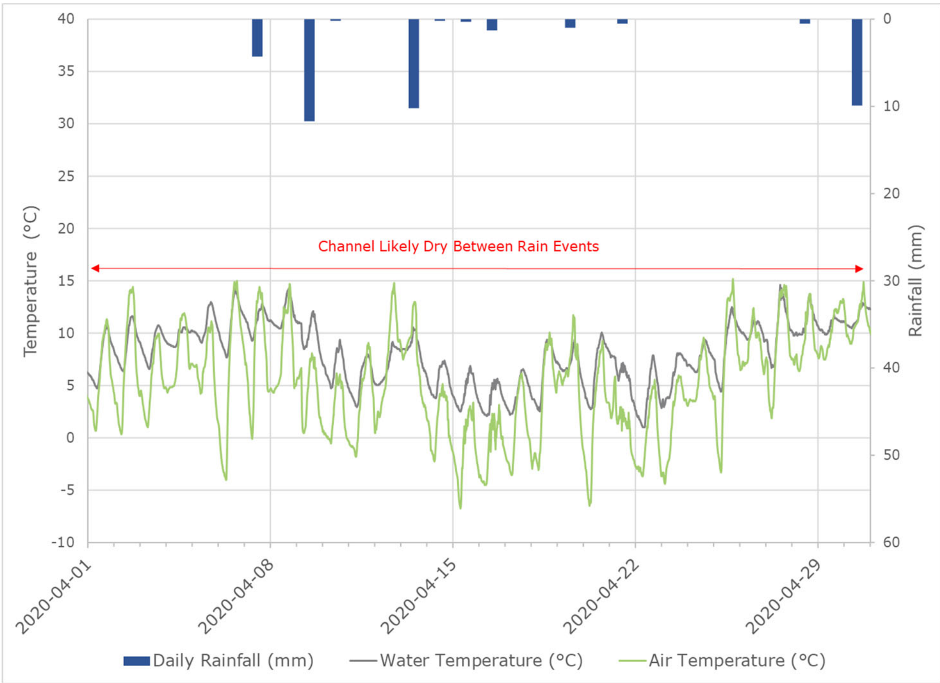
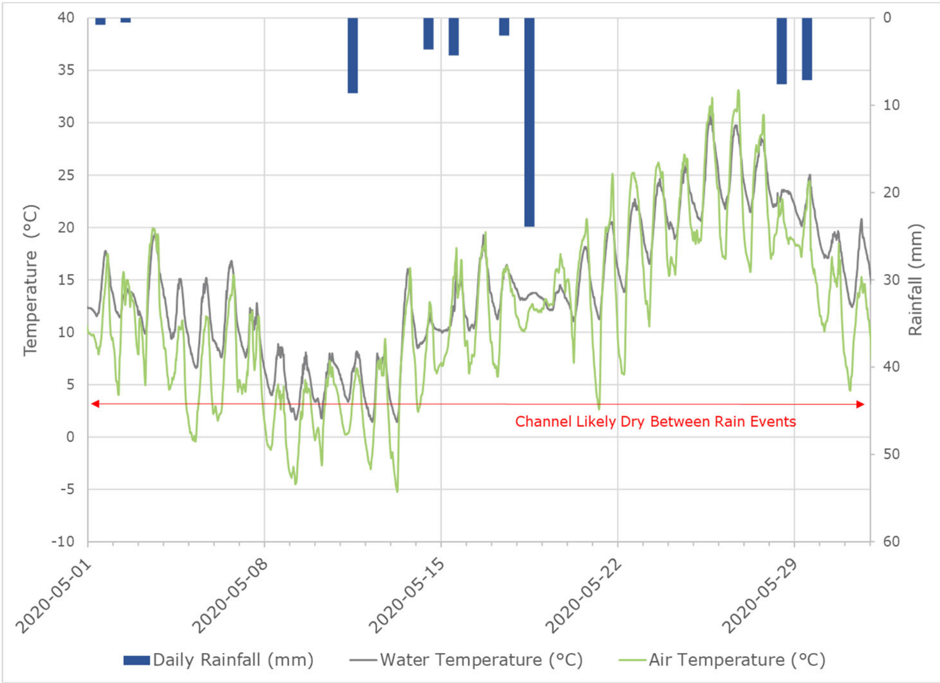
Figure 89	
	Water temperature, air temperature and daily rainfall at **Outlet** for April 2020.
Figure 90	
	Water temperature, air temperature and daily rainfall at **Outlet** for May 2020.

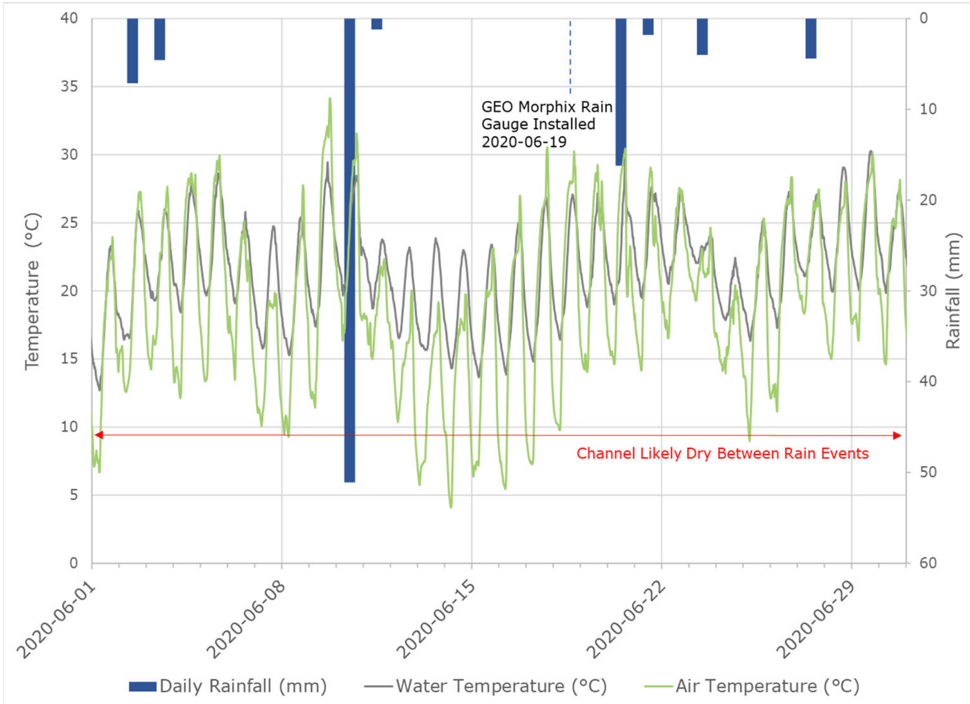
Figure 91	
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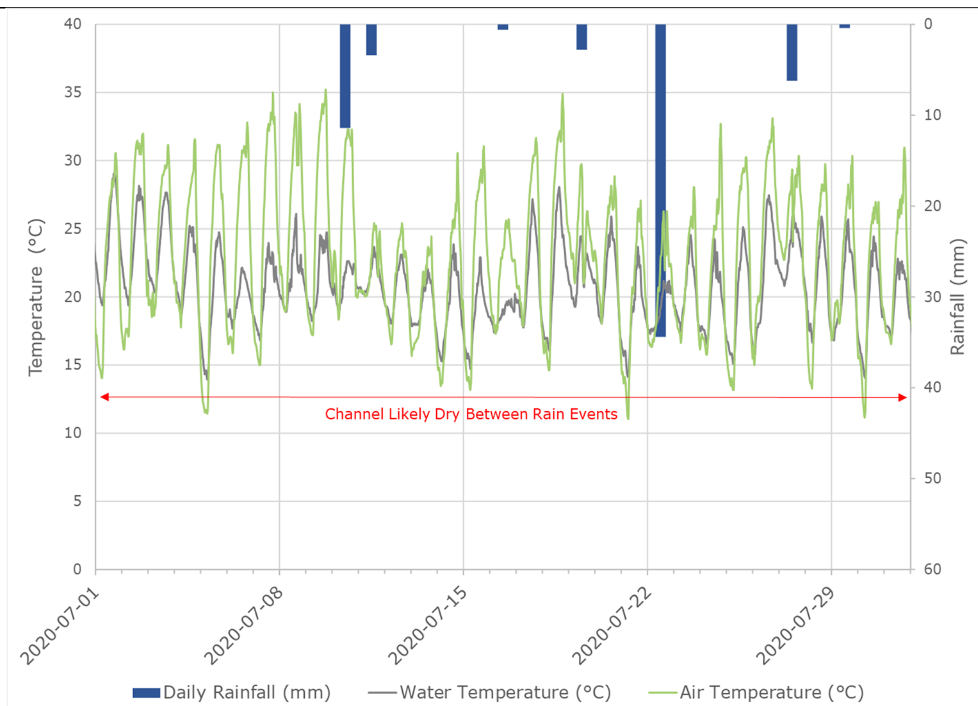
Figure 92	
	Water temperature, air temperature and daily rainfall at **Outlet** for July 2020.

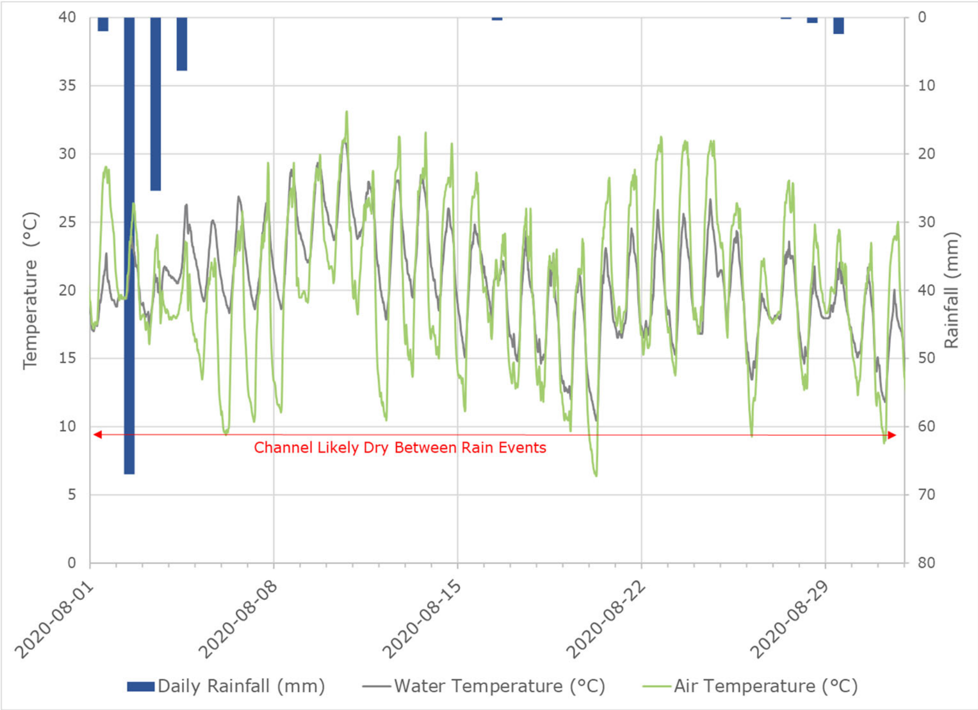
Figure 93	
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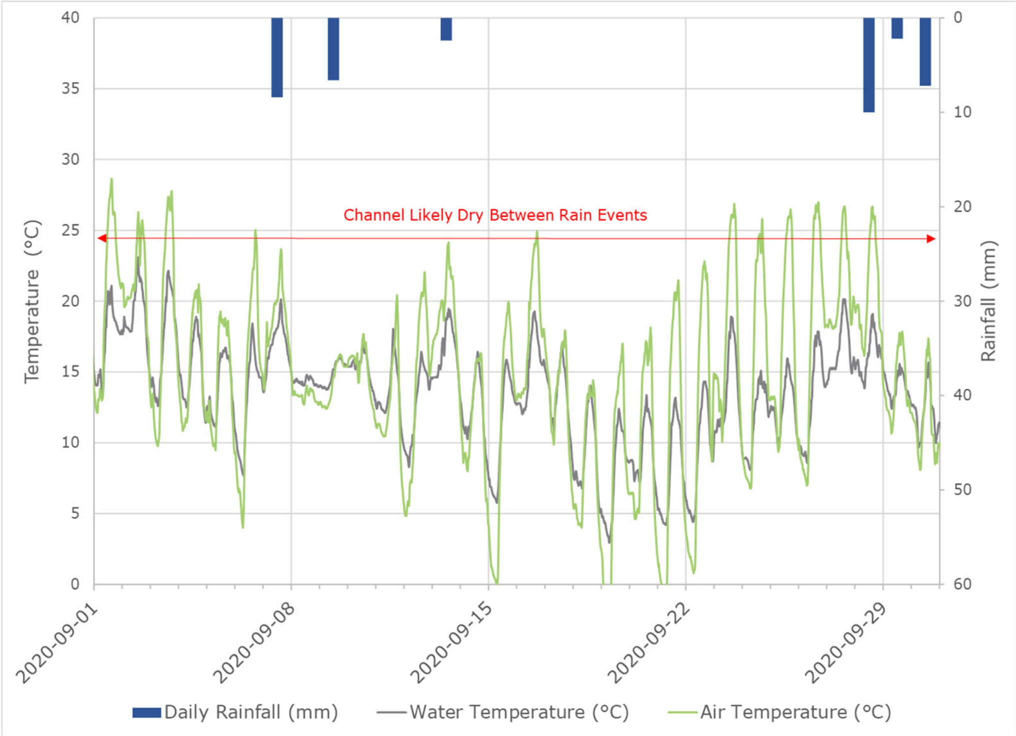
Figure 94	
	Water temperature, air temperature and daily rainfall at **Outlet** for September 2020.

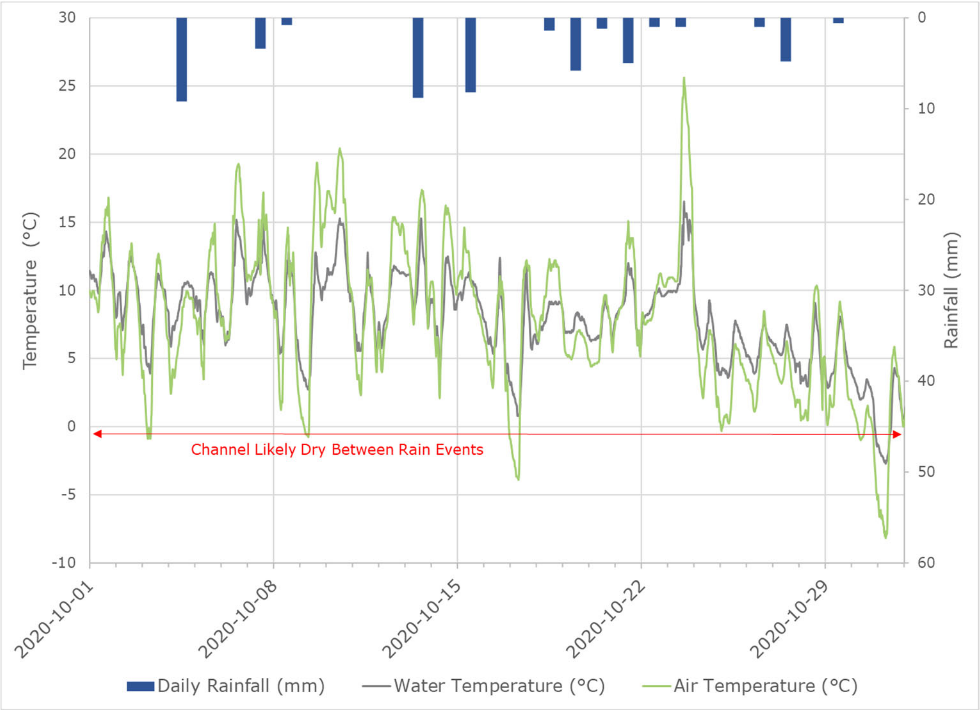
Figure 95	
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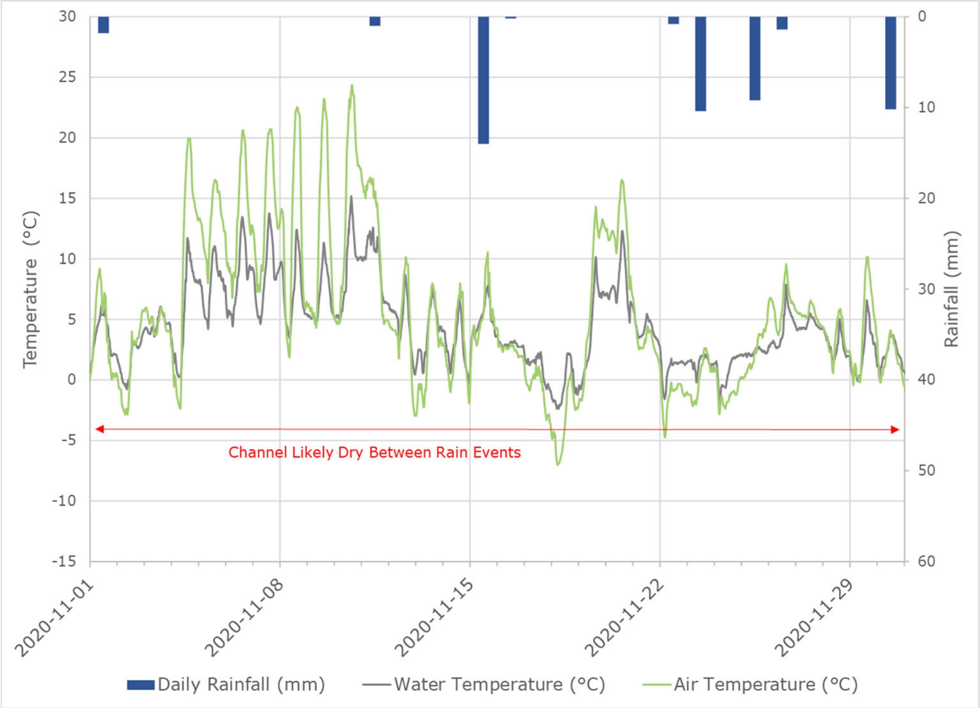
Figure 96	
	Water temperature, air temperature and daily rainfall at **Outlet** for November 2020.

2020 W Inlet Water Level

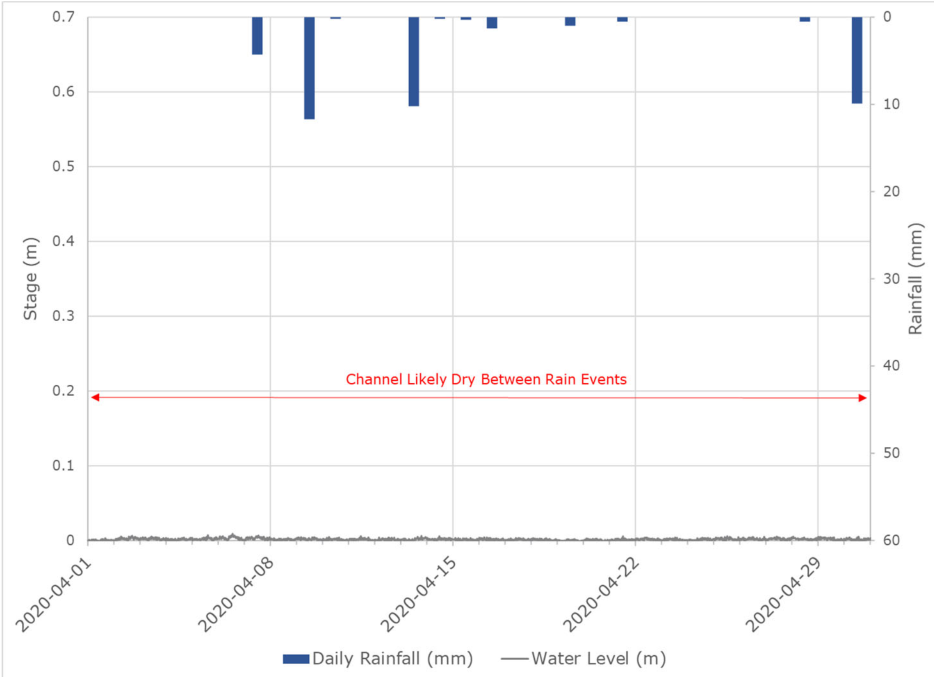
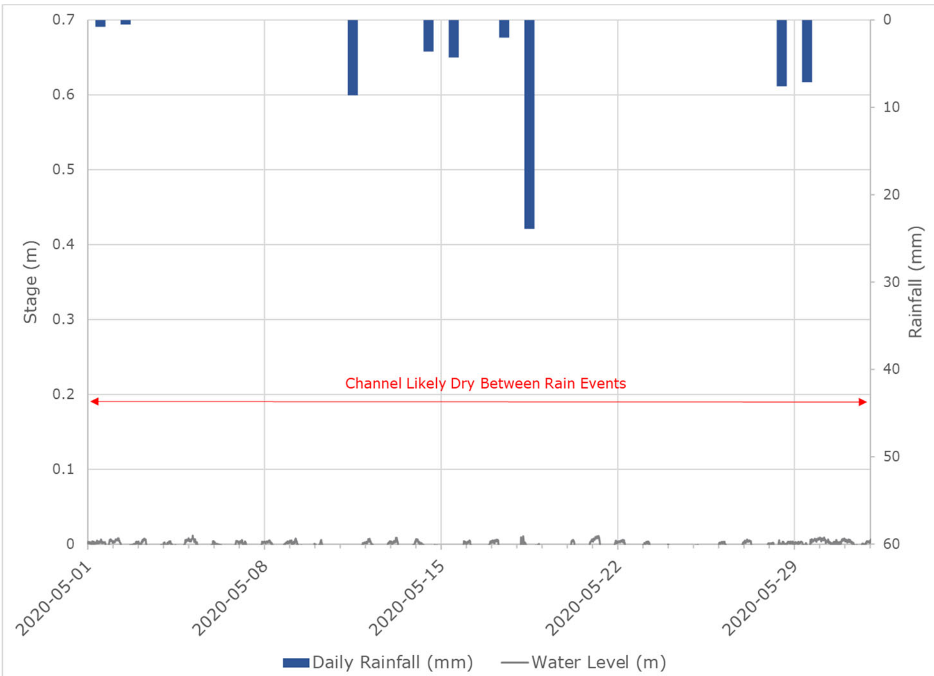
Figure 97	
	Water level and daily rainfall at **W Inlet** for April 2020.
Figure 98	
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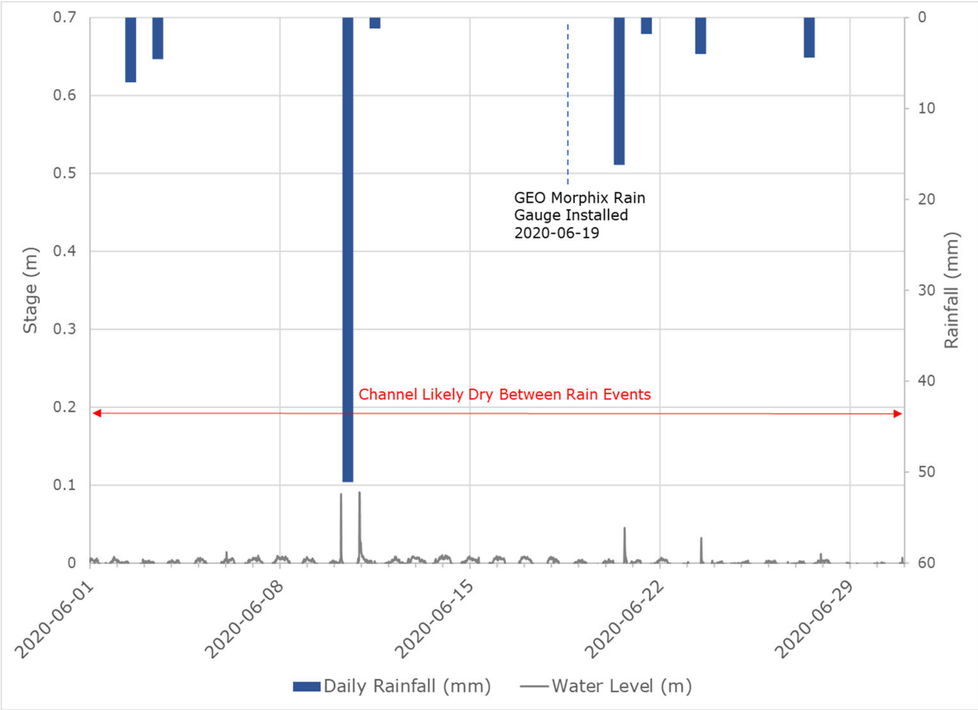
Figure 99	
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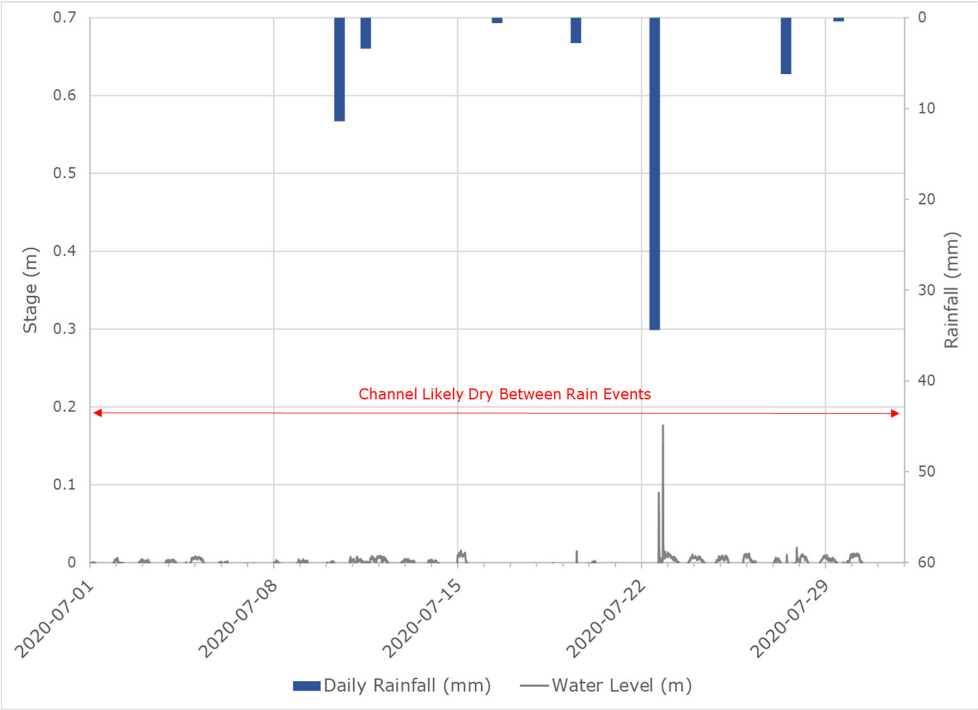
Figure 100	
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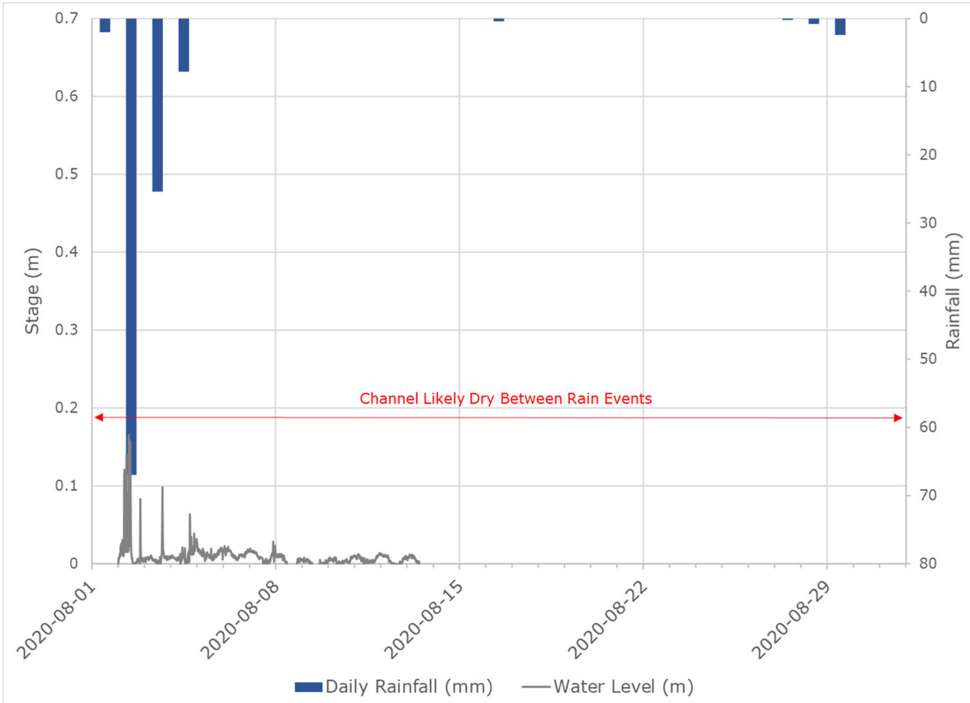
Figure 101	
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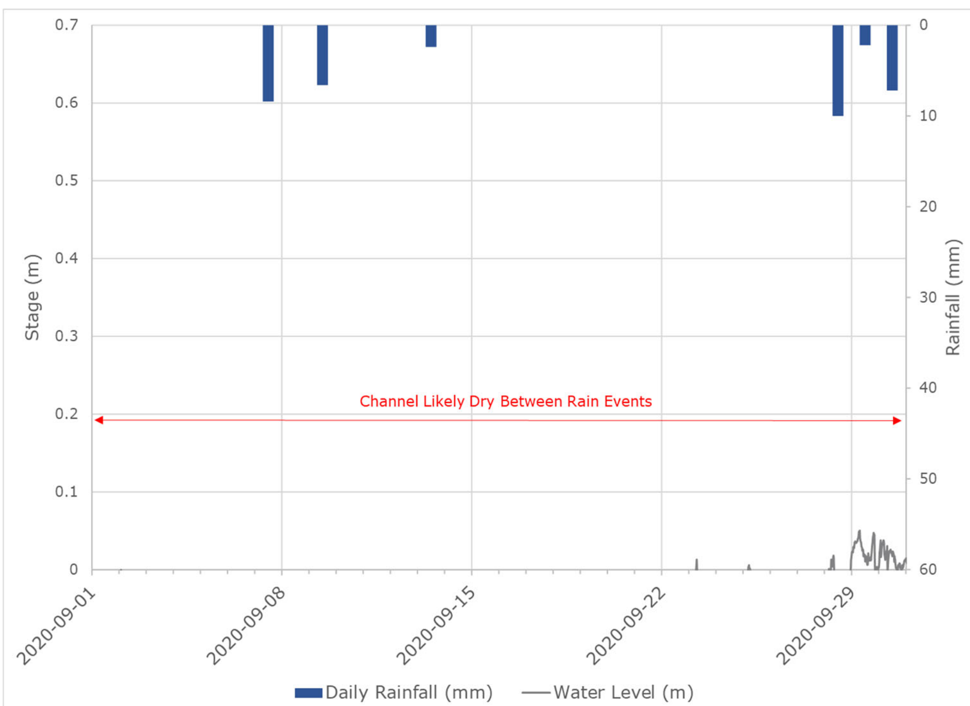
Figure 102	
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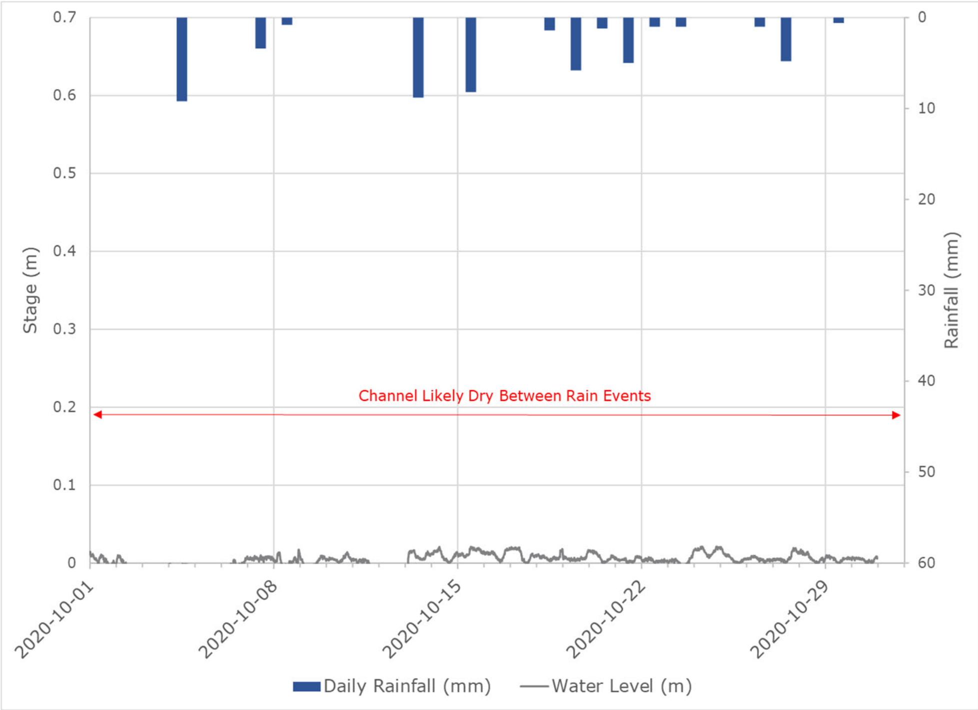
Figure 103	
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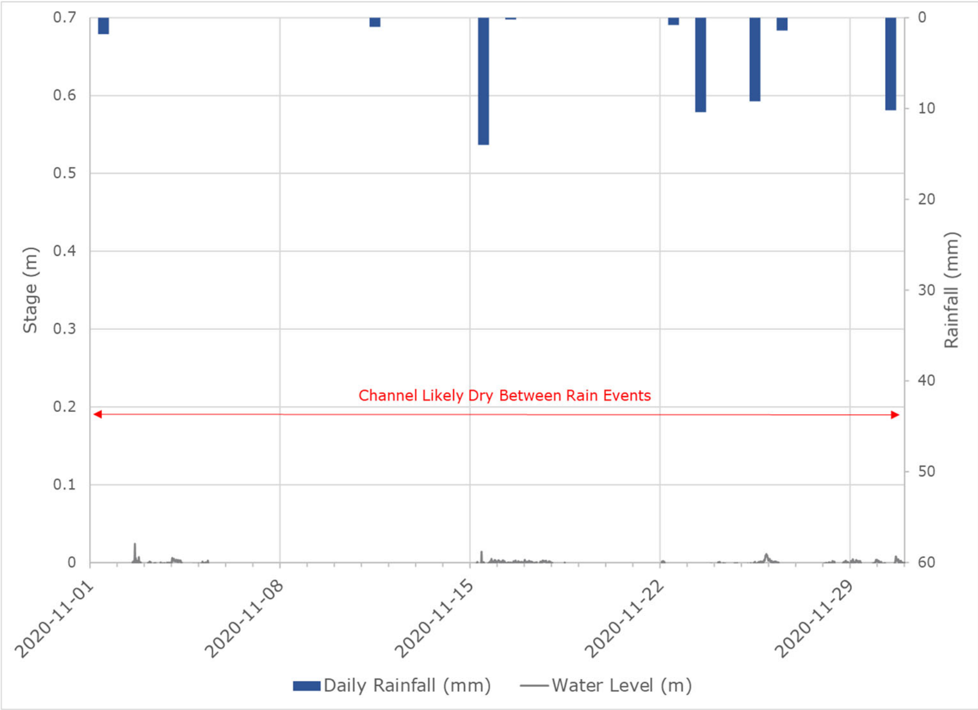
Figure 104	
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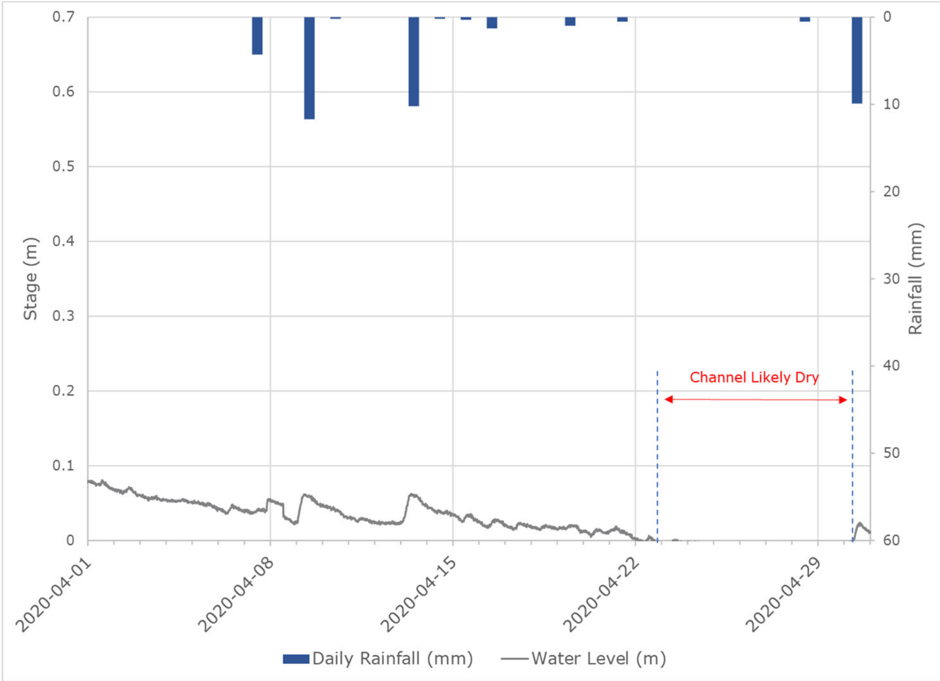
Figure 105	
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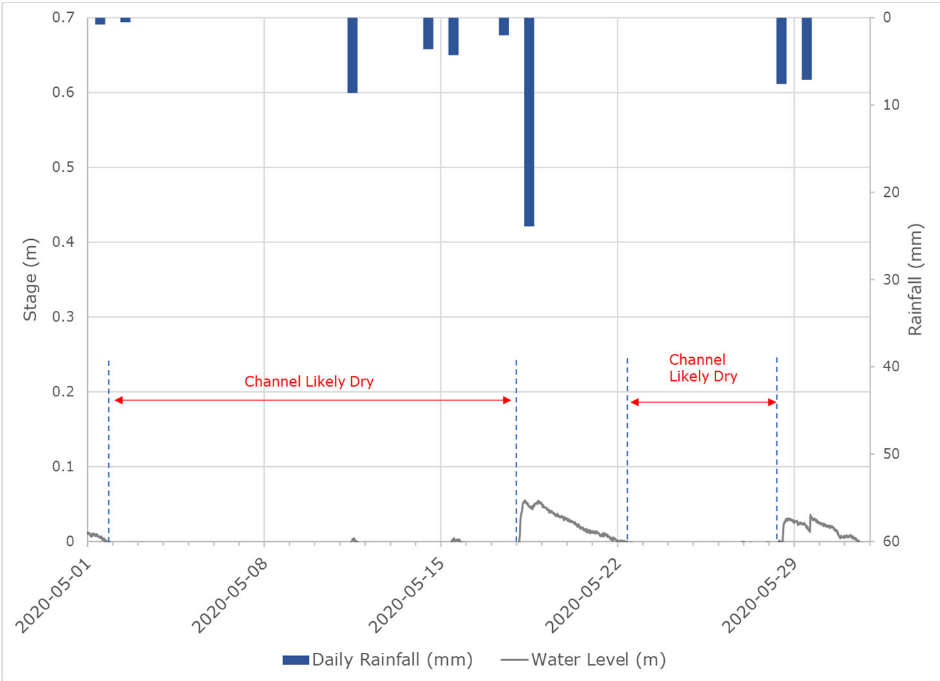
Figure 106	
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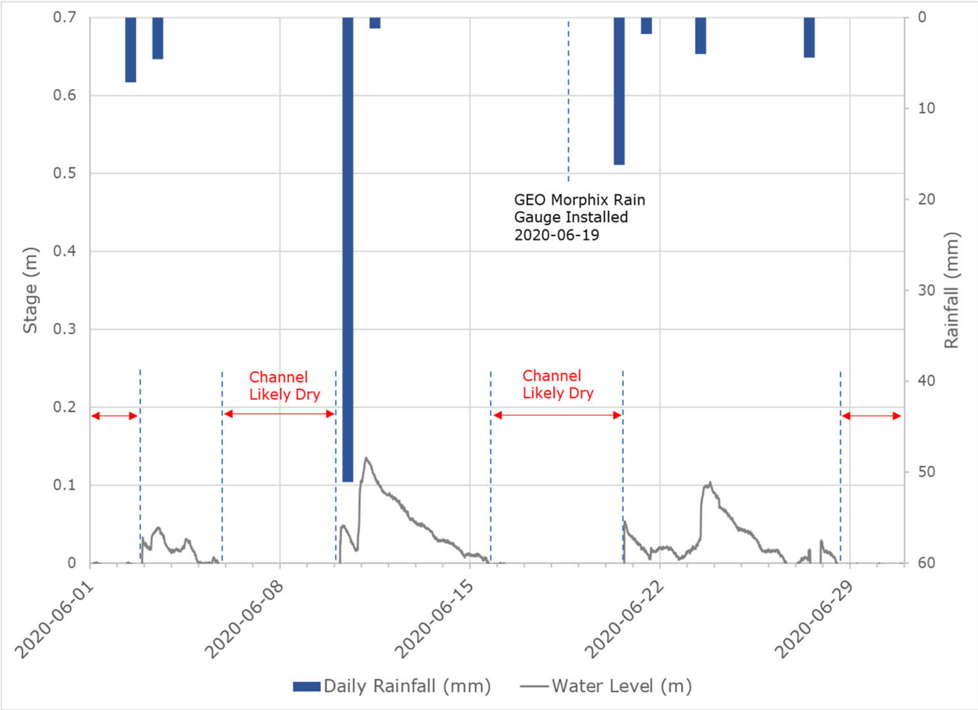
Figure 107	
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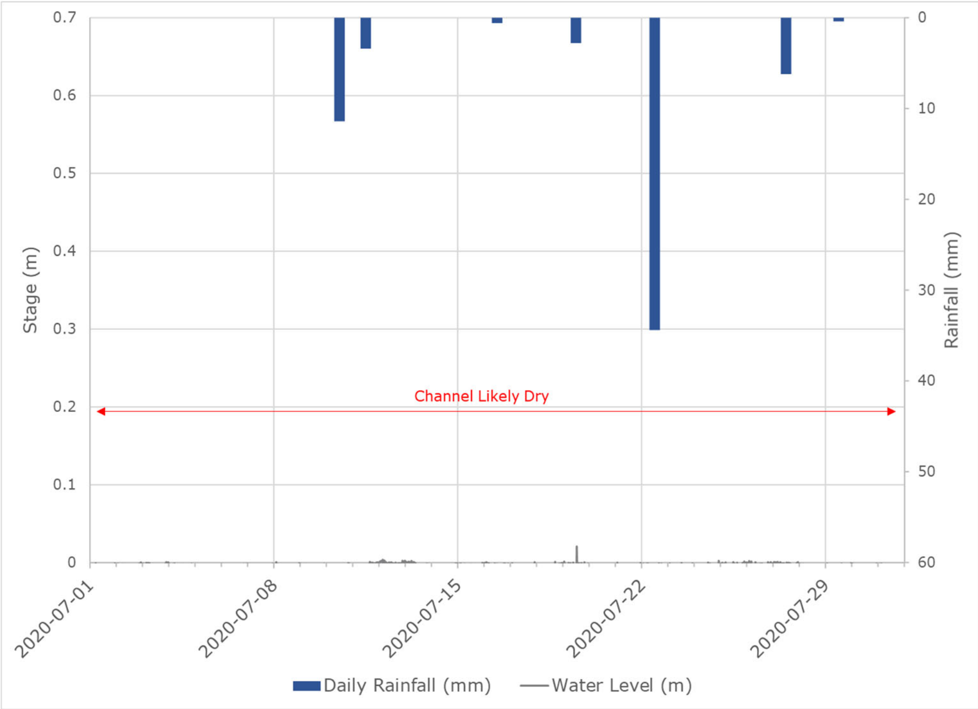
Figure 108	
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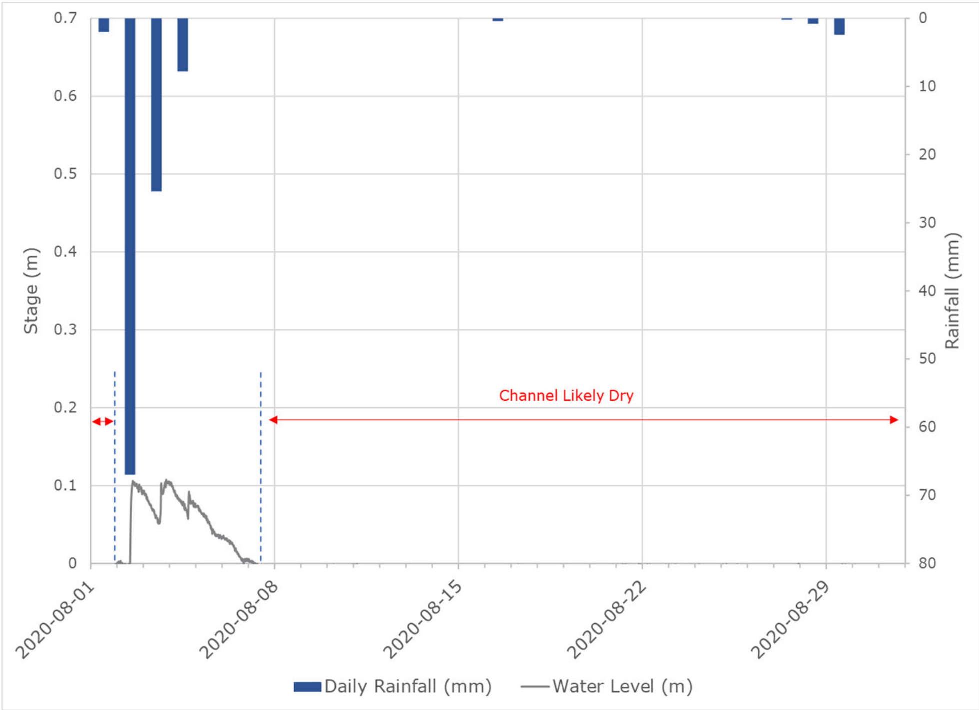
Figure 109	
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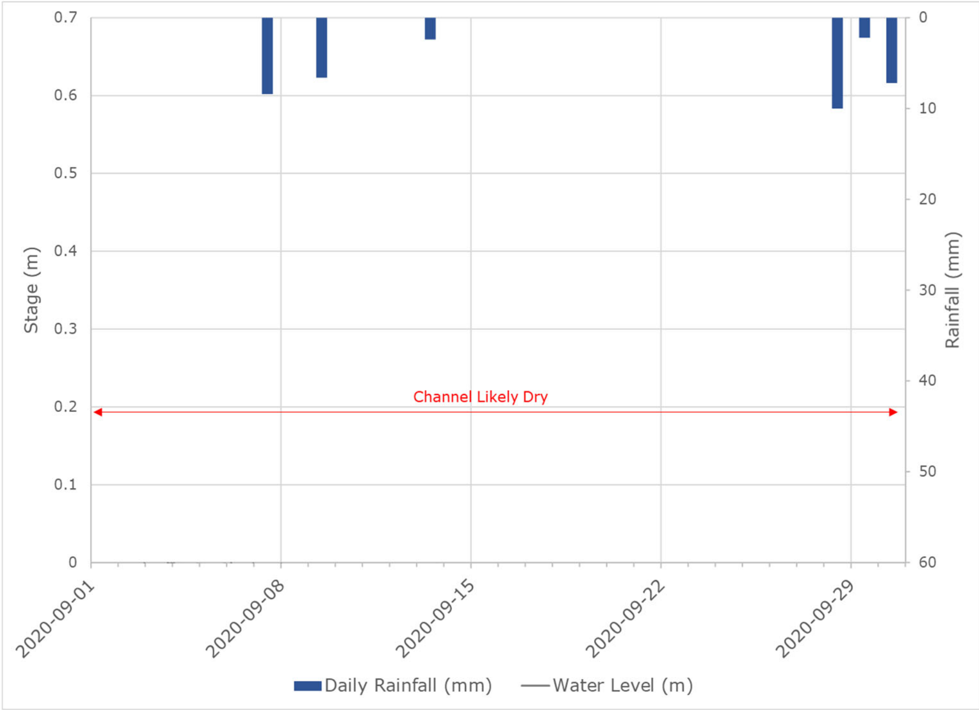
Figure 110	
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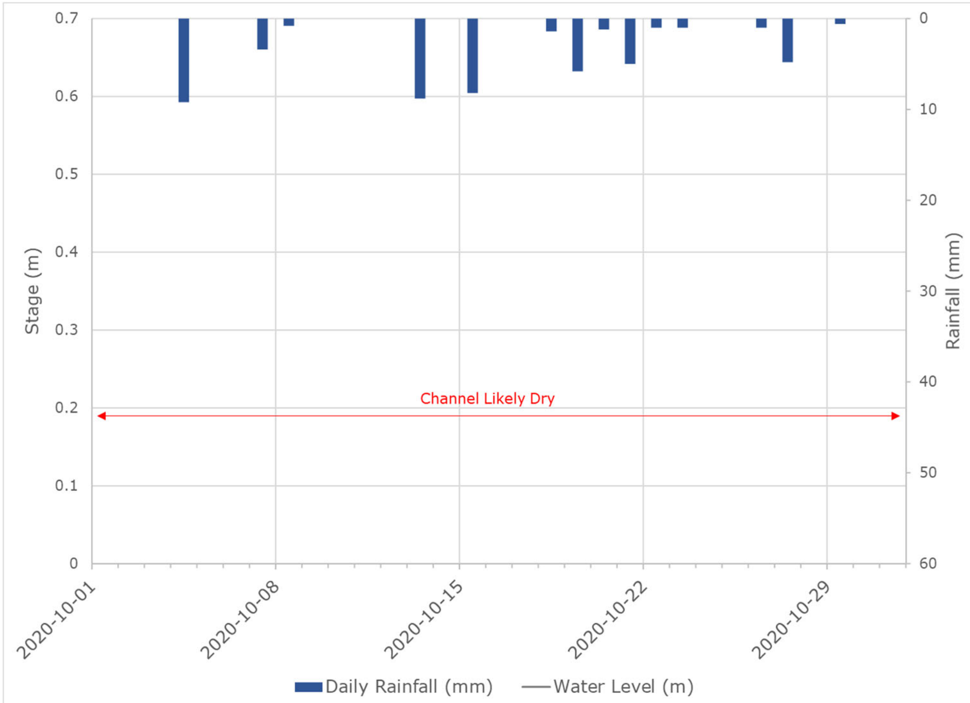
Figure 111	
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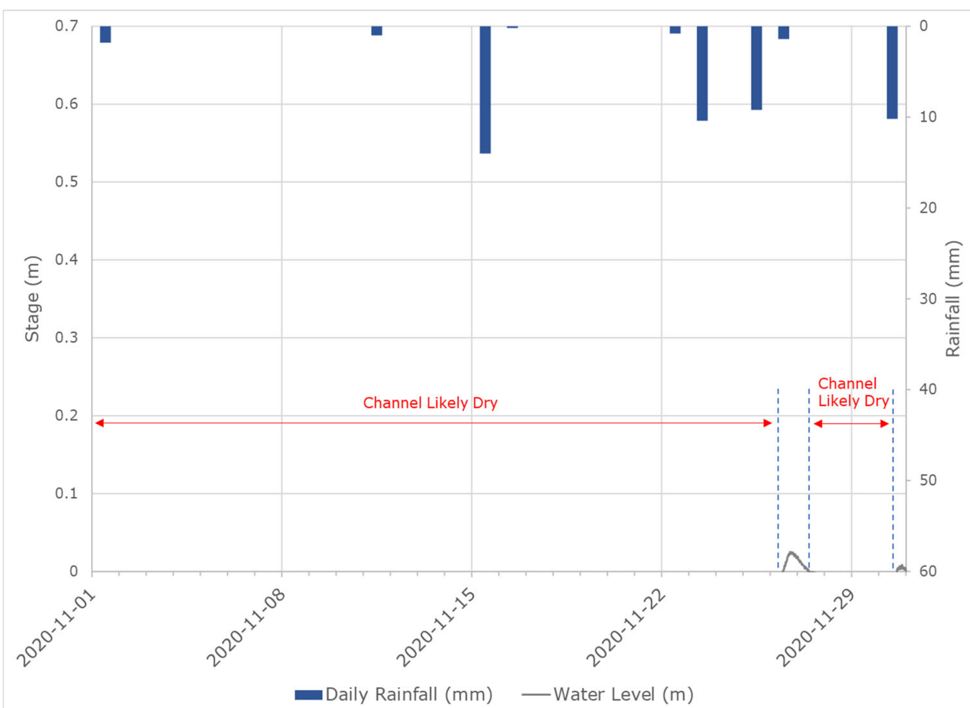
Figure 112	
	Water level and daily rainfall at **S Inlet** for November 2020.

2020 Bridge Water Level

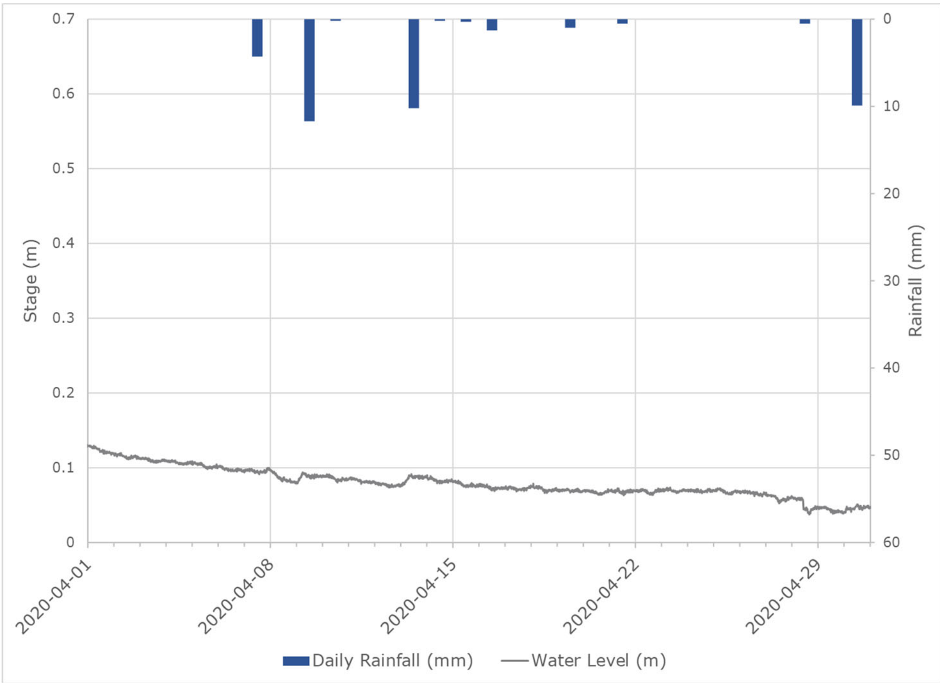
Figure 113	
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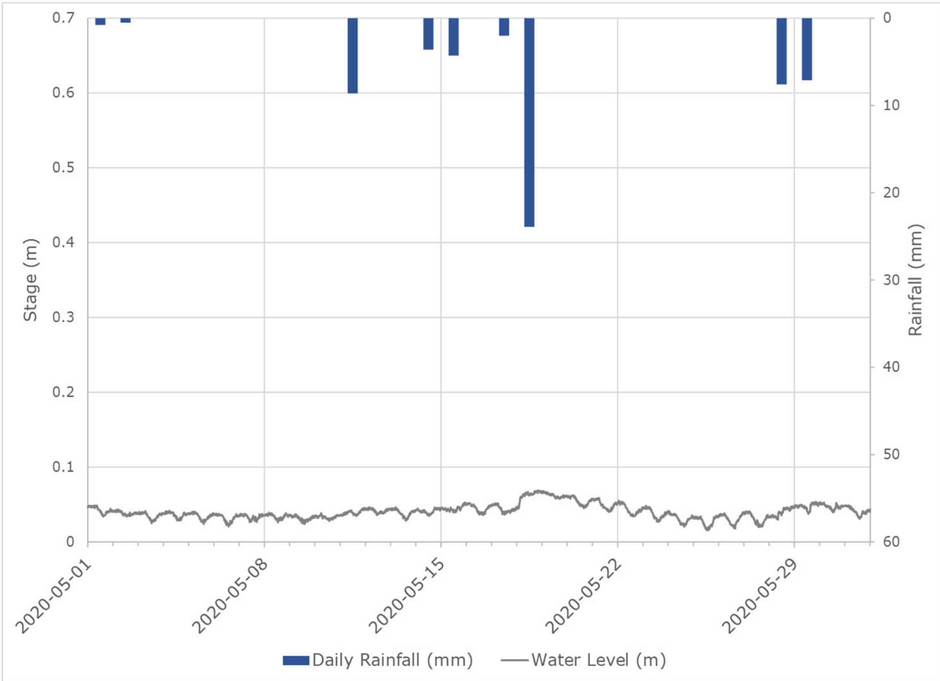
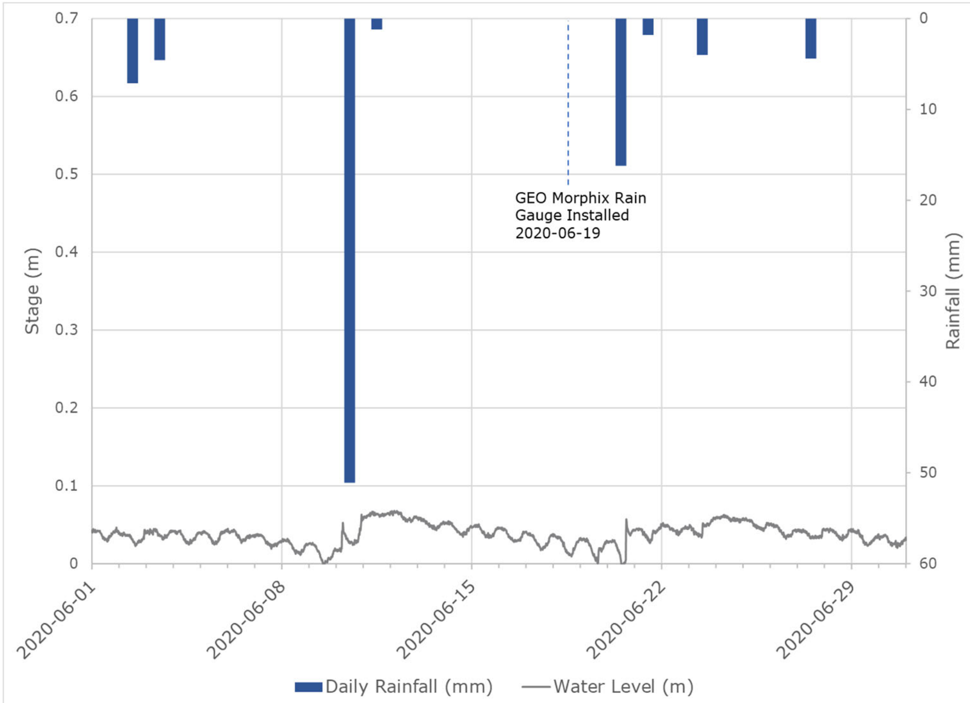
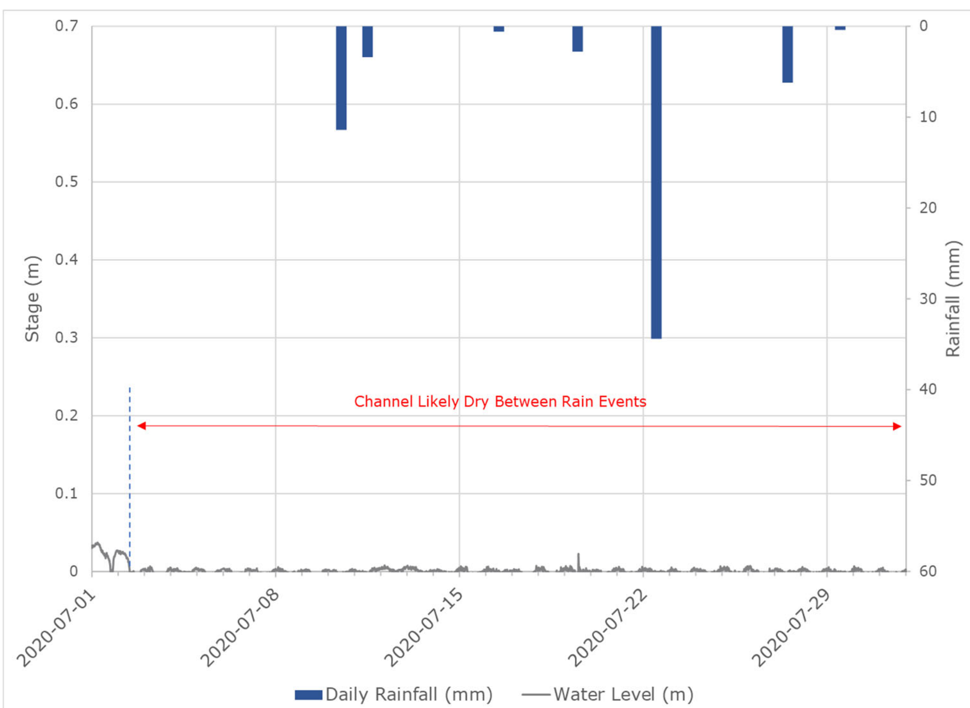
Figure 114	
	Water level and daily rainfall at **Bridge** for May 2020.

Figure 115



Water level and daily rainfall at **Bridge** for June 2020.

Figure 116



Water level and daily rainfall at **Bridge** for July 2020.

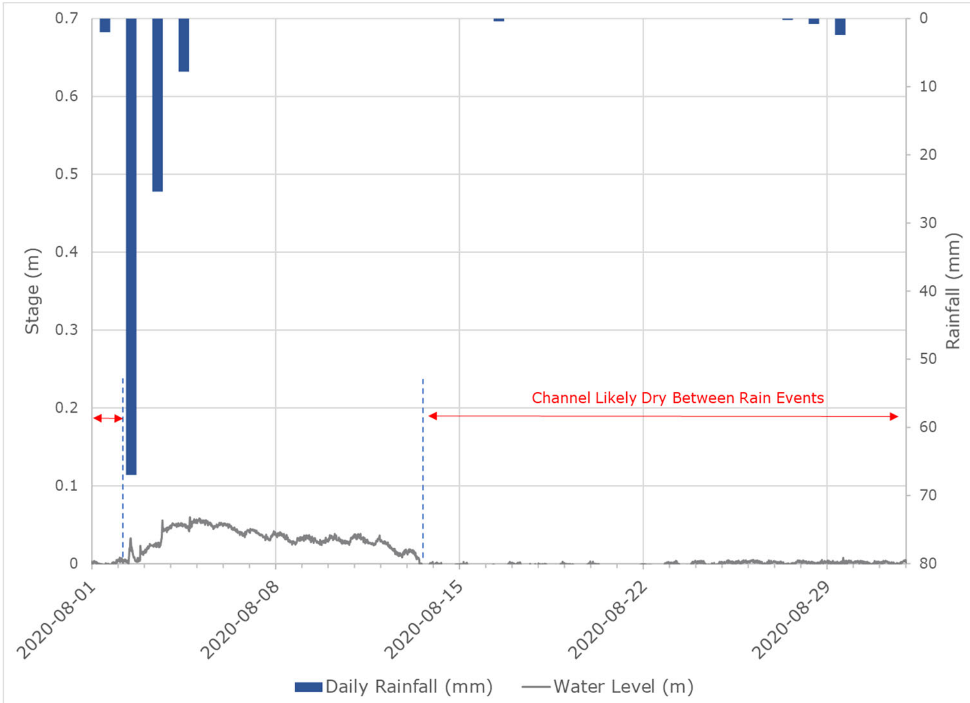
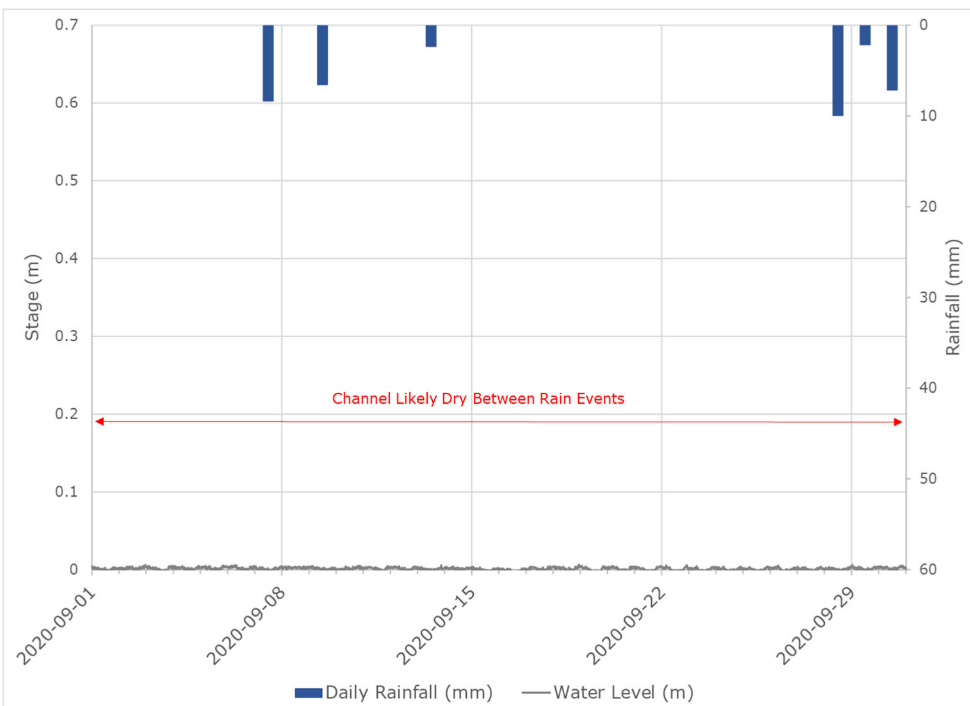
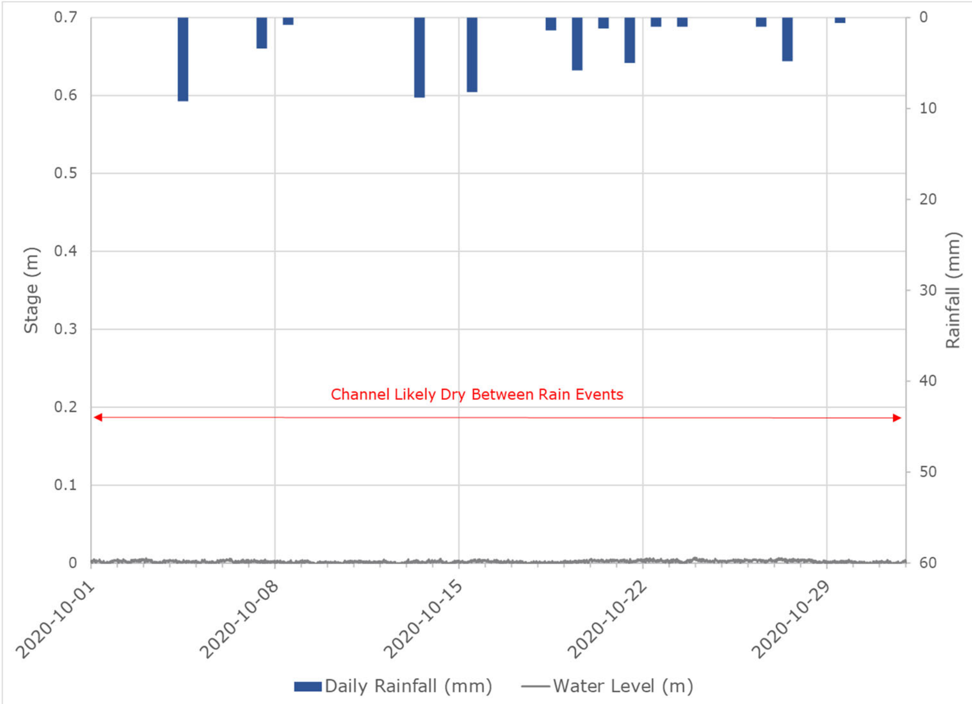
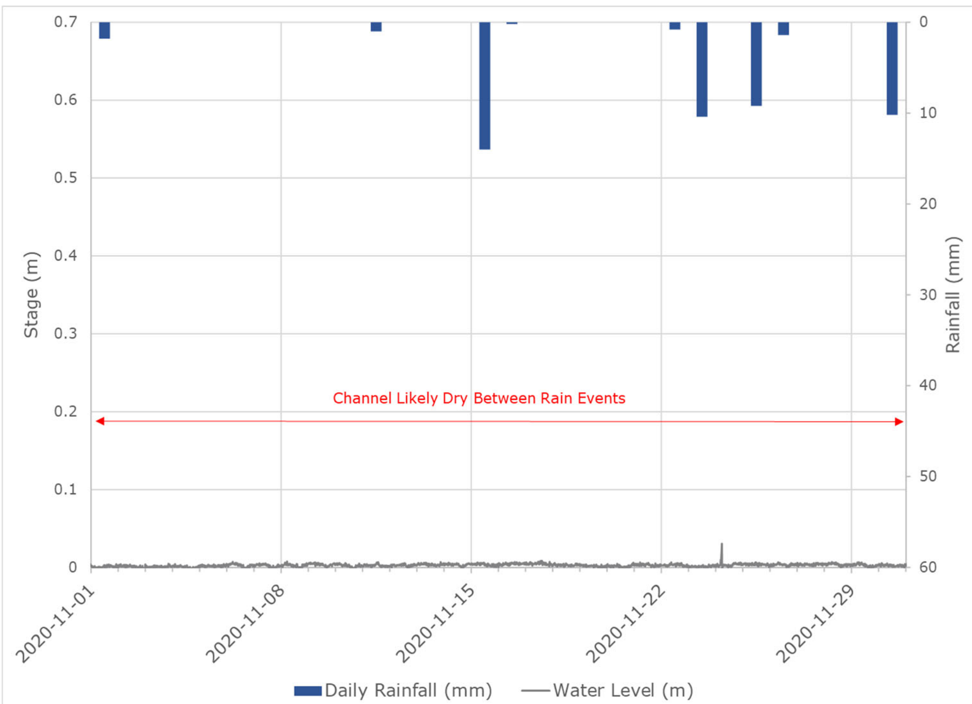
Figure 117	
	Water level and daily rainfall at **Bridge** for August 2020.
Figure 118	
	Water level and daily rainfall at **Bridge** for September 2020.

Figure 119	
	Water level and daily rainfall at **Bridge** for October 2020.
Figure 120	
	Water level and daily rainfall at **Bridge** for November 2020.

2020 Outlet Water Level

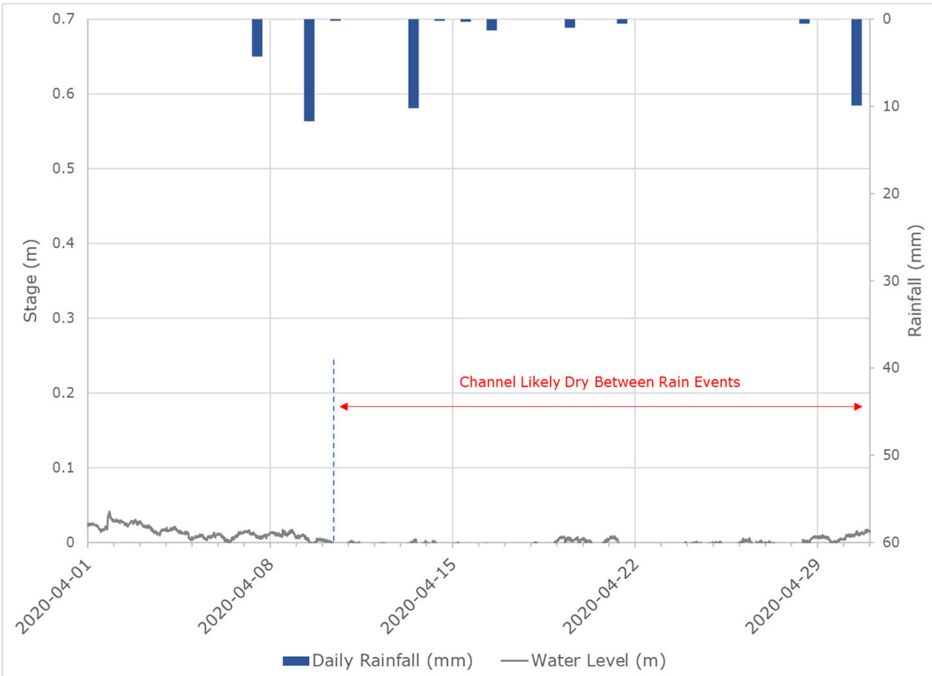
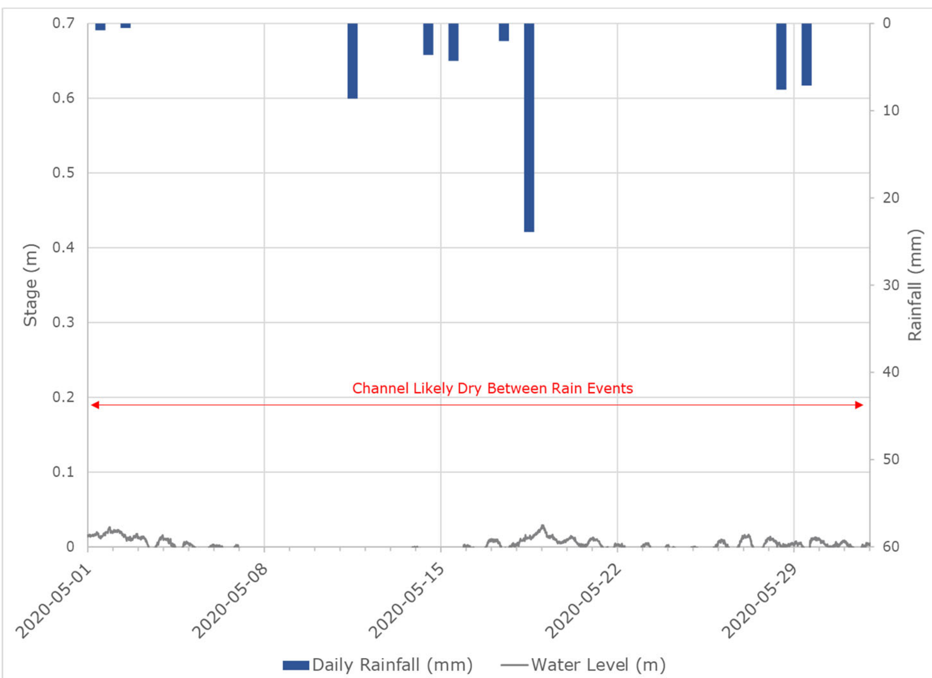
Figure 121	
	Water level and daily rainfall at **Outlet** for April 2020.
Figure 122	
	Water level and daily rainfall at **Outlet** for May 2020.

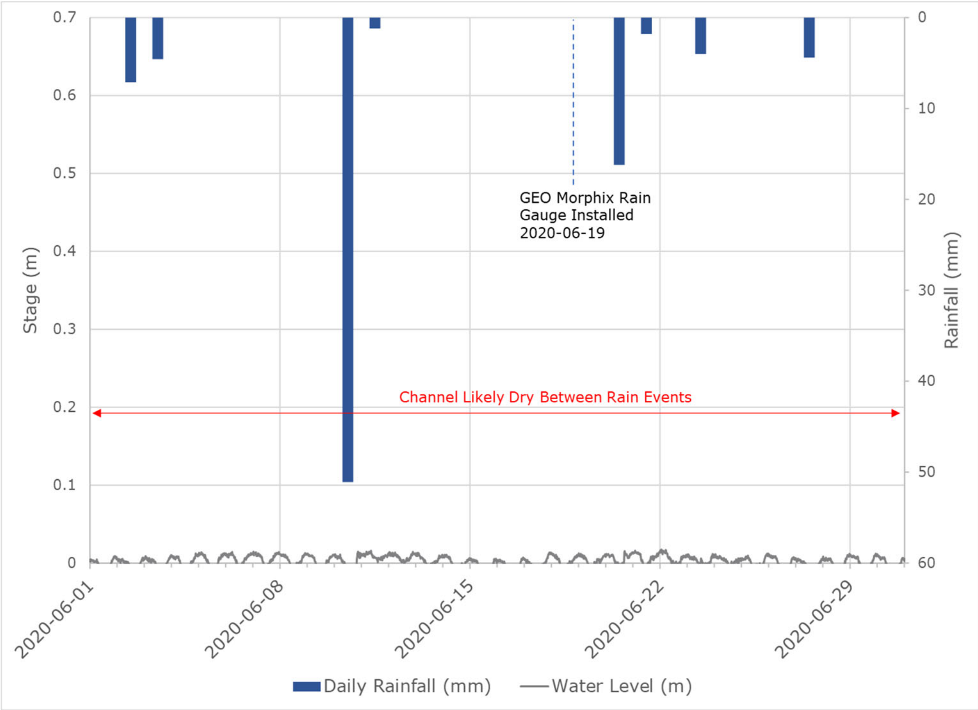
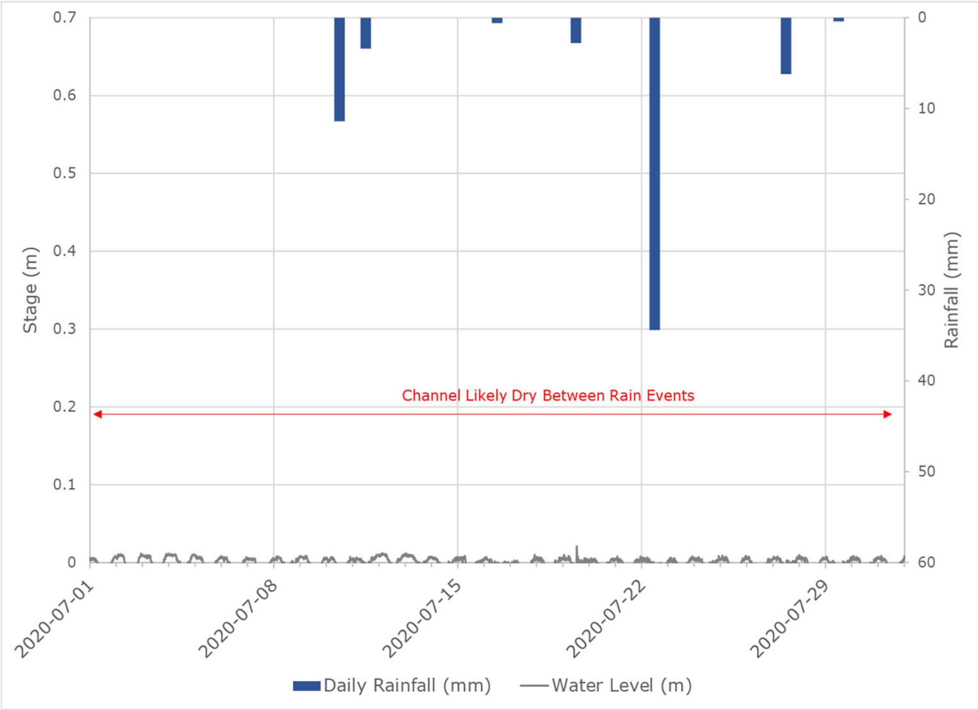
Figure 123	
	Water level and daily rainfall at **Outlet** for June 2020.
Figure 124	
	Water level and daily rainfall at **Outlet** for July 2020.

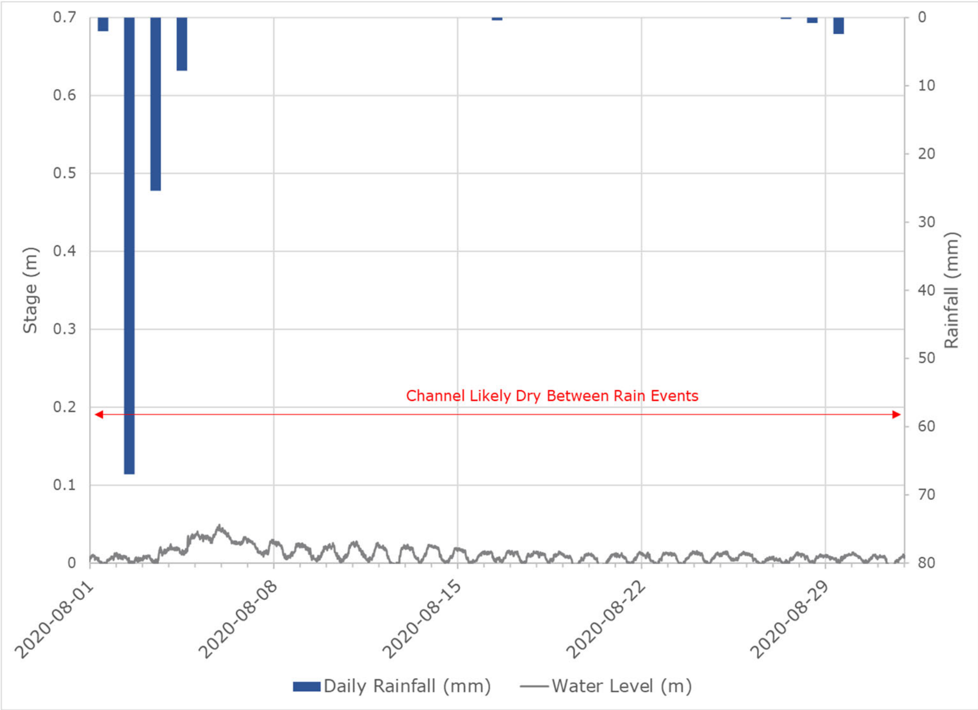
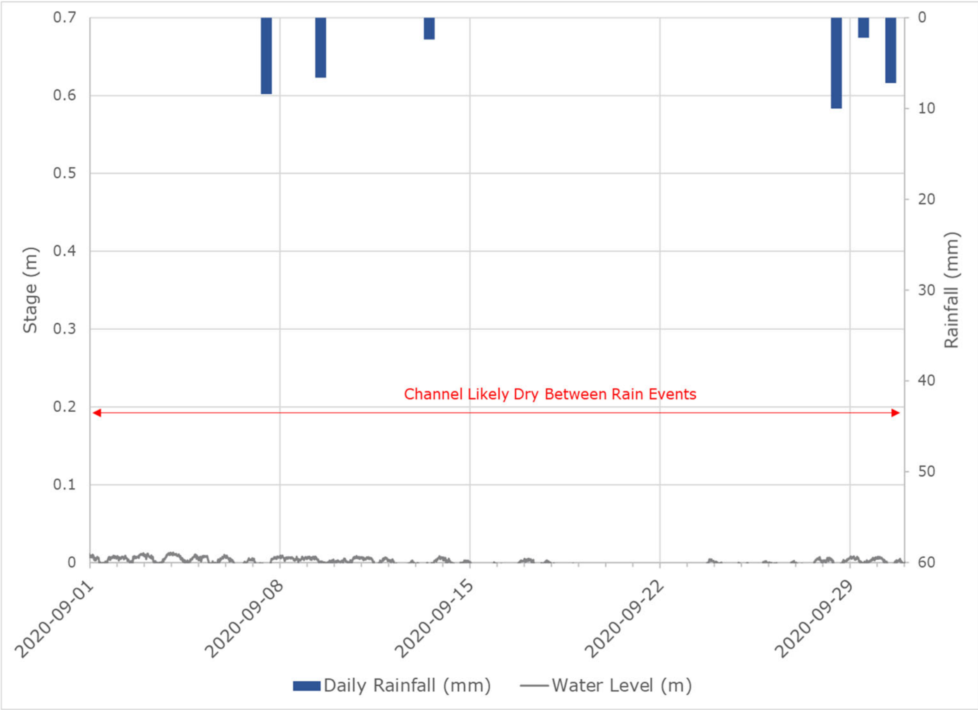
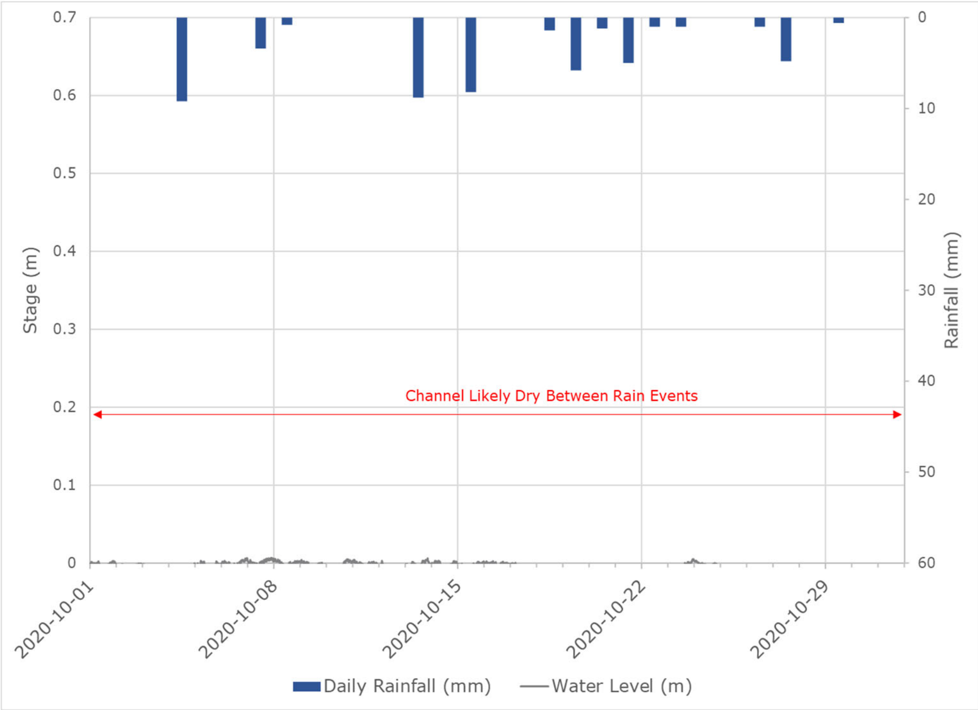
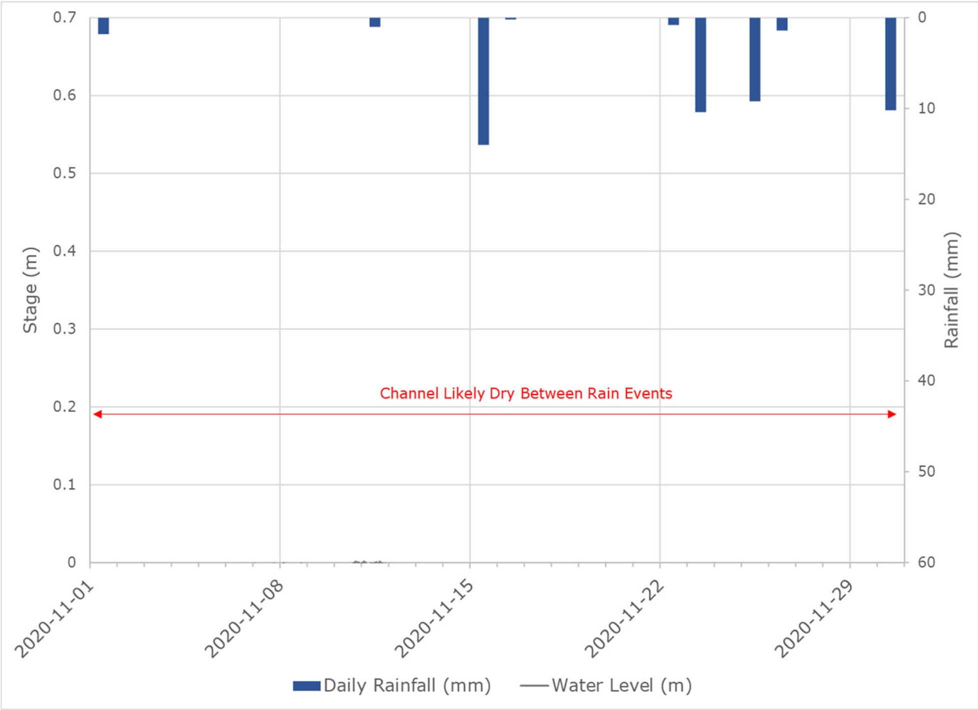
Figure 125	
	Water level and daily rainfall at **Outlet** for August 2020.
Figure 126	
	Water level and daily rainfall at **Outlet** for September 2020.

Figure 127	
	Water level and daily rainfall at **Outlet** for October 2020.
Figure 128	
	Water level and daily rainfall at **Outlet** for November 2020.

2020 N Pond Water Elevation

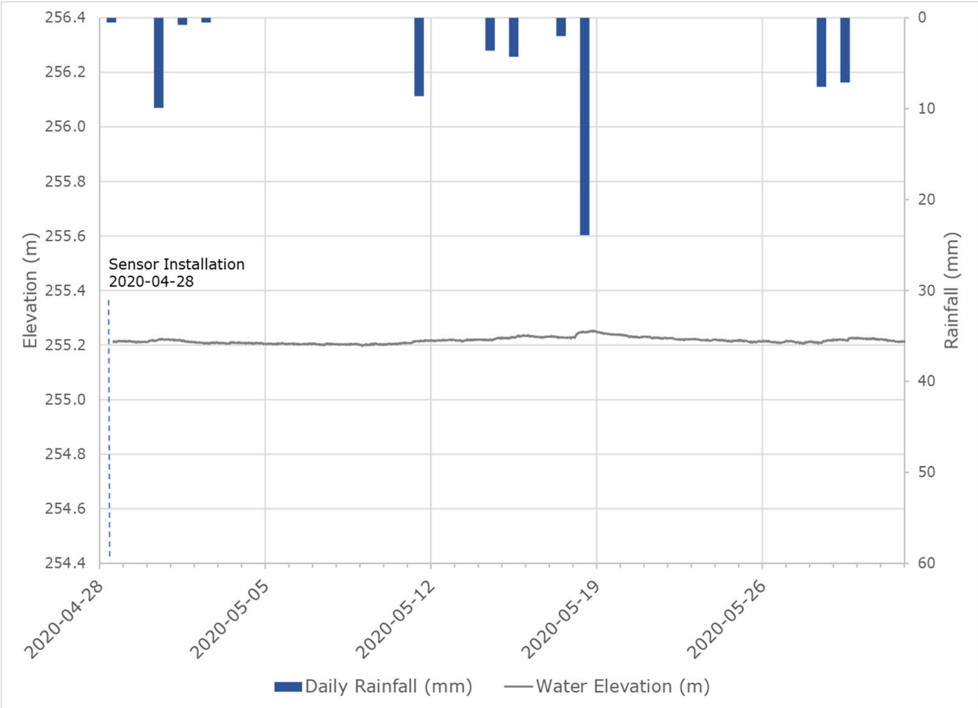
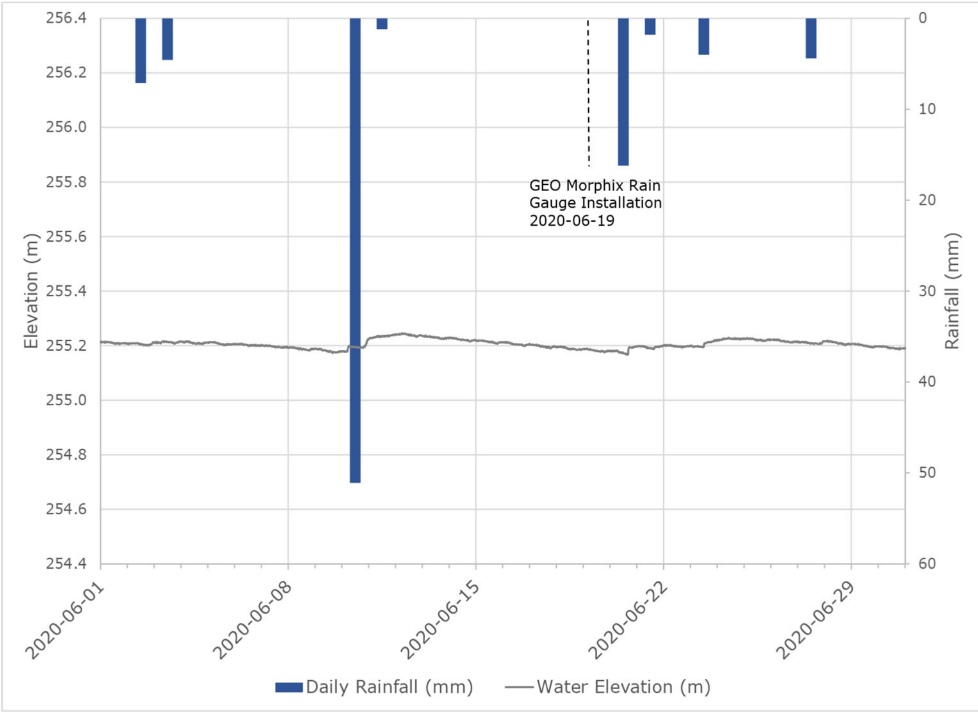
Figure 129	
	Water elevation and daily rainfall at **N Pond** for April-May 2020.
Figure 130	
	Water elevation and daily rainfall at **N Pond** for June 2020.

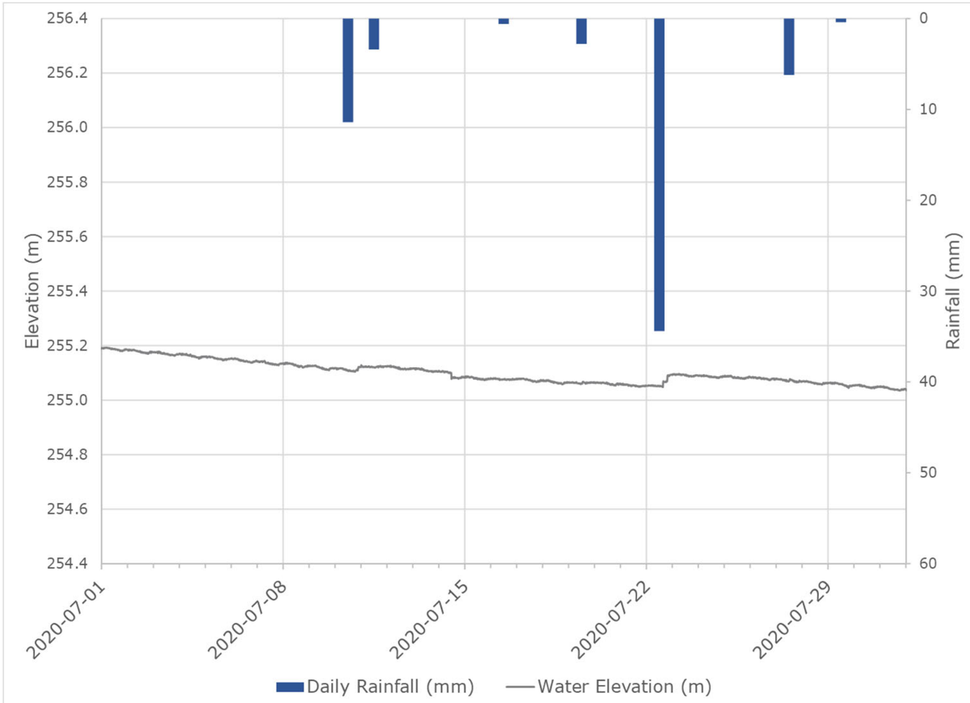
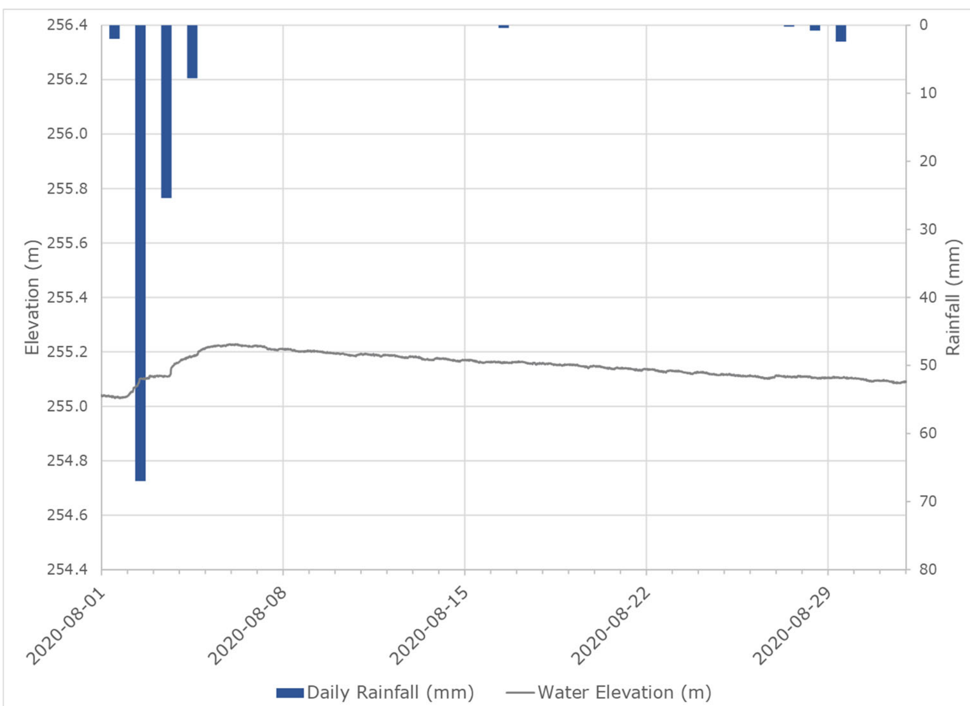
Figure 131	
	Water elevation and daily rainfall at **N Pond** for July 2020.
Figure 132	
	Water elevation and daily rainfall at **N Pond** for August 2020.

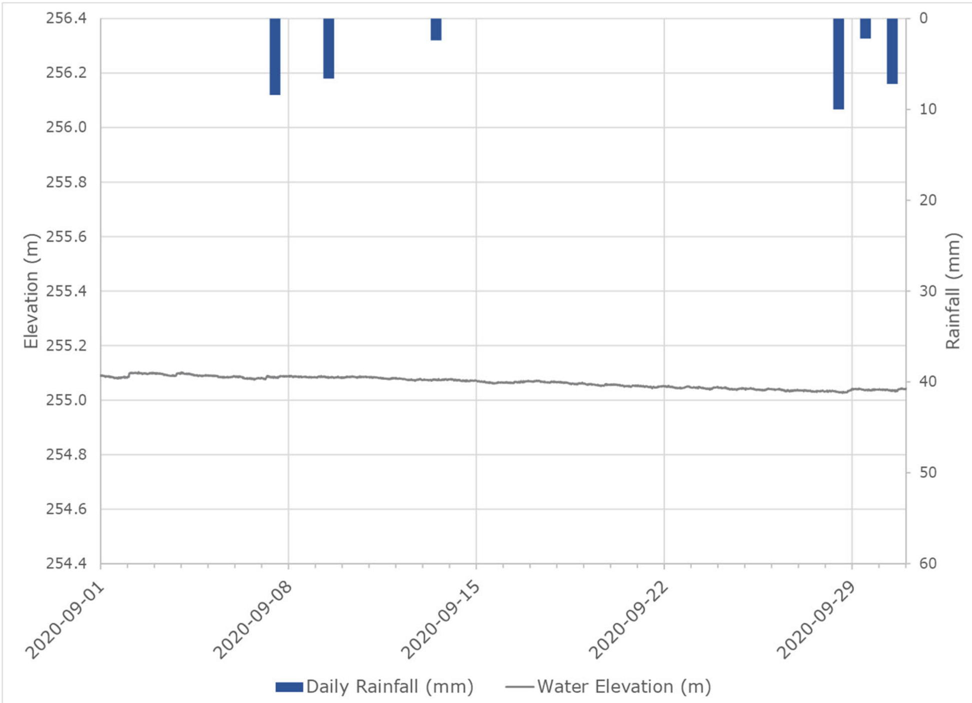
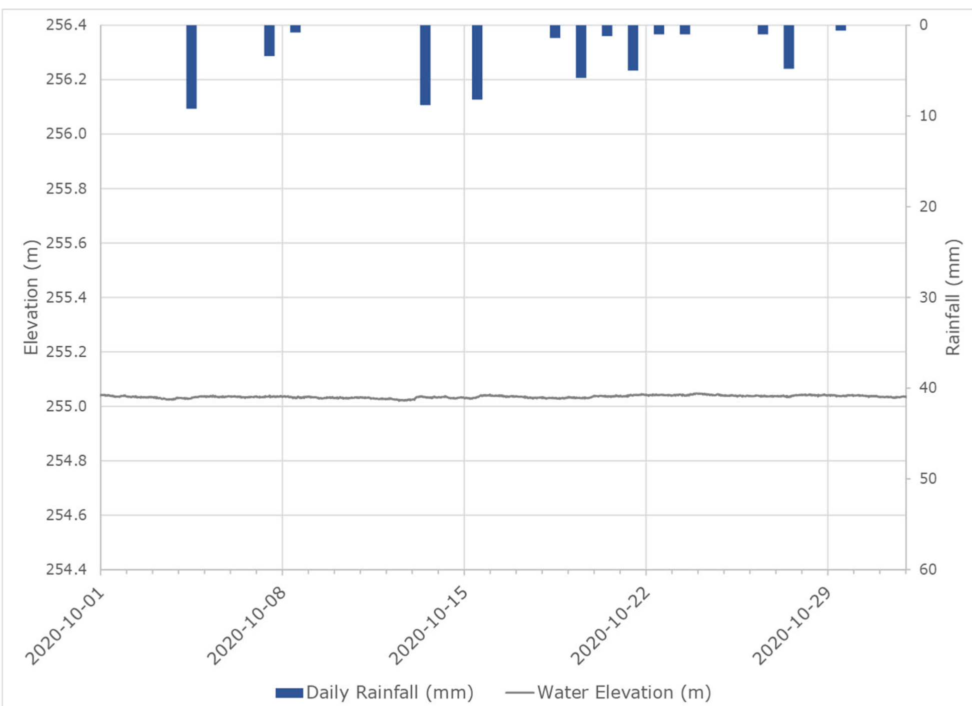
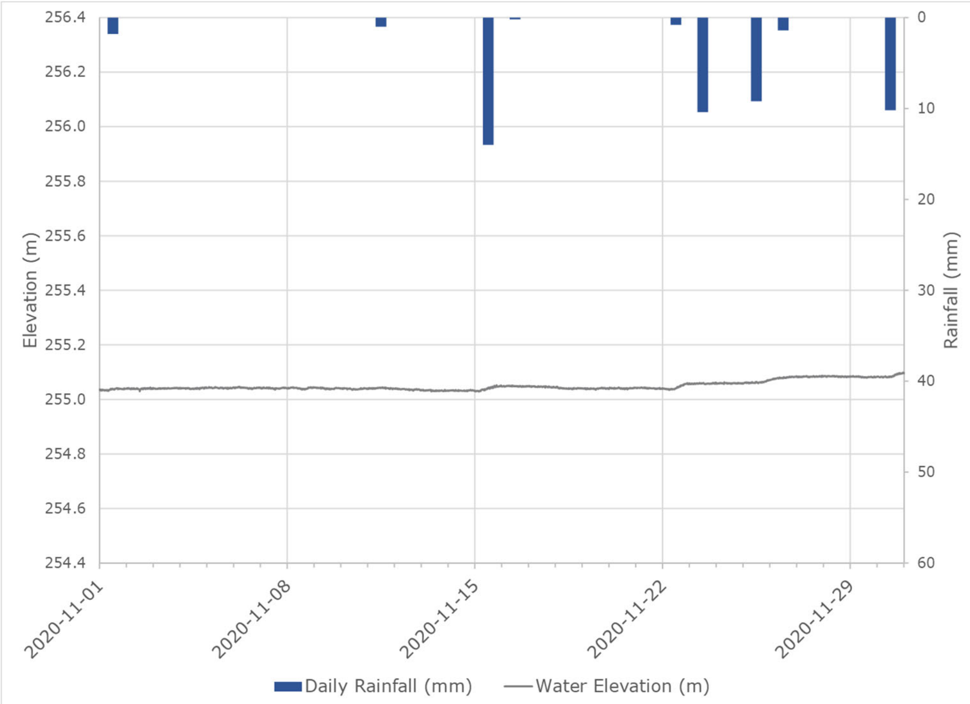
Figure 133	
	Water elevation and daily rainfall at **N Pond** for September 2020.
Figure 134	
	Water elevation and daily rainfall at **N Pond** for October 2020.

Figure 135	
	Water elevation and daily rainfall at **N Pond** for November 2020.

2020 S Pond Water Elevation

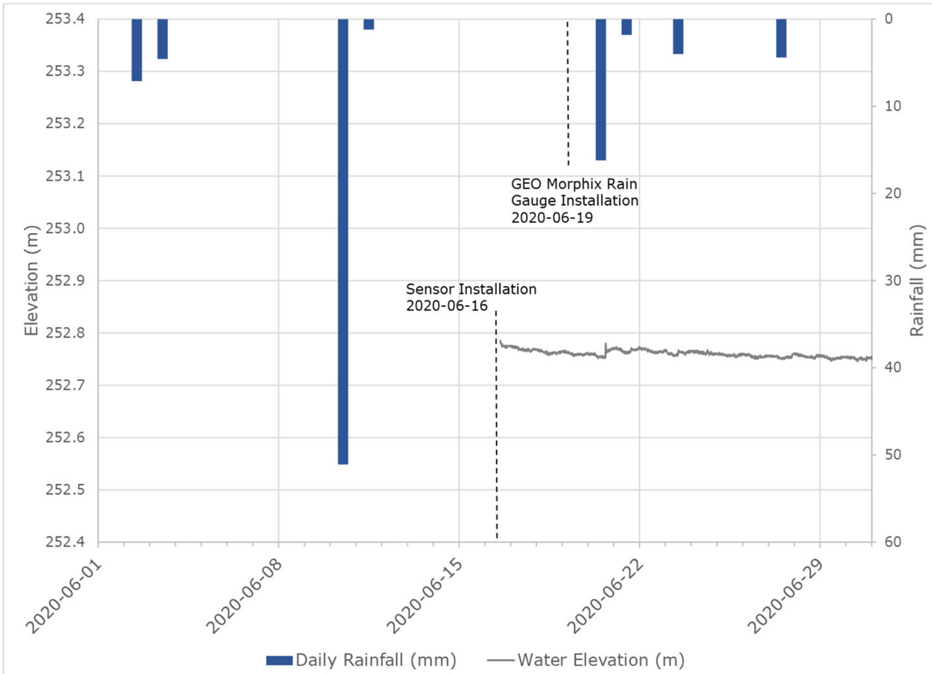
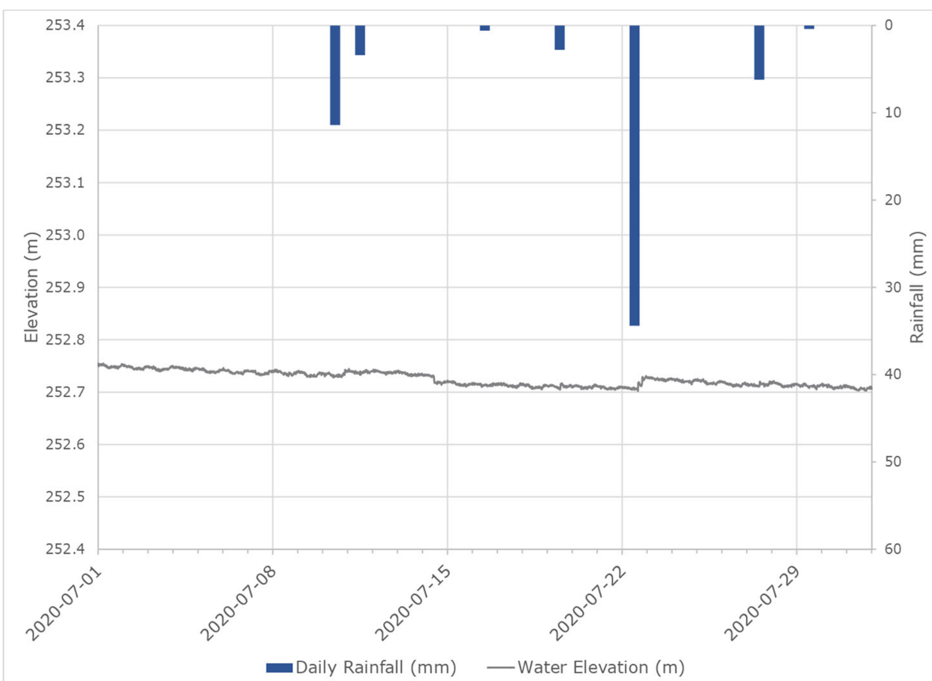
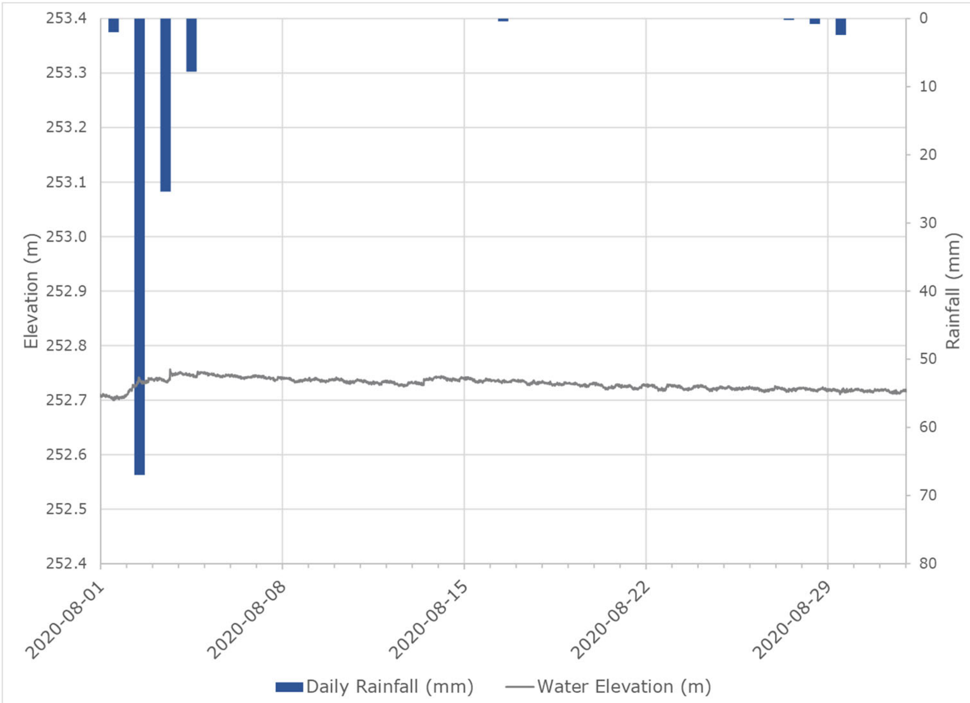
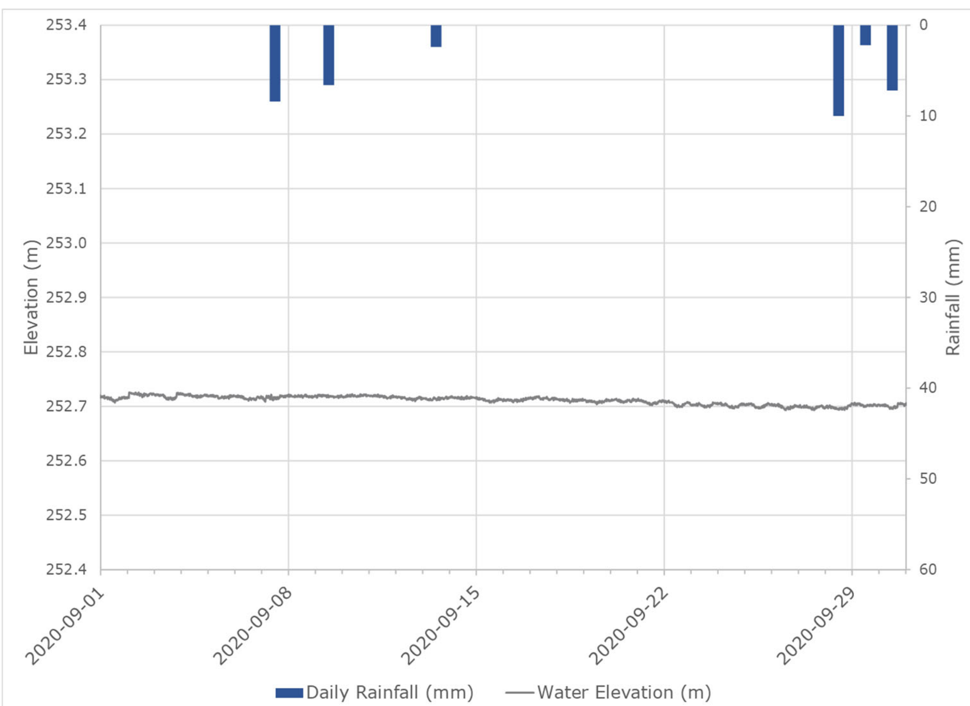
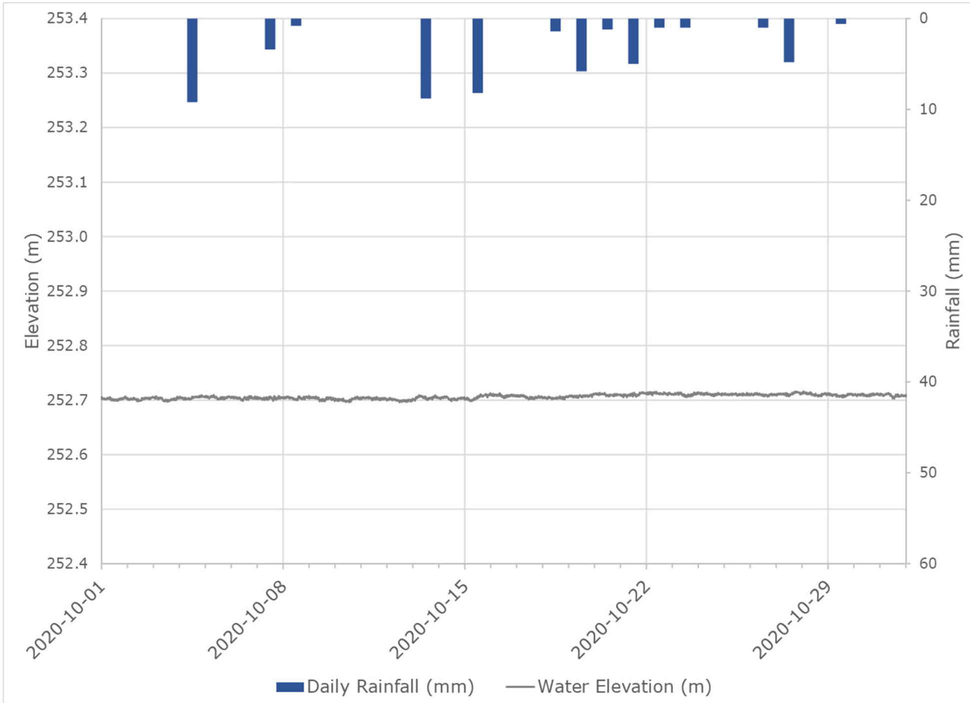
Figure 136	
	Water elevation and daily rainfall at **S Pond** for June 2020.
Figure 137	
	Water elevation and daily rainfall at **S Pond** for July 2020.

Figure 138	
	Water elevation and daily rainfall at **S Pond** for August 2020.
Figure 139	
	Water elevation and daily rainfall at **S Pond** for September 2020.

<table>
<tr><td rowspan="2">Figure 140</td><td>
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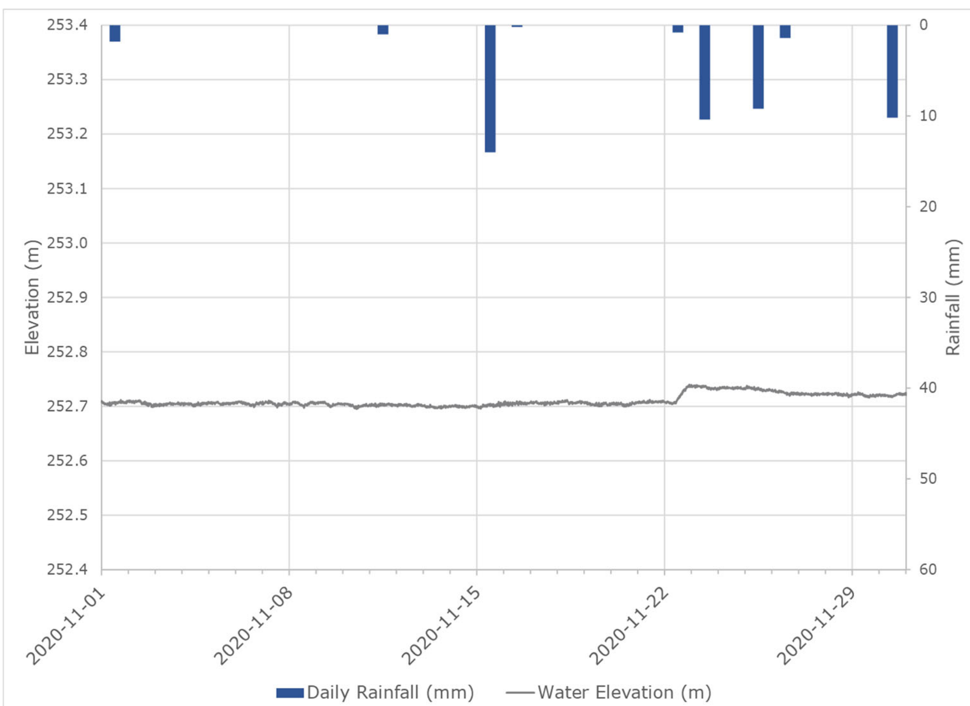
<tr><td>Water elevation and daily rainfall at S Pond for October 2020.</td></tr>
<tr><td rowspan="2">Figure 141</td><td>
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<tr><td>Water elevation and daily rainfall at S Pond for November 2020.</td></tr>
</table>

2019 ADV Discharge Measurement Summary

Measurement Date (yyyy-mm-dd)	Location	Average Velocity (m/s)	Measured Discharge (m^3/s)
2019-04-09	W Inlet	0.0114	0.0002
	S Inlet	0	0
	Bridge	0	0
	Outlet	0.2734	0.0150
2019-05-10	W Inlet	0.0538	0.0009
	S Inlet	0	0
	Bridge	0.0400	0.0023
	Outlet	0.3392	0.0180
2019-06-20	W Inlet	0	0
	S Inlet	N/A	N/A
	Bridge	N/A	N/A
	Outlet	0.0170	0.0004
2019-07-16	W Inlet	N/A	N/A
	S Inlet	N/A	N/A
	Bridge	N/A	N/A
	Outlet	N/A	N/A
2019-08-13	W Inlet	N/A	N/A
	S Inlet	N/A	N/A
	Bridge	N/A	N/A
	Outlet	N/A	N/A
2019-08-30	W Inlet	N/A	N/A
	S Inlet	N/A	N/A
	Bridge	N/A	N/A
	Outlet	N/A	N/A
2019-10-01	W Inlet	N/A	N/A
	S Inlet	N/A	N/A
	Bridge	N/A	N/A
	Outlet	N/A	N/A
2019-10-30	W Inlet	N/A	N/A
	S Inlet	N/A	N/A
	Bridge	N/A	N/A
	Outlet	N/A	N/A

N/A - Channel dry/too shallow, unable to complete measurement

2020 ADV Discharge Measurement Summary

Measurement Date (yyyy-mm-dd)	Location	Average Velocity (m/s)	Measured Discharge (m^3/s)
2020-04-08	W Inlet	N/A	N/A
	S Inlet	0	0
	Bridge	0	0
	Outlet	N/A	N/A
2020-04-28	W Inlet	0	0
	S Inlet	N/A	N/A
	Bridge	0	0
	Outlet	N/A	N/A
2020-05-26	W Inlet	N/A	N/A
	S Inlet	N/A	N/A
	Bridge	0	0
	Outlet	N/A	N/A
2020-07-14	W Inlet	N/A	N/A
	S Inlet	N/A	N/A
	Bridge	N/A	N/A
	Outlet	N/A	N/A
2020-08-13	W Inlet	N/A	N/A
	S Inlet	N/A	N/A
	Bridge	0	0
	Outlet	N/A	N/A
2020-09-16	W Inlet	N/A	N/A
	S Inlet	N/A	N/A
	Bridge	N/A	N/A
	Outlet	N/A	N/A
2020-10-06	W Inlet	N/A	N/A
	S Inlet	N/A	N/A
	Bridge	N/A	N/A
	Outlet	N/A	N/A
2020-11-02	W Inlet	0	0
	S Inlet	N/A	N/A
	Bridge	N/A	N/A
	Outlet	N/A	N/A
2020-11-30	W Inlet	N/A	N/A
	S Inlet	0	0
	Bridge	N/A	N/A
	Outlet	N/A	N/A

N/A - Channel dry/too shallow, unable to complete measurement