# Lower Mamquam Hydroelectric Project

## Interim Monitoring Report

## Year 1



Prepared for:

**Capital Power Corporation**
**P.O Box 5383**
**Squamish, B.C., V8B 0C2**

31 March 2011

Prepared by:

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# Lower Mamquam River Hydropower Project

## Ramping Study Report – Draft for Agency Review V2



Prepared for:

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5th floor, TD Tower
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December 20th, 2010

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Ministry of Forests, Lands and Natural Resource Operations

Water Stewardship Division

# OPERATING PARAMETERS AND PROCEDURES

## Lower Mamquam Hydroelectric Project

**December 23, 2014**

# Atlantic Power Corporation

# Operating Parameters and Procedures Report

## Lower Mamquam Hydropower Project

Version 5

**December 23, 2014**

Mamquam River Generating Station
39241 Powerhouse Springs Road
Squamish BC V8B 0C2

**Prepared by Atlantic Power Corporation**

# APPROVAL PAGE

## Approved Operational Parameters and Procedures Report

| | |
|---|---|
| **Date of OPPR:** | March 31, 2014 |
| **Revision of OPPR** | December 23, 2014 |

## On behalf of the Proponent (Licensee)

| | |
|---|---|
| Full Name: | Marc Nering |
| Signature: | |
| Date: | |

## On behalf of the Water Stewardship Division

Full Name:

Signature:

Date:

# Revision Tracking

Versions and revisions of the OPPR and supporting appendices have be described and tracked to provide a revision history and to identify the current version:

**Operational Procedures and Parameters Report**

| Revision Number | Date | Description | Prepared By (Proponent) | Agency Review (WSD) |
|---|---|---|---|---|
| A | 31-04-2014 | Revised OPP for Review | MN, TS | |
| B | | Revised as per MFLNRO request | MN | |
| C | September 19, 2014 | Revised as per MFLNRO request | MN | |
| D | December 5, 2014 | Revised as per MFLNRO request | MN | |
| E | December 23, 2014 | Revised sections 3.3.3, 3.3.2.2, 4.2.1, as per MFLNRO request | MN | |

**OPPR Supporting Appendices**

| Appendix | Revision Number | Date | Description | Prepared By (Proponent) | Agency Review (WSD) |
|---|---|---|---|---|---|
| **Addendum B** | D | December 5, 2014 | Added Addendum B | Ecofish | |

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# Section 1.0 - LIST OF ACRONYMS

| | |
|---|---|
| AMSL | Height above mean sea level |
| BC DSR | BC Dam Safety Regulation 44/2000 |
| DFO | Fisheries and Oceans Canada |
| EPP | Emergency Preparedness Plan |
| IDF | Inflow Design Flood |
| ESD | Emergency Shut Down |
| FLNRO | Ministry of Forests, Lands and Natural Resource Operations |
| FSL | Full Supply Level |
| FSR | Forest Service Road |
| GWh | Giga Watt Hour |
| HMI | Human Machine Interface |
| HP | Horsepower |
| HPU | Hydraulic Power Unit |
| IFR | Instream Flow Requirement |
| LCO | Leave to Commence Operations |
| mA | MilliAmps |
| MCC | Motor Control Centre |
| MFLNRO | Ministry of Forests, Lands and Natural Resource Operations |
| mg/l | milligrams per litre |
| MRF | Minimum Release Flow at Headworks |
| MW | Megawatt |
| NTU | Nephelometric Turbidity Units |
| OPP | Operating Parameters and Procedures |
| OMS | Operation Maintenance and Surveillance Plan |
| PEP | Provincial Emergency Program |
| PEP-EMBC | Provincial Emergency Program within Emergency Management British |
| Columbia PIR | Project Interconnection Requirements |
| PLC | Programmable Logic Controller |
| POI | Point of Interconnection |
| SDM | Statutory Decision Maker |
| TSV | Turbine Shut-off Valve |
| VAC | Volts, Alternating Current |
| VDC | Volts, Direct Current |
| WSE | Water Surface Elevation |

# Section 2.0 - PROJECT INFRASTRUCTURE

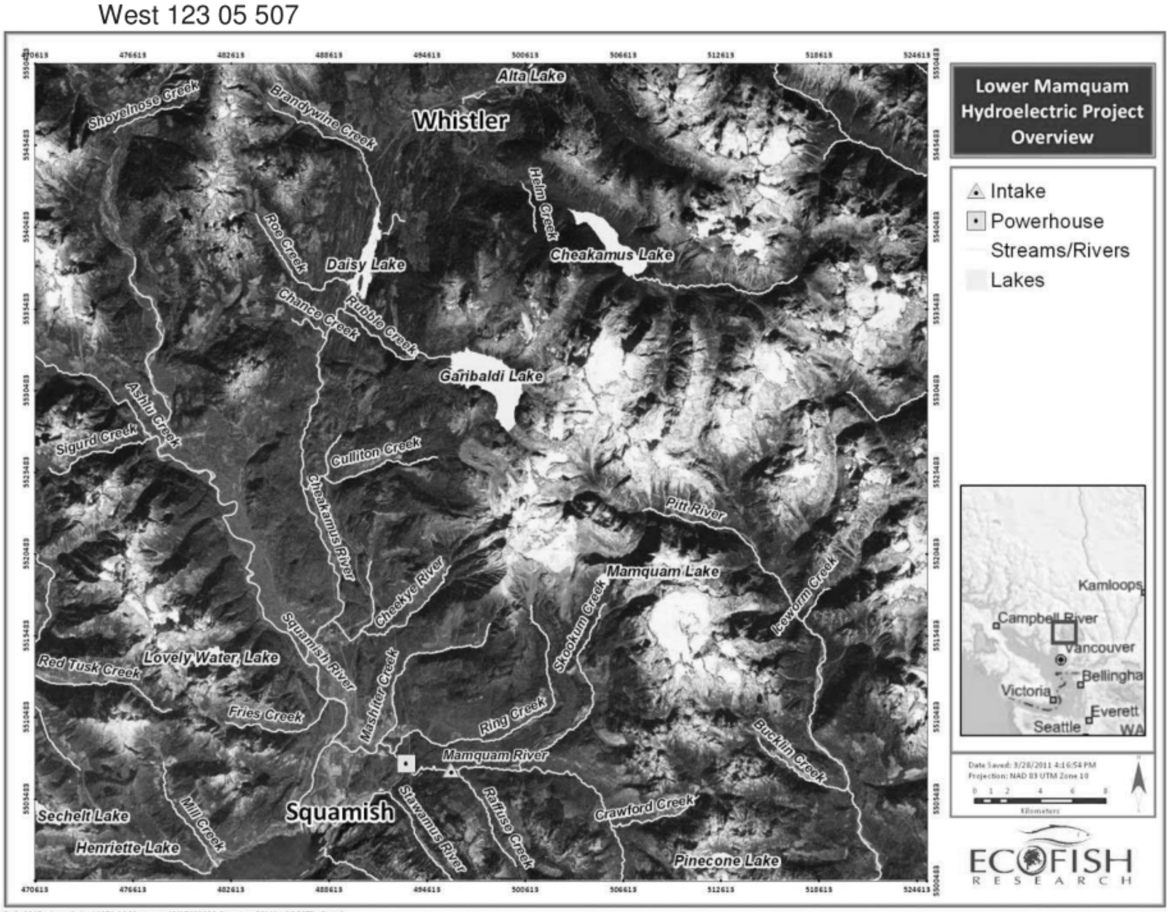
## 2.1 LOCATION, OWNER, and PERMITS

### 2.1.1 Project Location and Ownership

The Mamquam River Hydroelectric Project is licensed to Atlantic Power Corporation and the legal owner is Atlantic Power Corporation. The Mamquam River Hydroelectric Project (Project) is located about 4 km east of the town of Squamish in western British Columbia. The project diverts water from the Mamquam River into a tunnel that feeds two turbines for power production. The powerhouse is at the downstream end of a tunnel approximately 3 km from the intake facilities.

The Mamquam River flows northwest from the Coast Mountains and joins the Squamish River near the town of Squamish. It drains 378 km2 of water into a mountainous area just south of Garibaldi Provincial Park. Elevations in the watershed range from near sea level at the mouth to over 2,600 m at Mount Garibaldi. The diversion site is located 8 km from the mouth of the Mamquam River, at the head of Mamquam Falls. The drainage area at the diversion site is 273 km2. Most of the drainage area is made up of steep sided valleys with very dense vegetation ranging from large trees to small shrubs and grasses. There is a small glacier-covered area at the headwaters of Skookum Creek, which drains into the Mamquam River upstream of the diversion.
Mapping location references are:

Latitude and Longitude: North 49 43 296
West 123 05 507



### 2.1.2 Detailed Location & Access

The Project is located off of the Mamquam River Forest Service Road, in Squamish, BC, Canada. The Mamquam River Forest Service Road is located approximately three km north of Shannon Falls Provincial Park and 1.3 km south of downtown Squamish. Proceed east up Forest Service Rd for approximately 3.8 kilometers, and turn left at a 3-way intersection. Follow this road for approximately four km to the gate to the Project Powerhouse, and proceed across the bridge, taking the left branch to the Powerhouse 0.1 km further down the road. .See Appendix A for Site Map of the Project. Detailed security measures are addressed in Section 2.3. Detailed information on access infrastructure is provided in Section 2.2.6.

### 2.1.3 Regulatory Permits & Authorizations

This section identifies regulatory permits and authorizations. The permits and authorizations for this Project are provided in Table 1.

**Table 1 List of Regulatory Permits and Authorizations**

| Permits/Authorizations | Identifier |
|---|---|
| Water file number(s) | 2000966, 2003040 |
| Land tenure number(s) | 241931, 236420, 236422, 236423, 236424 |
| Conditional Water Licence. | 102850 & 123692 |
| Road Use Permit | 9283-13-02 |

The Project Water License is an all-encompassing license issued by the BC Ministry of Environment, Land and Parks which outlines Atlantic Power's water usage rights for Mamquam and includes the requirements of several regulatory bodies. The original conditional license, CWL 102850, was granted in May 1994 and allowed for the diversion of up to 23.45 $m^3$/sec from the Mamquam River. In 2009, Atlantic Power's predecessor company, EPCOR, was granted a conditional water license, CWL 123692 that allowed for the diversion of an additional 6.55 $m^3$/sec. The new license had a number of requirements based on current reporting requirements on new hydroelectric plants as well as historical information requirements for Mamquam.

These requirements include:

1. Submit and implement a plan to monitor in-stream flows.
2. Submit and implement an Operational Environmental Monitoring Plan. The plan will assess the impact of operations on the river fish habitat with a focus on ramping and dam lowering operations.
3. The monitoring plan will be in effect for five years with a final report submitted at the end of the five year period.
4. A water reserve of 1 $m^3$/sec for use of the Crown for the protection of fish.
5. Inspection requirements, specifically dam safety and penstock inspections in accordance with the BC Dam Safety Regulation.

All Mamquam staff and management shall ensure that the Mamquam Generating Station is operated in accordance with the conditional water license for the facility and all requirements for the license are satisfied.

### 2.1.4 Adjacent Water Licenses and Other Users

#### *2.1.4.1 Adjacent Water Licence Holders*

[If Applicable] The Project stream also supports other water licence holders. These licence holders are listed in Table 2

***Table 2 Other Water Licence Holders in Watershed***

| Water Licence Number | Water Licence Holder | Location Relative to Project |
|---|---|---|
| *C102839* | *Canadian Hydro Developer* | *1 km upstream* |
| *C129047* | *SCPP Holdings* | *6 km upstream* |
| | | |

#### 2.1.4.2 Other Users

Recreational – Fishing and kayaking

## 2.2 PROJECT INFRASTRUCTURE

This section describes all physical works authorized under the Water Licence, and any other infrastructure associated with monitoring or confirmation of regulatory/licence requirements. The Project's general arrangement drawings are provided in Appendix B.

**Diversion Structures**

This section describes in detail the diversion structures of the Project.

#### 2.2.1.1 Diversion Weir Rubber Dams

**General**
The project's two air inflatable rubber dams were supplied by Bridgestone Engineered Products Co. The air blowers, air control valves with actuators, level and pressure transmitters and control system software were also provided by Bridgestone. The Allen Bradley controller and MCC were provided by RSL Systematic.

**Description**
The rubber weirs are designed to operate for extended periods of time at any position from fully inflated to fully deflated with the upstream water level between El. 296.000 and 297.000. In addition, the rubber weirs are capable of operation for extended periods in fully deflated position with the headpond as high as El. 298.000

The rubber weir is fabricated from reinforced sheet rubber that is formed into a tube and it is anchored at the base and piers of the diversion weir foundation. The rubber is clamped using continuous clamp plates retained by a series of anchor bolts embedded in the concrete. The clamps are continued up the sides of the piers.

To avoid material deterioration caused by ozone and ultraviolet, EPDM (Ethylene Propylene Diene Monomer) additive is incorporated in the rubber fabric, Vibration suppression is achieved through the finned rubber body structure which allows aeration under the nappe.

Each rubber dam is provided with an air blower and control system. There is an interconnection which allows either air blower to inflate either rubber dam

The control system is capable of operating the weirs in manual, automatic and remote control modes. The control system monitors and controls the water level upstream of the rubber weirs by controlling the internal pressure of the weirs. On command from the PLC the control system is capable of maintaining the rubber weirs at any specific elevation and adjusting the height of the rubber weir to maintain constant head-pond level, at any level between El. 296.800 and El. 297.200.

An automatic flood control safety device is provided to fully deflate the rubber weirs when head-pond level reaches El. 297.600

**Maintenance**
The rubber dam maintenance procedures shall be in accordance with "Bridgestone" instructions contained in the rubber dam maintenance manual. For the air blowers maintenance requirements refer to the "Service and Parts Manual for Blower model DR9" by "Rotron Incorporated."

## Sluiceway Logboom

**General**
A sluiceway log boom is provided in the head-pond to restrain entry of floating objects into the approach channel.

**Description**
The boom is formed from Tuffboom waterway barriers chained together and anchored in four places.

**Maintenance**
Inspect and restore the log boom as required.

## Sluiceway Radial Gate

**General**
The sluiceway radial gate equipment, including radial gate, embedded parts and guides, gate hoist and hoist support bridge is supplied by Linita Welding. The gate is installed at the end of the sluiceway to allow sediment and debris to be flushed from the approach channel.

**Description**
The sluiceway radial gate is a vertical lift gate with an upstream skin plate and a side upstream Teflon seal. It is assembled from two main sections with a splice plate.

The gate is lifted by four falls of galvanized wire rope, type 6 x 19. - 19mm diameter. Reducer, motor and brakes are a single unit assembly manufactured by “FLENDER" It combines a "Flender" Motor helical worm gear speed reducer will a disk brake and a 2hp 1750rpm, 575 VAC/ 3ph NEMA 4 motor.

**Maintenance**
Maintenance of the sluiceway radial gate shall be performed in accordance with manufacturers' instructions

## Stop-Logs

***General***
One set of stop-logs is provided to allow de-watering of the power tunnel for inspection and maintenance. This stop-log set is also used for de-watering the sluiceway and diversion structure. The set is complete with a follower for handling the stop-log sections.

One additional stop-log is provided to allow de-watering of a diversion weir for inspection and maintenance of the rubber dams.

***Description***
The intake facilities stop-log equipment has been designed by ”Associated Engineering"

The intake stop-log set sections are of fabricated steel construction with main- horizontal beams connected to end members designed to transfer the hydraulic loads to the embedded guides.

The gate seals are Huntington, 3-type rubber seals coated with a layer of fluorocarbon bolted to the stop-logs with stainless steel fasteners.

One stop-log section fitted with a 300mm diameter rubber seated butterfly valve which allows re-watering of a de-watered power tunnel. A 9000mm valve operator is provided to allow both opening and closing the valve from the top of the stop-log guides at EL. 299.500, with the valve on the bottom stop-log section.

The stop-log follower consists of a horizontal follower beam with two hooks designed to engage at pickup points on the stop-logs. The follower is guided by the stop-log such that the follower hooks will positively engage a submerged stop-log. The hooks are retracted by a tiller mechanism with a nylon tiller rope attached to it. The stop-log hooks are pivoted on stainless steel pins and have self-lubricating bronze bushings. The follower can be handled with a single point lift using a mobile crane.

The stop-log for diversion weir structure, used together with an above described stop-log set, allows de-watering of a diversion weir for inspection and maintenance of the rubber dams.

The stop-log is of fabricated steel construction with main-horizontal beams connected to end members to transfer the hydraulic loads to the embedded guides. The J-type rubber seal is bolted to the stop-log with stainless steel fasteners.

The stop-log may be handled with a single point lift using a mobile crane.

***Operation***
**Installation Recommendations**
Under no circumstances are the stop-logs to be installed under flowing water conditions. The units must be shut down with wicket gates and inlet valves closed.

The proper sequence of the tunnel unwatering and refilling is described in the section on the Tunnel, in this manual.

Installation of the intake structure stop-log set is accomplished by the procedure outlined below:

a. Attach the crane hook to the follower beam. Connect tiller rope to the tiller.
b. Using the follower beam, raise the bottom stop log section (the one with a valve)
c. Wet sealing surfaces to minimize abrasion.
d. Guiding the follower by the stop-log guide, carefully lower the section until it rests on the sill beam and crane ropes become slack
e. Using the tiller mechanism, unhook the follower.
f. Using the follower beam, raise next stop-log section.
g. Repeating steps 3 - 6 install the remaining sections.

**Removal Recommendations**
Removal of the draft tube gate is accomplished by the procedure outlined below:

a. Attach the crane hook to the follower beam. Connect tiller rope to the tiller.
b. Guiding the follower by the stop-log guide, engage the follower's hooks at pickup points on the stop-log section. Check that follower's hooks are positively engaged a submerged stop-log at both points.
c. Lift the stop-log section, move it to the storage place and disengage the follower beam.
d. Repeating steps 2 and 3 remove the remaining sections.

Installation recommendations for the diversion structure stop-logs and bulkhead gate

a. Install an intermediate stop-log guide
b. Attach a crane hook to the lifting lugs of the bulkhead gate
c. Wet sealing surfaces to minimize abrasion.
d. Lower the gate until it rests on the sill beam and crane ropes become slack.
e. Install five section intake structure stop-log set as described above.

Removal Recommendations for the diversion structure stop-log

Removal of the stop-log is accomplished in the opposite order to installation procedures.

**Note:**
If a stop-log section becomes jammed while lowering through guides, i.e., main hoist rope goes slack, attempt to raise the section and re-lower. Should the section jam again, do not attempt to move the section again until the condition has been thoroughly investigated and the jam rectified.

If a crane overload device trips while the stop-log is being raised, the section may have jammed in the guides. Do not bypass the overload device or attempt to raise the section farther. Lower the section, verifying the movement, i.e., the rope does not slack. If the section can be lowered, attempt to raise it again. If the overload device operates again, or if the section will not lower, do not attempt any further movement of the section until the conditions have been thoroughly investigated and the situation rectified.

***Maintenance***
Inspect the stop-log sections prior to and following each use. Note in particular the following items:

- Stop-log section
- Condition of seals
- Condition of the valve and operating mechanism
- Possible structural damage
- Follower beam
- Condition of bumpers
- A hook release mechanism
- Tiller rope
- Possible structural damage

If painting is required, refer to the "Associated Engineering" documents for the protective coating originally supplied. The paint material should be compatible with the system and should be applied in accordance with manufacturer's instructions.

**Intake Trashrack**

***General***

Four intake trashrack sections, complete with lifting slings are provided for installation at the front of the intake to prevent large debris from entering the power tunnel.

***Description***

The trashrack sections were designed by "Associated Engineering" and manufactured by "Lochhead - Huggerty". The sections are fabricated steel construction with vertical rack bars welded to five horizontal support members which transmit loads to the vertical embedded guides.

Two wire rope lifting lugs are attached to the top of each section to allow removal and installation of the sections with a mobile crane. The sling length allows the top to be docked at deck level (EL. 299.500).

Differential pressure across the trashrack is monitored by two sets of three water level transmitters.

***Operation***

The trashrack sections should be installed or removed only when the units are shut down with wicket gates and turbine inlet valves closed.

**Installation Recommendations** - Prior to reinstalling the trashrack sections, the intake area downstream of the trashrack guides should be inspected (by diver) to ensure no debris has fallen into the intake area downstream of the trashracks.

Attach the crane hook to the trashrack sling. Carefully lower the section until it rests on the bottom of the embedded angle.

**Note:** If a trashrack section becomes jammed while lowering through guides, i.e., main hoist rope goes slack; attempt to raise the section and re-lower. Should the section jam again, do not attempt to move the section again until the conditions have been thoroughly investigated and the jam is rectified.

If a crane overload device trips while the trashrack is being raised, the section may have jammed in the guides. Do not bypass the overload device or attempt to raise the section farther. Lower the section, verifying the movement, i.e., the rope does not slack. If the section can be lowered, attempt to raise it again. If the overload device operates again, or if the section will not lower, do not attempt any further movement of the section until the conditions have been thoroughly investigated and the situation rectified.

***Maintenance***

The trashrack should be kept clear of debris and trash to minimize head losses. The frequency of cleaning will be dictated by the operating characteristics of the station and by seasonal changes in water quality

Table 3 provides a summary of the key diversion structures, their dimensions and elevations.

**Table 3 Summary of Diversion Structures**

| Diversion Structures | Height (m) | Width (m) | Elevation (AMSL) (m) |
|---|---|---|---|
| Headpond | 3.25 | 40 | 297.1 |
| Intake Screen | 4 | 11.5 | 293 |
| Top of Weir | 3.25 | 15 | 297.1 |
| Bottom of Sluicegate | 6.2 | 10 | 291 |

### 2.2.1 Water Conveyance System

This section describes in detail the Project's water conveyance system, which consists of Tunnel and penstock The total volume of the system, when filled with water, is approximately *10000*$m^3$. The total gross head from the full headpond level to the tailrace water level is *267* m.

## Tunnel

***General***

The water passage from the intake to the powerhouse consists of a 420 m long upper tunnel, a 157 m vertical shaft and a 2600 m long lower tunnel. The upper tunnel is a "D" shaped tunnel 3.6 m wide by 3.6 m high driven by drilling and blasting. The shaft is a 3.1 m diameter raise bored vertical shaft connecting the lower tunnel with the upper tunnel. The lower tunnel is 4.1 m diameter driven by a tunnel boring machine (TBM).

***Description***

The upper tunnel, shaft and most of the lower tunnel are not lined. however, the rock is reinforced using rock bolts or protected with shotcrete in sections which require special treatment. In the section of the lower tunnel where the ground cover is not sufficient to withstand the internal water pressure, a 2.1 m diameter steel penstock is installed within the tunnel. This penstock is 435 m long and is surrounded by a concrete plug at the upstream end to form a seal with the rock. At the downstream end, this penstock divides into two 1.3 m diameter penstocks which extend through the powerhouse wall and connect to the turbine inlet valves on the generating units.

There are two rock traps in the tunnel. The first rock trap is located at the downstream end of the upper tunnel, just upstream of the vertical shaft. The second rock trap is located in the lower tunnel just upstream of the 2.1 m diameter penstock.

***Operation***

The procedure for filling the tunnel after it has been unwatered for inspection or maintenance is contained in Unit Dewatering System of this Operations Manual.

The rate at which the tunnel is depressurized (drained) for inspection or maintenance must be carefully controlled. If the tunnel is depressurized too rapidly, high seepage pressures may loosen shotcrete and rock causing local failures. The procedure to be followed in Dewatering the Tunnel is contained in the section on Unit Dewatering System of this manual.

Note: The tunnel outside the steel penstock must be unwatered if the lower tunnel is unwatered. This procedure will limit the stress in the anchor bolts which would occur if the penstock was unwatered and floated in the tunnel. The procedure for unwatering the annulus between the steel penstock and the rock is outlined in the Penstock section of this manual.

***Maintenance***
Pressure changes resulting from unwatering the tunnel are the most likely cause of local rock failures. Therefore, the tunnel should be unwatered carefully and infrequently. However, at least once in the first five years of service, the tunnel should be partially unwatered so that the rock trap in the upper tunnel can be inspected and cleaned out if necessary. The amount and size of the material deposited in the rock trap should be used to judge if the lower tunnel rock trap needs to be cleaned out. This inspection should also be used to judge the frequency of subsequent inspections.

## Penstock

***General***
The penstock is a steel conduit installed inside the tunnel. The penstock is designed to provide the water passage in the section of the tunnel where the strength of the rock is not sufficient to withstand the hydraulic pressure. The penstock is 2.1 m diameter and 435 m in length. Near the powerhouse, a bifurcation distributes the water into two 1.3 m diameter penstocks. These smaller penstocks pass through the powerhouse upstream wall and are connected to the turbine inlet valves.

The upstream end of the 2.1 m diameter penstock is anchored with a concrete plug poured and grouted to the rock of the tunnel. At the downstream end, the bifurcation is embedded in a concrete anchor block.

Between these two concrete anchors, the penstock is supported on saddles and ring girders. It is held in place by the ring girders and hold-down straps at the saddle supports. The annulus between the outside of the penstock and the rock of the 4.1 m diameter rock tunnel is normally filled with water but can be unwatered to make inspection of the penstock and tunnel possible.

***Operation***
Ground water will seep into the annulus in the tunnel outside the penstock. This annulus will fill with water but cannot rise above elevation 43. This level will be constant because a drain is installed in the wall of the manhole.

This annulus can be unwatered to permit access to the annulus for inspection of the tunnel or penstock. To unwater this area, follow the procedure outlined below:

1. Open the checker plate manhole cover.

2. Lower the Flygt Model 2201 or equal submersible pump down to the bottom of the shaft, with sufficient flexible discharge piping and sufficient power cord attached.

3. Route the discharge pipe to tailrace either through the drain pipe at elevation 43 or on the yard at elevation 50.

4. Close the appropriate breakers to supply power to the pump and start the dewatering pump.

5. The water level in the shaft will be lowered. Leave the pump running to handle seepage water after the water level has reached the bottom of the penstock.

6. Air to ventilate the annulus during inspection can be provided by powering the existing blower and operating it for at least one hour prior to annulus entry. Always check air quality readings prior to entering annulus.

7. At the end of inspection, stop the pump and blower, disconnect the power supply, and raise the pump out of the shaft.

8. Replace the checker plate manhole cover and ensure it is properly attached and sealed.

***Maintenance***
The annulus outside the penstock must be unwatered if the lower tunnel is unwatered. This will limit the stress in the anchor bolts which would occur if the penstock was unwatered and floated in the tunnel.

Table 4 summarizes the attributes of the Project's water conveyance system.

**Table 4 Summary of Water Conveyance Systems**

| Water Conveyance Structures | Length (m) | Elevation (AMSL) (m at entry) | Diameter (m) | Number of Stream Crossings |
|---|---|---|---|---|
| Upper Tunnel | 420 | 293 | 3.6 | N/A |
| Vertical Tunnel | 157 | 254.5 | 3.1 | N/A |
| Lower Tunnel | 2600 | 97 | 4.1 | N/A |
| Penstock | 435 | Est. 45 | 2.1 | N/A |

### 2.2.2 Powerhouse Power Generation Equipment

## TURBINES

***General***
The two Francis turbines are each rated at 25,000 kW at a net head of 243.5 m. The units were supplied by DEC and manufactured in the DE 1W factory in Deyang, China.

The turbine is directly connected to the vertical shaft synchronous generator. The turbine spiral case is connected to the turbine inlet valve through a removable pipe section which incorporates a dismantling coupling at the inlet valve.

Hatches are provided for personnel access to the spiral case and draft tube. A hinged inspection port is also provided in the spiral case at the small end of the spiral case. The design allows runner removal from below the spiral case.

The turbine wicket gate is controlled by two servomotors with oil supplied by the hydraulic power unit (HPU).

***Operation and Maintenance***
The pressure relief valve, hydraulic cylinders, HPU, displacement transducers and limit switches should be maintained as outlined in their respective operating and maintenance manuals provided by Bailey, Parker and Hydra-Power Systems.

The need for minor overhauls of the equipment can be expected on a routine basis. The inspections listed in the manufacturers' instruction manuals provide a good indication of when these repairs are necessary.

## TURBINE INLET VALVES

### *General*

A spherical type turbine inlet valve is provided at the entrance to each turbine spiral case. The purpose of the valve is the following:

- to permit unwatering of the turbine passages for turbine inspection and maintenance
- to close when the turbine is shut down to prevent leakage through the turbine wicket gate
- to close in an emergency under flowing water conditions, in the event of loss of control of the turbine.

### *Description*

The turbine inlet valve (TIV) is a 1300 mm diameter spherical valve. There is one valve for each of the two generating units. Both valves were manufactured in Deyang China.

The TIV has one hydraulic cylinder operator and a counterweight for closing the valve. A rigid flange connection is provided between the valve and the penstock upstream. The connection to the pipe section between the valve and the turbine spiral case is through a dismantling coupling.

The valve has both service (downstream) and maintenance (upstream) seals. The seals are operated by water pressure. The maintenance seal has a positive mechanical locking device. Oil for the hydraulic cylinder operator will be supplied from the hydraulic power unit (HPU).

### *Operation*

The valve disc must be fully open during normal operation of the turbine. It is not allowed to stay at any other position to regulate the flow rate, or to be locked by the full-open-position manual lock of the servomotor. Otherwise, the valve cannot serve the purpose of emergency protection. When the valve is to be shut down for TIV maintenance, or to examine the turbine, the following procedure is followed:

a. Service seal water is diverted to the drainage system by the four way solenoid valve.
b. Close the spherical valve using the hydraulic cylinder. Secure the locking device on the servomotor to guarantee the safety of maintenance personnel.
c. The manual four way valve is opened to allow seal water to pressurize the upstream maintenance seal.
d. Using procedures outlined in the unwatering section of this manual, unwater the TIV and turbine.

### *Maintenance*

The turbine inlet valves, cylinders, and seal water valves should be maintained as outlined in their respective operating and maintenance manuals provided by Dongfang Electrical Machinery Company.

A maintenance schedule should be adjusted by the operating personnel as experience is gained with the system.

The need for minor overhauls of the equipment can be expected on a routine basis. The inspections listed in the manufacturers' instruction manuals provide a good indication of when these repairs are necessary.

## HYDRAULIC POWER UNIT (HPU)

### *General*

The Hydraulic Power Unit (HPU) develops a hydraulic control signal of sufficient magnitude to operate servomotors which position turbine wicket gates, Turbine Inlet Valve (TIV) and Pressure Relief Valve (PRV).

HPU has been designed and supplied by "Hydra Power Systems" (HPS). There is one HPU for each of the two generating units. Each HPU system is independent of the other.

In addition to the HPU's, HPS supplied the operating cylinders for the TIV's and the servomotor cylinders for the turbine.

***Operation***
The HPU system is located on the turbine floor of the powerhouse and it is PLC controlled. The HPU is setup to be fail safe with the loss of control power or PLC causing the unit to unload. The HPU consists of a lead/lag pumping system that loads according to system pressure. The lead pump comes on at 1270 psi and the lag pump comes at 1240 psi. At a pressure of 1210 psi the system will shut down. The lead/lag pump unload pressure is 1440 psi. The lead pump is started when the pressure reaches 1270 psi. A two second timer elapses before the pump is loaded and the accumulators charged. When the pump reaches the unload pressure, valve DV1 de-energizes causing the pump to run unloaded. A ten minute timer will keep the pump running and then a pump will run loaded for an additional 3 minutes until the pressure reaches 1500 psi and then the pump will stop. If during the 10 minute timer the pressure drops below 1270psi, the pump will again be loaded.

The HPU accumulator has total volume of 160 gallons and is available to absorb sudden changes in system pressure. The default condition for the turbine when the system is de-energized is for the wicket gates and TIV to be closed and the PRV to be open. The operation of the HPU is controlled by four pilot valves that receive commands from the PLC system. The four solenoids have the following operation:

| Relay | Function |
|---|---|
| SD1 Wicket Gates | SD1 controls the valve which transmits system pressure to SV1. SV1 controls the position of wicket gates. When SD1 is de-energized SV1 is closed and the wicket gates will close as well. |
| SD2 PRV | SD2 is associated with the operation the Pressure Relief Valve (PRV). While SD2 is energized the PRV is controlled by SV2. On a startup, the PRV is closed by energizing SD2 which gets SV2 to operate until the PRV is closed. A normal shutdown de-energizes SD2 resulting in the operation of the PRV being a slave to the wicket gates operation. A slave circuit will open the PRV when the wicket gate is closing, this is accomplished by venting the oil from the slave servomotors that operate the wicket gates through the rod side of the PRV servomotors. |
| SD3 TIV | SD3 is used to open or close the Turbine Inlet Valve through the operation of SV3. When SD3 is energized the TIV is opened and will remain open as long as SD3 is energized. De-energizing SD3 has the effect of closing the TIV. |
| SD4 PRV Failure Relay | SD4 is used for shutting down the unit when the PRV fails to open. SD4 is de-energized resulting in the wicket gates closing in 30 seconds and the inlet valve closing in 90 seconds. |

When the PLC generates a startup condition, SD2 is energized applying system pressure to SV2 and then closing the PRV. Next, SD3 is energized in order to open the TIV. The SV3 valve is given system pressure and then opens the TIV. When the inlet is being opened the HPU pumps are run so that the accumulator is not discharged during this operation. The turbine is now ready for the start sequence.

The PLC energizes all four SD pilot valves during a turbine start. With the system armed, the PLC opens the wicket gates through SV1 to the set point. When the wicket gates are at the set point, SV1 will remain in the neutral servo position. During normal operation the slave circuit that operates the PRV is isolated from the movement of the wicket gates and the slave servomotors.

A normal system shutdown is initiated by the plant operator. Initially SD1 and SD2 are de-energized which does two things: the wicket gates begin to close using 10 second timing and the slave circuit to the PRV is active meaning that he PRV will open as the Wicket Gates close. A low pressure shutdown is the same as a normal shutdown with the exception that the shutdown signal comes from the HPU pressure transducer and not the operator.

If the PRV does not open during the shutdown sequence, a feedback signal will tell the PLC that the PRV has failed. The PLC will then de-energize SD4 and SD3 and the result will be that the Inlet Valve will close in 90 seconds and the wicket gates will close a bit slower (30 seconds) without the pressure relief valve available to vent pressure. Otherwise the pressure would rise to unacceptable levels in the tunnel.

Total loss of power will de-energize all four SD pilot valves and the hydraulic system will close the wicket gates in 10 seconds while opening the PRV using the slave circuit. The Inlet valve will also close in 90 seconds.

The HPU system is programmed to automatically recovery from any shutdown 1 hour after the event occurred.

***Automatic Control and Alarms***
HPU has the following control actions:

| ACTION | RESULT |
|---|---|
| System Pressure < 1210 psi | Shutdown – Normal |
| Wicket Gate Failure | HMI Alarm |
| PRV Failure | Shutdown – PRV |
| Inlet Valve Failure | HMI Alarm |
| 600 V Power Lost | De-energize SD1which will bring the unit to No load. |
| Accumulator Proximity Switch activates and gas pressure is below 1400 psi. | HMI Alarm – HPU gas leak. |

***Relay Protection***
An HPU low/low pressure signal, wired in series with the turbine speed switch, trips locking-out relay 86M if accumulator pressure drops to 175 kPa (1210 psi) and turbine is rotating.

***Maintenance***
HPU maintenance should be done in accordance with HPS instructions.

Relay protection should be checked as part of the scheduled maintenance of the generating unit relay protection equipment.

## GENERATORS

***General***
Two vertical shaft synchronous generators rated 31.25MVAl25N1W, 13.SkV, 60Hz 720rpm were design and supplied by "Dongran Electrical Machinery Works" (DFEN1) Sichuan, China.

***Description***
For a detailed description of the generator units see DFEM document No F574 "Instruction of Vertical Shaft SF25-10/3250 Hydro Generator" and document No F575 "Operation and Maintenance Manual of SF25- I 0/3250 Hydro Generator"

***Operation***
The generators are capable of continuous operation at the rated parameters. Continuous overload capabilities depend on ambient air and water temperatures and conditions of the turbine-generator unit. In no case manufacturer's stated parameters shall be exceeded. For detailed operation instruction refer to DFEN1 document No F575 "Operation and Maintenance Manual of SF25- 10/3250 Hydro Generator"

Under normal automatic mode of operation, the generator controls and the Static Excitation System (SES) will maintain the operation within the specified limits.

Although a number of alarm and indicating devices, permissive devices, interlocks, and protective devices have been provided for the generator, an operator performing a manual operation must always be deliberate, i.e., characterized by awareness of the consequences.

### *2.2.3.1 Generating Equipment*

This section describes details on the numerous components comprising the generating equipment.

## TURBINES

Turbine details are provided below:

| | |
|---|---|
| Turbine Type | Francis |
| Number of Units: | Two |
| Unit Capacity | 26MW |
| Shaft Orientation: | Vertical |
| Synchronous Speed: | 720RPM |
| Overspeed Rating | 1270 RPM |

### GENERATORS

Generator details are provided below:

| | |
|---|---|
| Manufacturer: | Dong Fang |
| Type: | Vertical |
| Rate Terminal Voltage: | 13.8KV |
| Rated Power Factor: | 0.80 |
| Frequency: | 60HZ |
| Enclosure: | Metal |
| Service Factor: | Continuous Duty |
| Synchronous Speed: | 720 rpm |
| Maximum Overspeed: | 1270 rpm |
| Stator Winding Connection: | Star |
| Insulation Rating: | Type F |
| Operating Temperature Rise: | 50 Degrees C |
| Rotation: | Clockwise form above |

### [COMPONENT NAME]

[Please add additional headings as required for your project, examples provided below.]

- Turbine shut off valves;
- By-pass Valve;
- Bearings;
- Hydraulic power unit;
- Switch gear;
- Cooling water; and
- Filtered water

#### *2.2.3.2* ***Energy Dissipation System***

### PRESSURE RELIEF VALVE

***General***

The pressure relief valves are connected to each turbine spiral case to reduce transient pressures in the power tunnel resulting from rapid closure of the turbine wicket gates, and to maintain river flow downstream of the facility when a rapid reduction in turbine discharge occurs.

**2.2.3.3**

***Description***

The pressure relief valve (PRV) is a 42" Bailey Model 810 Inline Polyjet valve. There is one pressure relief valve for each of the two generating units. Each of the 42 inch Bailey Polyjet valves is operated by two hydraulic cylinders. The hydraulic cylinders have a 13 inch stroke.

2.2.3.4 The hydraulic system is designed so that the relief valve operates as a synchronous bypass, and opens automatically on wicket gate closure. Valve closure is controlled by the station PLC. The hydraulic system also has provision for manual operation of the pressure relief valve, independent of wicket gate movement.
The system is failsafe so that the turbine wicket gate closure rate will be physically restricted if the relief valve fails to open on turbine shutdown. This ensures that the maximum transient pressure does not exceed design values.

The valve has flanged and bolted inspection ports to allow for inspection of the valve for debris.

The flow of each PRV can be varied from 0 to 12 (m3/s)

***Operation and Maintenance***
The pressure relief valve, hydraulic cylinders, HPU, displacement transducers, and limit switches should be maintained as outlined in their respective operating and maintenance manuals provided by Bailey, Parker, and Hydra-Power Systems.

The need for minor overhauls of the equipment can be expected on a routine basis. The inspections listed in the manufacturers' instruction manuals provide a good indication of when these repairs are necessary.

### 2.2.3 Tailrace

The tailrace is located on the downstream portion of the powerhouse and feeds directly into the Mamquam river. River levels determine the level of the tailrace, although the tailrace is 10+ meters deep. The tailrace has isolation gates for the draft tubes and bypass valves for both units.

### 2.2.4 Switchyard and Interconnection

This section describes details on the switchyard and interconnection.

#### 2.2.5.1 [Component Name]

## SWITCHYARD AND TRANSMISSION LINE

***General***
The switchyard consists of an incoming line structure with a 3-phase line disconnect, three lightning arresters, set of instrument current transformers, set of instrument potential transformers, two unit step-up transformers with a set of bushing current transformers, two unit breakers and disconnects.

The unit step-up transformer is covered separately in a different section. This section covers the balance of the equipment.

***Description***
The 69kV switchyard contains the high voltage equipment necessary for linking Mamquam Power station to the BC hydro power distribution system via a 4.8km 69kV transmission line. It is located in fenced area adjacent to the east wall of the control building. The equipment is mounted on a concrete foundation and has concrete retaining walls around the transformers' area to contain oil spills. The switchyard has a drainage pit with the provisions for oil separation.

The switchyard grounding system, connected to the powerhouse grounding system, reduces touch and step voltages to the safe values. Under the normal operating conditions the generated power is supplied to BC Hydro through step-up transformers, transformers' breakers 52T1 and 52T2, transformers' disconnects DT1 and DT2 linked by a 69kV bus, which is connected to the transmission line by the line disconnect switch DL1.

A set of potential and current transformers supply voltage and current values to the metering and transmission line relay protection systems.

Station class surge arresters located on the dead end tower protect station electrical system from incoming voltage surges.

Although normally each of the generators is connected to the common 69kV bus independently, in the case of one of the transformers outages both generators can work with a single step-up transformer, provided that the transformer's rating is not exceeded.

Automatic Controls, Protection and Alarms

The transmission line electrical protection is based on the two similarly and separately wired line protection relays "ABB," type REL511 to form redundant relay protection system.

The relay trip coil "A" is tripped by the breaker failure signal. The breaker failure signal is activated if current continues to flow or if either of the transformers' breakers is not tripped after a predetermined time. It causes an immediate trip of the generator breakers 52G1, 52G2, transformers' breakers 52T1, 52T2, tie breaker 52B and unit(s) shutdown.

The relay trip coil "B" is tripped by the following signals: 21 - Distance Protection, Zone I & Zone 2
50/51 - Overcurrent
27/59 - Under/Over Voltage
81 - Over/Under Frequency
59G - Ground Fault 60FL - PT Fuse Loss BC Hydro Trip
Coil "B" trips transformers' breakers 52T1, 52T2. Unit(s) unloaded to "no load" mode and stopped with an hour time delay.
For the particulars pertaining to the RELS 11 refer also to the "ABB" "User's Guide REL511, Line Distance Protection Terminal. No INIDU06030-EN Version 1.1"

***Operation and Maintenance***
Operations and maintenance shall be in accordance with manufacturers' recommendations.

BCH interconnection equipment shall be maintained in accordance with the requirements of the Electricity Purchase agreement between CBC and BC Hydro and Power Authority. In particular, maintenance of protection equipment shall include but not limited to calibration testing all protective relays and trip testing to circuit breaker at intervals of not more than three years.

### 2.2.5 Access

#### 2.2.6.1 Infrastructure

Access to the intake is via the Mamquam forestry service road. Access to the powerhouse is via the forestry service road and then Powerhouse Springs Road

2.2.6.2 Permits/Agreements

Road use permit 9283-13-02

## 2.3 SECURITY

### 2.3.1 General

Site security and measures are required for the following reasons:

- *Proximity to Mamquam river access*
- *Proximity to area trails*
- *Road access via Powerhouse Springs Road for the powerhouse*
- Road access via Mamquam Forestry Road

The security for this Project is provided by the following systems and processes:

- *Fencing, Gates, and Doors;*
- *Alarm Systems*
- *Video Surveillance.*
- Auto callout for Alarms

### 2.3.2 Fencing, Gates, and Doors

The powerhouse and intake each have 2 sequential access gates that are locked during non-business hours. The intake building and powerhouse have full perimeter fencing, and the switchyard has additional perimeter fencing. Both the intake building and the powerhouse have lockable doors with a security system.

### 2.3.3 Communication

In this section communication links between project infrastructure and to the outside are described, including land lines, cellular, and satellite communication. Communication links include:

- *A fiber optic line with both telephone and internet communications to the outside as well as between intake and powerhouse*
- *Cell phone communications to outside*
- *Radio communication to intake and outside*
- *PA system within powerhouse*

### 2.3.4 Alarm System

The plant HMI's record all alarm data including security, fire, and unit alarms and sounds an audible alarm within the plant and intake buildings. After hours alarm events are sent to the operators by auto-dialer to the on call operator's cellphone.

The fire alarm is a separate system with its own audible alarm within the plant and intake. It is triggered by smoke detectors and temperature gauges which are located throughout the powerhouse and intake buildings.

In the event of a plant trip there is a fog horn system to alert river users that river level changes may occur.

#### 2.3.5 Video Surveillance

There are 3 cameras for security and surveillance; One at the intake and two at the powerhouse. Each camera can be remotely controlled for viewing different parts of their coverage area. The video is recorded onto a 1 terabyte hard drive with approx. 1 month recording ability before being overwritten.

# Section 3.0 - OPERATING PARAMETERS

## 3.1 DESIGN PARAMETERS

### 3.1.1 Instream Flow Requirement ("IFR")

#### 3.1.1.1 IFR Schedule

In this section the instream flow requirements (IFR) under the water license are described.

The minimum IFR flow is one (1) cubic meter per second through-out the year and does not change seasonally. The IFR is provided via a manually adjusted slide gate that discharges into a one meter diameter IFR discharge pipe which bypasses the intake structures. The gate is located downstream of the intake screen to avoid plugging from debris.

#### 3.1.1.2 IFR Gauging

Accurate real-time instantaneous flow data will be collected to monitor instream flows over the life of the project to ensure compliance with the water license and to provide measures of environmental conditions that will assist in the interpretation of changes in biological components of the environmental monitoring program. For the purposes of verifying compliance with the IFR and flow ramping specifications, stage will be sampled at a frequency of 15 seconds, with a 2 minute average for storage in the data logger.

Flow measurements will be measured at all compliance points with a hydrometric gauge.

*Compliance Point*

Three (3) river level gauges are located immediately (within 100 meters) downstream of the intake structures in a protected pool. A visual staff gauge is not possible in this location.

These gauges are linked into the intake PLC for plant control, as well as a satellite link for remote monitoring. The gauges are now mounted in a protected location out of potential debris flow. The river profile should not change due to the channel being cut into solid bedrock. Stream channel discharges and post-Project rating-curves will be verified annually.

The reach location, gauge type, installed equipment, date of installation, are documented in Table 5

**Table 5 Hydrometric gauges: reach, location and number, type, & install date**

| Reach Location | Location | Type | Insta llatio |
|---|---|---|---|
| Upstream of Intake | 500M upstream of intake (USLG01) | Transducer (1) | 2010 |
| Diversion | 60M downstream of intake (DVLG01) | Transducer (3) | 7- May- 2012 (re-installed after flood event damaged previous gauge |
| Lower Diversion | 50M upstream of tailrace (DVLG02) | Transducer (1) | 2010 |
| Downstream of Powerhouse | 500M downstream of powerhouse (DSLG01) | Transducer (3) | 2010 |

Similar to the downstream of intake gauges, all other gauge flow curves used for regulatory compliance will be verified following the Land and Water BC (LWBC) Hydrometric Guidelines (LWBC, 2005) and RISC (2009) standards..

Details of the access to and the location of the gauges are provided in the attached 1:20,000 scale map (Appendix B).

#### 3.1.2 Ramping Rate Requirements

##### 3.1.2.1 Ramping Rate Schedule

In this section the ramping rate requirements under the water license are described The ramping schedule is provided in Table 6 by river flow rates, including compliance points and ramping schedules. The ramping rates have been developed by Ecofish Research following provincial and federal guidelines.

This section also describes the equipment installed to meet ramping rate requirements. Ramping rates will be achieved on this Project because the following equipment has been installed: The Francis style turbines have been modified and programmed via the PLC to ramp within the ramping guidelines described in table 6. In the event of a plant trip, the pressure reducing bypass valves (PRV's) are designed to transfer the water flow from the turbines through the full operational range and bypass the water through the power plant to maintain uninterrupted river flows. Only in the event of a critical trip will flow through the plant be interrupted. A critical trip is defined as a condition where human safety is in peril or major equipment damage can occur.

Since river ramping is compounded by other factors out of control of the Lower Mamquam plant including natural ramping and ramping from upstream plants, only ramping incidents caused by the lower Mamquam plant will be reported.

If ramping by the lower Mamquam plant is compounded by natural ramping or ramping from upstream events and exceeds the specified ramp rates due to natural or upstream events, these events will be recorded, but will not be considered ramping events if the lower Mamquam plant is ramping at its allowable rates.

**Table 6 Ramping rates by compliance point, showing the flow range specific ramping rates by season**

| Compliance Point | Flow Range | Maximum Operational Flow Rate | Ramping Rate at Compliance Point (cm/hr) |
|---|---|---|---|
| **Compliance Point 1 (DVLG01 - 60 meter downstream of intake gauge in diversion reach)** | | | |
| Year round | 0 -10 m3/s | 30 $m^3/s$ | 7.5 cm/hr |
| Year round | 10 - 24 $m^3/s$ | 30 $m^3/s$ | 19.9 cm/hr |
| Year round | >24 $m^3/s$ | 30 $m^3/s$ | unrestricted |
| **Compliance Point 2 (DSLG01 - 500 meter downstream of powerhouse gauge)** | | | |
| Year round | *0 - 30 m3/s* | *30 $m^3/s$* | *3.6 cm/hr* |
| Year round | *30 – 50 m3/s* | *30 $m^3/s$* | *9.9 cm/hr* |
| Year Round | *>50 m3/s* | *30 $m^3/s$* | *unrestricted* |

#### 3.1.2.2 Ramping Rate Gauges

Accurate real-time instantaneous flow data will be collected to monitor ramping rates and ensure compliance with the specified rates over the life of the project. Flow ramping measurements will be measured at all compliance points identified. Hydrometric gauges have been established to allow independent verification of flow conditions at any time.

### 3.1.3 Sediment Transport

Sediment transport of sands and silts occurs throughout the year as river flows increase to the point where these particles are mobilized. However the headpond does trap large gravels and boulders due to the reduction in flow velocity in the headpond, and the damming action of the weirs.

To mobilize these larger aggregates, and to prevent head pond infilling, sluicing and headpond flushing occurs annually, coinciding with very high river flows (above 80 $m^3/s$). This normally occurs during the fall season in October and November when the river is extremely turbid and little noticeable or measureable effect on water quality occurs.

A turbidity gauge has been installed downstream of the intake which will capture changes in river turbidity throughout the year, including times when sluicing occurs. Duration of headpond sluicing and turbidity levels prior to and during will be included in the annual compliance report. This gauge will be calibrated every two years.

## 3.2 CONTROLLING AND MAINTAINING PARAMETERS

### 3.2.1 General

This section describes how the project will be monitored and controlled. Table 7 provides a summary of flows continuously monitored by the control system.

**Table 7 Methods for Control**

| System Point | Method |
|---|---|
| Upstream of Intake (USLG01) | 1 Calibrated water level gauge |
| Downstream of intake(DVLG01) | 3 calibrated water level gauges below weir |
| Upstream of Power Plant (DVLG02) | 1 calibrated water level gauge |
| Downstream of Power Plant (DSLG01) | 3 calibrated water level gauge |
| Penstock Flow Meter | Dual flow gauges (to be installed Q3 2014) |

All water level gauges measure changes in water level in 1mm increments, scan for stage readings every 15 seconds, and log average readings every 2 minutes. These instruments have calculated flow curves where changes in water level are converted into cubic meters per second water flows.

The upstream of intake gauge (USLG01) measures water inflow from upstream sources. It does not include Raffuse Creek which flows into the Mamquam River downstream of this gauge.

The downstream of intake gauge (DVLG01) measures the instream flow release (IFR) as well as spill over the weirs and through the sluice gate. IFR is assessed from mean hourly flows. Ramping compliance is assessed by mean hourly flows, and is value calculated as the difference in stage between a particular point and the maximum stage during the previous hour (Addendum B). There are 3 gauges connected to the intake PLC.

The upstream of power plant gauge (DVLG02) measures flows slightly upstream of the plant. This gauge was installed to measure spill transit times from the intake to power plant for PLC programming.

The downstream of plant gauges (DSLG01) measure total river flow approx. 1/2 kilometer downstream of the power plant. Ramping compliance is assessed by mean hourly flows, and is value calculated as the difference in stage between a particular point and the maximum stage during the previous hour (Addendum B).. There are 3 gauges connected to the auxiliary PLC in the power plant.

The penstock flow meter measures flow through the turbines via the penstock. This gauge has been purchased and will be installed in Q3 2014. This gauge will help to program plant PLC's to accurately control ramping and river level changes downstream of the power plant.

#### 3.2.2 Protection Relays

Mamquam upgraded its protective relay system in 2013 using the latest ABB multifunction relays. Each generating unit has its own multifunction relay, and there are two line protection relays for any power line issues

#### 3.2.3 Human Machine Interface ("HMI")

Mamquam upgraded its plant PLC architecture in 2012/2013 using the latest Allan Bradley PLC's. The intake, each generating unit, and the power plant auxiliary have its own PLC. These are displayed on HMI's in the plant and at the intake for operator interaction. The plant is normally fully automated, however when operator intervention is required, processes can be put into manual condition where the operator has control.

#### 3.2.4 Historian

The Allen Bradley PLC has its own historian system to record events. In addition, there is an eDNA historian that records plant operating parameters in Atlantic Power's main servers.

#### 3.2.5 Web Based Digital Video System

There is 1 camera at the plant intake, and two at the plant powerhouse. These record video onto 1 terabyte hard drives which have approximately 2 months data before being overwritten

### 3.3 MONITORING PARAMETERS

#### 3.3.1 IFR Monitoring

##### 3.3.1.1 Monitoring Commitments

Instream flow data collected from the compliance points described in Section 3.1.1.2 will be recorded continually for the life of the project. The gauges will be monitored in real time and linked to automated alarms to provide timely notification of ramping events. This data will be stored and submitted to the regulatory agencies if requested.

Instantaneous water level and flow data will be made available upon request. Any non-compliance with the 1 $m^3/s$ IFR specified in Section 3.1.1 will be reported to Fisheries and Oceans Canada (DFO) and BC MFLNRO within 24 hours, and measures taken to ameliorate the risk of downstream impacts. Non-compliance reports describing the conditions of non-compliance, the contributing factors, and measures taken to minimize immediate and future impacts will be submitted to DFO and BC MFLNRO within a week of the incident. For the IFR and Ramping compliance gauges, stream channel discharges and post-Project rating-curves will be collected and developed based on the Land and Water BC (LWBC) Hydrometric Guidelines (LWBC, 2005) and RISC (2009) standards. Instantaneous water level and flow data will be made available upon request to regulatory agencies and in annual monitoring reports on instream flow compliance over the life of the Project. Download Schedule: Data will be downloaded & reviewed continuously and submitted annually to agencies.

### 3.3.2 Ramping Monitoring

#### 3.3.2.1 Monitoring Commitments

Compliance with the prescribed ramping rates established by Ecofish Research as per DFO and FLNRO ramping guidelines will be followed for the life of the project

Non-compliance with the downstream of powerhouse ramping rates caused by the Lower Mamquam hydroelectric power plant, based on calculations in the ramping rate guidelines, will be reported to DFO and MFLNRO within 24 hours of the event.

Non-compliance reports describing the conditions of non-compliance, the contributing factors, and measures taken to minimize the chances of recurrence will be submitted to DFO and MFLNRO within a week of the incident. Instantaneous water level and flow data will be made available upon request to regulatory agencies and in annual monitoring reports on instream flow compliance over the life of the Project.

#### 3.3.2.2 Flow Non-Compliance Resulting from Flow Changes Upstream

Ramping rate exceedances caused by rapid flow changes originating upstream of the Lower Mamquam Plant whether natural or other are outside the operational control of the Lower Plant. Any non-compliance resulting from flow changes that originate upstream of the Lower Mamquam Plant will not be reported by the Lower Mamquam Hydro-Electric Project. Reporting of flow changes from upstream plants resulting in flow non-compliance are the responsibility of the plant responsible.

### 3.3.3 Fish Stranding Monitoring

Following any violation of downstream of powerhouse ramp rates caused by the lower Mamquam plant, fish stranding potential will be monitored. A decision to perform a fish stranding survey will be based upon the environmental monitor's conclusion on the ramping violation's potential to strand fish.

***In the event of a stranding survey being performed, the results of the stranding survey will be included in the non-compliance report issued within one week of the incident.***

#### 3.3.4 Diversion Flow Monitoring

Diversion flow monitoring is calculated based upon precise flow measurements taken by Hydro Quebec when the plant was commissioned. Hydro Quebec created a flow chart with correlations between unit output and flow in cubic meters/second.

A penstock flow meter has been installed, however at this time there are issues with its reliability due to its location Maximum diversion flows are 30 CMS. If diversion flows exceed 30CMS this will be reported to MFLNRO within 24 hours

## 3.4 COMPLIANCE REPORTING ON PARAMETERS

Annual compliance reporting will be conducted for the full length of the OEMP (Operating Environmental Monitoring Plan) which will be concluded in 2015. Reporting will include all aspects of the OEMP. IFR, ramping, maximum diversion flow complaince, turbidity during headpond sluicing will be reported annually for the life of the project.

**Table 8 Reporting Requirements**

| Reporting Requirement/ Commitment | Frequency | Date |
|---|---|---|
| OEMP | Annually until 2015 | December 31 |
| IFR, ramping, maximum diversion flow compliance | Annually | December 31 |
| Turbidity during headpond sluicing | Annually | December 31 |

## 3.5 NON-COMPLIANCE REPORTING

### 3.5.1. Downstream Ramping Non-Compliance Incidents

Instances of non-compliance will be initially reported within 24 hours to the Engineer or Regional Water Manager (MFLNRO-WSD) and DFO with a report to be submitted within a week of the incident (see Section 6.1.2 Notification and/or Section 7.4 Contact). All reporting will be in digital format.

1. Ramping will be monitored by a third party environmental consultant.
2. In the event of a non-compliance event downstream of the powerhouse, an

automated alarm email will be distributed to plant staff and to the environmental monitor.

3. The environmental monitor will contact plant staff to determine the cause of the incident.
4. An initial report will be delivered via email to MFLNRO and DFO within 24 hours if the incident was caused by the Lower Mamquam plant
5. If it is determined the Lower Mamquam plant caused the ramping incident, and if the environmental monitor recommends a fish stranding search, a fish stranding search will be conducted in the stranding hot spots downstream of the plant (located at the high way bridge).
6. If fish are stranded, a report with fish stranding results, conditions of non-compliance, contributing factors, and measures taken to minimize immediate and future impacts will be delivered to MFLNRO and DFO within one week

# Section 4.0 - OPERATING PROCEDURES

## 4.1 PLANT OPERATIONS

### 4.1.1 Operating Modes

Head Pond Level Control

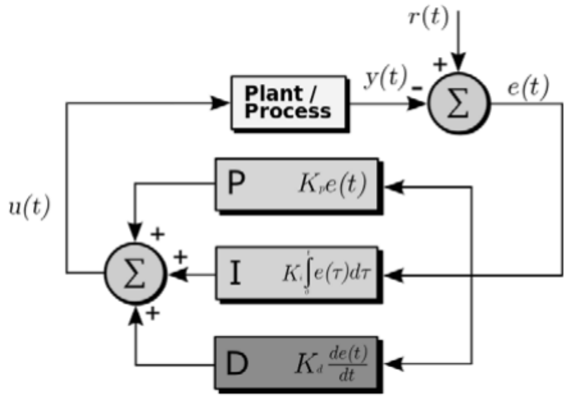
Two rubber weirs maintain the head pond at a constant level of 297.1 m with the provision to operate up to 298 m when the flows are high. The level is maintained by diverting river flow into the tunnel for power generation, spilling the water over the top of the rubber weirs by adjusting their pressure and in high flow conditions, releasing water through the sluice gate. The headpond level is measured in three different locations with the controller selecting the average of the two closest in value. In controlling head pond level the additional variable of rate of change must also be taken into consideration. With the large size of the head pond it takes time for the changes to alter the level. The control is done via a finely tuned PID loop that help compensate for over/undershoot.

The net effect is that the controller will maintain the level through ramping the units or changing the dam pressure at different rates depending on how far the level is from the setpoint and the rate at which the level is changing. For example, after a large rainstorm, the level would rise on the head pond quickly and the controller would respond by quickly raising generation and/or lower the dam pressure to spill more water. At other times if the head pond level is low but the level is rising quickly the controller may take no action. If it took action based solely on the low level, the pond level would overshoot to a higher level.

With two units at the plant that can operate in a couple of different modes, there are a number of different scenarios in which level will be controlled. In some cases both units will be available to be automatically ramped by the level controller. Other times one of the units will be held at a certain level or be offline making it

unavailable for ramping but the other unit will still be available. The final case is when both units are unavailable for ramping and the only remaining means to control the pond level is through the pressure of the weirs.

In general the controller can be explained in that it is a response to error. The larger the headpond level is from the set point of 297.1 m the quicker it will respond. This allows us to react quickly to fast changes such as a flood or disturbance from the upstream plant while also eliminating constant fluctuations from over-reacting to small changes in headpond level.




An example of the control loop is shown above. In this example the Plant process output would the signal to raise/lower generation or inflate/deflate the weirs.

Unit Modes of Operation
The two units are able to operate in three modes of operation: Automatic, Power and Manual.

Automatic is the most common mode of operation. In this mode, the unit output is controlled by the level controller to compensate for changes in head pond level. It will raise generation at allowable ramps rates as long as there is available spill. The unit will automatically start in this mode and sync to the grid if there is sufficient spill.

In Power Mode, the unit is held at a user inputted MW set point. The set point can be changed in 0.1 MW increments. The ramp rate is limited to an accepted river stage rate but can be overridden if necessary. The unit can be started and synchronized to the grid using this mode.

Manual Mode allows to the operator to control the actual wicketgate position which relates back to the MW output. The unit cannot be started in this mode.

Ramping
The ramping of the units must be done within an accepted river stage rate. This accepted river stage rate depends upon the total river flow at the current time and must be slow enough to not strand fish. Currently, the limit is dynamically calculated dependent on current river level. The rate is converted to a change in flow or cumecs per hour and then used in ramping the setpoint. Ramping is done in auto and power mode.

The ramp rates are in place during auto mode and power mode. They are ignored during the following situations:

- Manual Mode
- Ramp Rate Override Enabled

- Low Low Forebay Level
- Low Tunnel Level

HMI indication for each unit

- Current Mode
- Total Power Produced (MW) – the total power – should be close to the Ramped Power Setpoint above. It always trends toward the Ramped Power Setpoint.

HMI control for each unit

- Mode Selection: Auto, Power and Manual
- Power Mode Start – end the current ramp
- Power Mode Setpoint
- Stop Pushbutton

Rough Zone Avoidance
The rough zone is the speed at which the angular velocity of the water entering the turbine excites the natural frequency of the runners. When the speed reaches the runner's natural frequency, the turbine begins to resonate and the increased vibration puts large stress on the turbine. This has been improved by automatic air injection into the runners. Operation in the rough zone is to be avoided regardless during two unit operation.

- If both units are below rough zone with rising head pond level resulting in more generation being required, the primary unit will cross the rough zone and the secondary unit will drop a matching amount in load.
- If one unit is below the rough zone and the other unit is above the rough zone with rising head pond level resulting in more generation being required, the unit crosses the rough zone while the other unit drops and equal amount.
- If both units are above the rough zone with the head pond level dropping resulting in less generation being required then the secondary unit will cross the rough zone while the primary unit will increase load by an equal amount.
- If one unit above the rough zone and the other unit is below the rough zone and the forebay level is dropping resulting in less generation being required then the primary unit will drop below the rough zone and the other unit will increase load by an equal amount.

Wicket Gate Control
The wicket gates are used to control the flow of water to the turbine runners. The Francis type turbines at Mamquam have a total of 20 wicket gates per machine.

When the unit is offline the position of the wicket gates is used to vary the speed of the turbine. When the unit is online the wicket gate position will control the loading or output of the turbine. In Auto Mode the wicket gates are positioned by the PLC to match the demand from the head pond level. In Power Mode the position of the wicket gates is modulated according the desired output of the unit. The Wicket Gates control can also be placed into Manual and fixed at a percent open value entered by the operator in the HMI.

Low Tunnel Level
The tunnel is designed to be supported by the water in the tunnel and should the level drop too low too quickly the tunnel could collapse. Low tunnel level is detected by three methods:

- Forebay Level
- Tunnel differential pressure compensated for head loss and converted to a level.

- Scroll case differential pressure for the running unit compensated for head loss and converted to level.

All three have low alarms: the forebay level below 296.5 m and the tunnel levels below 294 m.

At low-low level there is a 2 out of 3 ramp down with the forebay below 295 m and the tunnel levels below 291 m. Two of them will initiate a ramp down of the running units (in Power or Auto Modes) at 10 cumecs per hour.

At low-low-low level there is a 2 out of 3 low-low-low unit trip with the forebay below 295 m and the tunnel levels below 265 m. Two of them will initiate a unit trip.

In the case of loss of communications to the Intake PLC, the tunnel pressures will still be active for a 2 out of 2 ramp down and trip.

It is critical to repair a failed tunnel pressure or scroll case pressure transducer as soon as possible, as it will be one out of 3 in the failed state.

#### 4.1.2 Daily Operating Procedures

***This section describes the daily operating procedures.***

DAILY CHECKS

The Daily Checks Form provides a list of items that the operator should check during the daily general site walk through. Any deviations from normal operating conditions should be documented and addressed as required. The following check sheet should be filled out and filed on site for future reference.

**Daily Plant Inspection for the week of ________________ 2014 to _____________________ 2014**

**Table 9 Daily Plant Inspection Chart**

| Inspection Location / Item | Mon | Tue | Wed | Thu | Fri | Sat | Sun |
|---|---|---|---|---|---|---|---|
| **Control Room** | | | | | | | |
| **Record in logs** | | | | | | | |
| • U1 & U2 output | | | | | | | |
| • Temperature & vibration | | | | | | | |
| • Seal flows-seal differential | | | | | | | |
| • Meter reading | | | | | | | |
| • Intake trashrack differential | | | | | | | |
| | | | | | | | |

| Inspection Location / Item | Mon | Tue | Wed | Thu | Fri | Sat | Sun |
|---|---|---|---|---|---|---|---|
| **Control Room** | | | | | | | |
| **Record in logs** | | | | | | | |
| • Strainer differential & flushing time | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| • Adjust strainer cycles according to river comp. | | | | | | | |
| • River level | | | | | | | |
| • Tailrace level | | | | | | | |
| • Seal water filter pressure differential | | | | | | | |
| • Oil levels U1 & U2 | | | | | | | |
| Comments | | | | | | | |
| **Generator Floor** | | | | | | | |
| • Inspect U1 & U2 brushgear for sparking & brushwear | | | | | | | |
| • Compressors 1 & 2 - filters & oil level | | | | | | | |
| • Thrust bearing oil recirculation | | | | | | | |
| ▪ Oil extraction drain valve-drain daily | | | | | | | |
| • Portable oil filtration cart | | | | | | | |
| Comments | | | | | | | |
| **Stator Floor** | | | | | | | |
| • Inspect stator rooms 1 & 2 | | | | | | | |
| • City water pressure (120 *psi*) | | | | | | | |
| • Auxiliary water strainers 3 & 4 - (no shaft seal leaks) adjust accordingly | | | | | | | |
| • Check Stator Rooms 1 & 2 for oil and water accumulations | | | | | | | |
| Comments | | | | | | | |
| **Turbine Floor** | | | | | | | |
| • HPU U1 & U2 | | | | | | | |
| Oil level | | | | | | | |
| Temperature | | | | | | | |
| Nitrogen Pressure | | | | | | | |
| Breather Desiccant | | | | | | | |
| • Oil mist extractor collection cans | | | | | | | |
| • Drain valves (open at all times) | | | | | | | |
| • Strainer Pit (no debris etc) | | | | | | | |
| • Ensure blower on for strainer pit if accessing | | | | | | | |
| • Manually backflush strainer U1 & U2 | | | | | | | |
| • Flush fire pump inlet elbow | | | | | | | |
| • Ensure "Y" strainer at 80 *psi* | | | | | | | |
| • Cooling water pump seal flow | | | | | | | |
| • Cooling water pump bearing temperature | | | | | | | |
| **Inspection Location / Item** | **Mon** | **Tue** | **Wed** | **Thu** | **Fri** | **Sat** | **Sun** |
| **Control Room** | | | | | | | |
| **Record in logs** | | | | | | | |
| **Turbine Floor** continued | | | | | | | |
| • Check strainers for excess water leakage & adjust seals | | | | | | | |
| • Check turbine pit for oil leaks | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| • Check shear pin air pressure | | | | | | | |
| Comments | | | | | | | |
| **TIV Floor** | | | | | | | |
| • Air pressure on airbags U1 & U2 seals (20 *psi)* | | | | | | | |
| • Seal water flow (80 *psi*) | | | | | | | |
| • Sump pump | | | | | | | |
| • Flush water seals | | | | | | | |
| • Primary oil skimmer (lower float daily to skim) | | | | | | | |
| • Secondary oil skimmer (belt not slipping or stopped) | | | | | | | |
| Comments | | | | | | | |

The Project shall operate as a run of river facility. This means part of the available river flow is diverted into the tunnel/penstock at the headwork's, through the plant for energy production, and then returned to the river at the powerhouse.

The minimum instream flow is released by a slide gate located downstream of the intake screen

The plant is staffed Monday to Friday during normal business hours. 1 operator is on call for all other times (evenings/weekends) via an auto-dialer system which calls the operator's cell phone. Normally the operator can be at site within ½ hour. The operator also has the ability to operate the plant from his home computer shortening reaction times

Notify BCTC at 604 455 1710 prior to starts after outages, and for special operating conditions (Guarantee of no re-closure, guarantee of isolation, etc.). This is a requirement for electrical power generation into the grid. As flow in the river is maintained at all times, unit starts and stops will not be reported for environmental purposes.

The balance of the river flow will be used for generation up to plant capacity. When the balance available for generation is below the minimum operating limit for the plant, the plant shall be shut down and the total river flow bypassed around the turbines or spilled at the weir.

When the inflow to the headpond exceeds the maximum plant flow and MRF, the plant shall operate at full capacity and the excess water will be spilled over the weir crest gate. The crest gate will be automatically adjusted down to maintain the headpond level at FSL.

The small headpond storage volume cannot be used for shaping energy output. Headpond storage within the level control deadband shall be used to buffer turbine-generator with respect to natural river flow fluctuations.

The plant is not required to be dispatchable, provide grid support, or operate in an isolated load state – output change rate will be a function of conveyance system pressure limits. This plant does not coordinate its output with other plants normally.

Power output change rate will be a function of natural river flow change rates, conveyance system pressure limits, and flow ramping requirements, whichever governs.

### 4.1.3 Start-Up Procedures

This section describes the manual and automatic start up procedures.

The plant is started up in a controlled safe manner following operating procedures MQ-OP-1 & 2. The procedure breaks the startup down into a number of steps summarized as follows:

1. Contact the Lower Mainland Control Centre (BCTC) to inform the system operator that the unit will be coming online. This is not required for starting the second unit.
2. Confirm that the oil levels to the Upper Guide, Lower Guide, Turbine Guide and the Thrust bearings are within normal limits.
3. Turn on the Cooling water to each of the three guide bearings to full. The cooling water to the Thrust bearing is set to 300 gpm. The water for the stator air coolers is set to 150 gpm. (40% open)
4. Confirm that the turbine brakes are in Auto, confirm that the forebay level is at 297.10m and that the Intake PLC is controlling the level in Auto.
5. Place the wicket gates, Turbine Inlet Valves(TIV) and Pressure Relief Valve (PRV) in Auto
6. Check that the turbine bearing temperatures as well as the stator cooling temperature are within acceptable limits. If necessary, adjust the flow to the stator cooling until the temperature is within limits ~45°C. Note the stator temperature will continue to rise for several hours after startup.
7. The unit is prepared to start. If the unit is in power mode press the start button otherwise place the unit in auto and it will start if there is sufficient water.
8. Check that the forebay level is above 297.1 m and that the air coolers and the stator cooler are within normal limits. The controls will automatically bring the machine up in load based on the head pond level. This will include going through the rough zone when enough water is available.

<u>Prerequisites for Unit Start</u>

1. Turbine Inlet Valve must be in auto mode.
2. Turbine brake must be in auto mode.
3. Shaft seal must be in auto mode or the seal close solenoid must be off and seal open sensor activated.
4. Cooling water variable speed drive must be in auto mode or running.
5. Air cooling water valve must be in auto mode.
6. Bearing cooling water valve must be in auto mode.
7. Hydraulic pump 1 or 2 must be in auto mode.
8. Wicket gate axis must be in auto mode.
9. Pressure relief valve axis must be in auto mode or closed.
10. Generator MCB must be in auto mode.
11. Transformer MCB must be in auto mode and closed.
12. Transformer isolating switch DTx and generator isolating switch DGx of the respective unit must be closed or transformer isolating switch DTx, generator isolating switch DGx and tie circuit breaker of the other unit must be closed.
13. An active shutdown must not be in progress

Unit Start

Unit start is a fully automatic procedure. When a start is requested, and providing the unit start prerequisites have been met, the controller will perform the following checks and functions.

1. Shaft seal is commanded to open.
2. Service seal is verified to be open.
3. Lubrication pump is started.
4. Cooling water variable frequency drive is started.
5. Air cooling water valve begins to regulate as necessary.
6. Bearing cooling water valve is opened.
7. Wicket gate is closed (should already be closed).
8. Turbine brake is released.
9. Pressure relief valve is ramped closed (held open at 3% after a unit shutdown).

Synchronization

Synchronization is a fully automatic procedure. When a start is requested, and providing the unit start prerequisites have been met, the unit will enter run mode by performing the following checks and functions.

1. Overhaul seal is verified to be open.
2. Shaft seal is verified to be open.
3. Service seal is verified to be open.
4. Lubrication system pressure is verified.
5. Head cover cooling water level is verified.
6. Discharge cooling water flow is verified.
7. Turbine, lower, upper and thrust bearing cooling water flow is verified.
8. Turbine brake release is verified.
9. Adequate penstock water elevation is verified.
10. Wicket gate closure is verified.
11. Pressure relief valve closure is verified.
12. Turbine inlet valve is opened.
13. Governor will ramp open the wicket gate using a PID loop to attain 60 Hertz. Wicket gate maximum position is limited during synchronization to mitigate the possibility of an over speed condition.
14. When the frequency, voltage and phase of the generator match the grid the Line Synchronization will initiate a generator main breaker closure.
15. Governor will ramp open the wicket gate using a PID loop to attain the target KW. Initial target following a successful synchronization will be the KW minimum setting.
16. Hydraulic system pressure is verified to be above 1100 PSI.

### 4.1.4 Shut-Down Procedures

This section provides the shut-down sequence and procedures for the following four scenarios.

#### *4.1.4.1* ***Normal Shutdown***

This section describes normal shutdown procedures.

In a normal shutdown the machine is brought offline and then to a full stop in a safe controlled manner with minimal impact to the river downstream of the powerhouse. During a shutdown the PRV ramps at the allowable ramp rates. Otherwise, the river would see drastic changes in water level if the flow was suddenly cutoff by shutoff the water from the turbine and the bypass at the same time. In a normal shutdown, the equipment operates in the following manner:

The “Stop” button on the Unit screen brings the unit down to the minimum setpoint in preparation for going offline. When at the minimum setpoint waterflow will be transferred to the PRV.

In a normal shutdown the operator follows at sequence to safely bring the unit to standstill in a controlled and safe manner. Plant procedures MQ-OP11 and 12 detail the steps in bringing a unit to safe stop, it can be summarized as follows:

1. The Lower Mainland Control Centre (BCTC) is contacted to inform the system operator that the unit will be coming offline.
2. The “Stop” button on the Unit screen brings the unit down to the minimum setpoint in preparation for going offline. When at the minimum setpoint waterflow will be transferred to the PRV.
3. The cooling water valves to the upper guide, lower guide, turbine guide and trust bearings should be closed. The water supply to the stator cooling water should be closed.

#### *4.1.4.2* ***Forced Outage***

This section describes shutdowns procedures associated with forced outages. A forced outage is associated with an unplanned, unscheduled outage that disrupts normal operation.

The same procedure as a normal shut down is followed

#### *4.1.4.3* ***Emergency Shutdown***

This section describes emergency shutdown procedures, including procedures for restarting the plant following satisfactory resolution of concerns. Emergency shutdown refers to plant shutdown under controlled conditions, i.e. vibration concerns, bearing temperature.

The same procedure as a normal shut down is followed, unless there is risk of human injury or major damage to plant equipment. If there is risk of injury or major equipment damage, the operator will hit the emergency shutdown (ESD) button for the unit or both units if necessary. This will initiate the immediate closing of the turbine inlet valve (TIV) which closes in 90 seconds. Once closed this valve stops all flow through the plant and will dewater the river below the plant.

A normal restart is always used to synchronize the plant online. Depending on the problem, plant MW output may be controlled in 1 MW steps as the unit ramps upwards.

#### *4.1.4.4 Long Term Outage*

This section describes shutdown procedures associated with long term outages. A long term outage is defined as an outage lasting more than four hours. It is typically associated with unplanned major equipment failures, scheduled maintenance, and/or extreme low-flow conditions.

The normal shut down procedure is used for long term outages. This leaves the generator ready for automatic restart if flows increase. If there is a scheduled outage for maintenance, a unit lockout is used to secure the unit for safety reasons

## 4.2 OPERATIONS

### 4.2.1 Headpond Filling and Flushing/Sediment Transport (sluicing)

Headpond sluicing is an annual fall event performed during periods of very high rain and river flows. Annual sluicing prevents excess build-up of sediment and must be completed annually. Inform the statutory decision maker (SDM) at MLFNRO and DFO region officer to inform them of planned sluicing. Since high river levels cannot be predicted in advance, provide the information in October and inform the regulators that sluicing will occur during the next high river event.

There are also other operational reasons to open the sluice gate. During high river flows and other storm events, flows can increase to the point where even deflating the weirs will not allow enough flow through the intake and cause head pond levels to be dangerously high. The sluice gate is designed to be opened during these flood events to prevent overflow of the intake structure with potential catastrophic damage. The sluice gate can flow 200+ CMS.

In addition, occasionally large trees/logs and other debris finds its way into the sluiceway and can damage trash rack cleaning equipment and plug the intake screens. This typically happens during high flow events. Opening the sluice gate is the only way to flush out these objects.

Before initiating sluicing, river flows must be above 80 cubic meters/second (CMS). This normally indicates extreme turbidity approaching 6000 NTU's as measured on the downstream of intake turbidity meter. The meter maxes out at 6000 NTU. In addition, at flows above 50 CMS the river is bank full with no chance of fish stranding. Duration of headpond sluicing and turbidity levels prior to and during will be included in the annual compliance report.

Steps to follow:

**1** Take plant offline. Be certain to keep downstream of powerhouse flows above 50 CMS at all times to allow for unlimited ramping.

**2** To initiate sluicing, crack open the sluice gate either manually at the gate, or through the HMI. Watch for an immediate increase in turbidity downstream upon opening the sluice gate through the intake camera or in person.

**3** Ensure that there is no sediment plume. If the sediment released is darker than the existing river flows close the sluice gate sufficiently until it is the same color as the water overtopping the weirs.

**4** Slowly and incrementally open the sluice gate allowing more and more water to flush away accumulated sediment, always being mindful not to increase sediment transport above the existing river flows. This can be determined by comparing the color of the water as noted above. Since the turbidity meter is pegged at 10000 NTU turbidity is not measured.

**5** At some point all water will flow through the sluice gate which will transport all sediment in the sluice way downstream. The sediment in the sluiceway is mostly sand.

**6** Depending on river flows the head pond level will drop. Conduct a fish stranding search by the sand bar upstream of the intake on the south side of the river. If any fish are found return them to the river.

**7** Deflate the south weir slowly. Using the same procedure for the sluice gate watch for excess sedimentation release and re-inflate as necessary. Normally the head pond has less sedimentation than the sluice way and the release consists mostly of gravels and larger rocks.

**8** Once the south weir is fully deflated, slowly close the sluice gate which will transfer the water flow from the sluice way to the south weir. Keep an eye on sedimentation release through this process and re-inflate the weir to control release as necessary.

**9** Once the sluice gate is fully closed all flow is going through the south weir. Maintain this flow until all noticeable sediment transfer is complete.

**10** Deflate the north weir, again watching for excess sedimentation release. Inflate as necessary to control the release.

**11** Once the north weir is fully deflated, start inflating the south weir to transfer all the flow though the north weir. Keep an eye on sedimentation release through this process and re-inflate the weir to control release as necessary.

**12** Once all flow is going through the north weir, maintain this flow until all noticeable sediment transfer is complete.

**13** Once observed sediment release tapers to nil, the sluicing process is complete.

**14** Initiate the head pond refill program on the HMI. This program slowly inflates the weirs until normal head pond elevation is complete at the allowable ramp rate. Always check to ensure there is 50+ cms flow downstream of the intake to ensure downstream fish are not stranded

**15** Restart plant.

**16** Record date and duration of flushing event, and turbidity readings before during and after flushing from the downstream turbidity gauge.

#### 4.2.2 Intake Water Level Management

This section describes how headpond water level is being recorded and managed below and above full plant capacity.

During normal operations the headpond level is 297.1 meters of elevation above sea level. There are 3 level gauges in the head pond, 3 level gauges in the sluice way, and 3 level gauges downstream of the intake screen in the forebay.

The intake PLC monitors intake levels. If the level starts to rise, unit output is increased to maintain 297.1 meters of elevation. If the intake level starts to decrease, unit output is decreased to maintain 297.1. The second unit can be automatically started and stopped based upon intake level conditions.

Once both units are at full production, the intake weirs deflate slightly to initiate spill from the intake which maintains head pond level control.

### 4.2.3 Water Conveyance Filling

#### 4.2.3.1 *Filling/pressurizing of water conveyance system*

This section describes the procedures for filling and pressurizing the water conveyance system and assumes the head pond is fully drained.

If the tunnel and penstock (water conveyance system) are drained for maintenance, these are the steps for refilling:

- *Install stop logs. The stop log with the 3 valves goes in first at the bottom. The other stop logs stack on top. Install all stop logs.*
- *Start the automated intake fill program on the HMI which fills the intake at the correct ramp rate. Fill the head pond to normal elevation of 297.1 meters of elevation*
- *Manually open the valves in the bottom stop log one at a time. Ensure that spill over the weirs being ramped downwards doesn't exceed the allowable ramp rate of depending on river flows.*
  - *<10cms – 7.5 cm/hr,*
  - *>10 < 24cms 19.9cm/hr*
  - *>24cms unrestricted*
- *The maximum allowable rate of fill in the tunnel is 10 meters of elevation per hour.*

### 4.2.4 Flood Handling

The head works are designed to pass the inflow design flood (IDF) without sustaining significant rebuild- type damage.

| | |
|---|---|
| ***Inflow design Flood:*** | ***600 $m^3/s$ instantaneous peak inflow Annual*** |
| ***Exceedance Probability:*** | ***Designed for 1 in 500 year flood*** |

The plant is designed for a one in 500 year flood event and flows to 600CMS. Increasing flows will cause the weirs to deflate. With the 2 weirs fully deflated, 200 CMS can flow through each weir channel. The sluice gate can fully open allowing another 200 CMS capability if necessary.

#### 4.2.5 Debris Management

This section describes how organic and woody debris will be accommodated and handled:

A dual cleaning head, automated trash rake is installed on the intake screen. When measured differential across the screen exceeds the designated set point, the trash rakes are automatically started. They rake the intake screen and pull leaves and woody debris to the surface and dump the debris onto the intake deck.

On an as required basis, the debris is stock piled at the end of the intake deck. It is then loaded into a trailer and dumped into the woods along the intake road where it serves as biomass material as it decomposes.

### 4.3 MAINTENANCE AND INSPECTION PROGRAM

The plant has a computerized maintenance management system (CMMS). The plant employs certified millwrights and electricians who follow the CMMS requirements to ensure the plant is properly maintained as per schedule. For larger projects, outside contractors are utilized.

There are daily, weekly, and monthly inspections and all checklist information is recorded. In addition there is a requirement for an annual civil engineer led dam inspection, and an annual third party engineering inspection of all plant equipment. The annual third party engineering inspection consists of three professional engineers in the mechanical, civil, and electrical disciplines.

They submit a report to the plant manager who then must submit the report by month end February to BC Hydro.

#### 4.3.1 Diversion Structures

##### *4.3.1.1* ***Weekly Inspections***

To ensure integrity of the structures, weekly inspections of the following equipment and structures are conducted by Atlantic Power staff. The weekly inspections include:

## WEEKLY INSPECTION CHECKLIST

**Table 10 Weekly Inspection Checklist**

| Inspection Location / Item | Checked | Comments |
|---|---|---|
| **Generator Floor** | | |
| • *Portable filter cart to alternate bearing-Indicated weekly change. Switched to:* | UGB<br>LGB | |
| • *Turbine thrust bearing stationary oil filtration unit-switch weekly if both units running* | | |
| • *Check HVAC system for proper operation* | | |
| **Yard** | | |
| • *Test backup generator for powerhouse (1/2 hr)* | | |
| • *Check building structure for structural integrity & security* | | |
| • *Check fence line integrity* | | |
| • *Check and record fuel level on diesel generator* | | |
| • *Check Transformer yard oil & temperature gauges* | T1 Oil Level<br>T1 Oil Temp<br>T1 Winding Temp | T2 Oil Level<br>T2 Oil Temp<br>T1 Winding Temp |
| • *Run fire pump* | | |
| • *Check deluge valves* | | |
| **Intake** | | |
| • *Riparian bypass gate measurement 89 5/16”* | | |
| • *Check and record fuel level on diesel generator* | | |
| • *Run intake diesel generator 30 min.* | | |
| • *Check radial gate for leaks* | | |
| • *Inspect weirs for leaks or damage* | | |
| • *Check HVAC system for proper operation* | | |
| • *Perform radio/phone check* | | |
| • *Clean Trashrack* | | |
| • *Check building structure for structural integrity & security* | | |
| • *Check fence line integrity* | | |

#### *4.3.1.2 Annual Inspections*

Annual inspections are conducted by a third party engineering firm. Knight Piesold has been retained for the past several years.

The annual inspection occurs in February, with the report submission to BC Hydro by March 1st. The engineering team employs civil, electrical and mechanical engineers to review all aspects of the site.

#### 4.3.1.3 Dam Safety Inspections and Activities

This section provides details on the dam safety inspections and activities. The status of the dam is regulated and the dam failure consequence classification is Low as defined in BC DSR 44/2000 and as verified by the Dam Safety Officer.

The Dam safety inspections and activities will be performed according to the schedule (annually) for each activity as itemized in Table 11.

**Table 11 Frequency of Dam Safety Inspections and Activities**

| Item | Activity | Frequency |
|---|---|---|
| 1 | Site surveillance | Quarterly |
| 2 | Formal inspection | Annually |
| 3 | Monitor instrumentation | As requested by the dam safety officer |
| 4 | Test operation of outlet facilities, spillway gates and other mechanical components | Annually |
| 5 | ***Update the emergency contact information in the EPP*** | Not Applicable |
| 6 | ***Review, and revise if necessary, the OMS manual and the EPP*** | Not applicable |
| 7 | ***Conduct dam safety review and submit dam safety report*** | Not applicable |
| 8 | ***Review downstream conditions, as set out in section 6.1 of BC DSR 44/2000, and notify a dam safety officer of any change in classification*** | Annually |

#### 4.3.1.4 Seepage Monitoring

Seepage Monitoring is conducted as part of the semi-annual inspection by. The plant maintenance staff inspect the dam in February and a civil engineer formally inspects the dam in September. The margins of the dam are inspected, as well as the downstream toe.

#### *4.3.1.5* ***Maintenance***

The plant has a CMMS system covering all aspects of plant maintenance. Some maintenance items are performed on an hourly or calendar basis. Other items are maintained on a predictive maintenance philosophy (higher vibration, temperatures, etc.)

### 4.3.2 Water Conveyance System

This section describes the maintenance and inspection program for the various components associated with the Tunnel.
The water conveyance system consists of the trash rake, intake screen, tunnel, penstock, and turbine inlet valve.

#### *4.3.2.1* ***Trash Rake***

The trash rake is visually inspected weekly to ensure proper operation. On an annual basis a more detailed inspection is performed (hydraulic oil levels checked, filters changed, lubricated, any adjustments to the range of operations, etc.)

#### *4.3.2.2* ***Intake screen***

The intake screen is visually inspected once per year when the head pond is lowered during sluicing operations. Normally no maintenance is required

#### *4.3.2.3* ***Tunnel***

Historically the tunnel has been inspected every 5 years. Normal maintenance includes cleaning material out of the two rock traps, and visual inspection of the tunnel rock and tunnel plug area.

#### *4.3.2.4* ***Penstock***

The penstock is now inspected annually on the exterior, and every 5 years on the interior. Maintenance staff look for corrosion, pitting, and security.

#### *4.3.2.5* ***Turbine Inlet Valve***

The TIV's are visually inspected annually. Leakage, corrosion, seal filters, cavity flushes and correct operation are normal inspection points.

### 4.3.3 Powerhouse Civil Works

No specific inspection is done on the powerhouse civil works. However any issues noted in day to day operations are reported and repaired if necessary

#### 4.3.4 Tailrace

The tail race equipment is inspected annually. The tail race crane, draft tube stop log, and PRV isolation gates operators are inspected to ensure proper operation

#### 4.3.5 Access Roads

The plant and intake access roads are inspected annually. Grading, tree pruning, ditching, etc. are performed on an as required basis.

#### 4.3.6 Turbines/Generators

The turbines and generators are monitored through the plant PLC's /HMI,s, and are visually inspected on a daily basis. Most maintenance is performed on as required basis with requirements noted on the HMI's (high differentials, high temperatures, etc.). The brush gear is tested weekly, the turbine wet end components (runner, wicket gates, etc.) are inspected annually, and the generators are inspected bi-annually by GE.

#### 4.3.7 Energy Dissipation System

The PRV's (pressure reducing valves) are visually inspected weekly, and after every load rejection. Annually a more in depth inspection is performed that includes the hydraulic system (servo's, intensifiers, filters, piping and hoses) as well as mechanical systems.

#### 4.3.8 Mechanical & Hydraulic Systems

The mechanical and hydraulic systems are inspected daily during the operator rounds. Depending on the equipment, maintenance is performed annually or on an hourly basis and includes filter changes, lubrication, and component replacement

#### 4.3.9 Back-up System

The plant back up diesel generators are tested weekly for proper operation and maintained annually (oil, filter changes, adjusting valves, testing glycol for proper additives, etc.) or as required. The plant UPS (uninterruptable power system) systems are inspected annually or as required. UPS batteries are replaced at the following frequencies:
Communications UPS – 3 years,
Intake UPS– 5 years,
Powerhouse main station UPS – 10 years

#### 4.3.10 Controls and Protection

Protective relays are serviced by outside contractors every three years. The plant PLC cabinets are cleaned on an annual basis.

#### 4.3.11 Switchyard and Substations

The transmission line is inspected annually and brushing or repairs are completed on an as required basis. Pruning is conducted with a qualified electrical worker or a certified utility arborist to ensure safe distances are maintained

The high voltage switch gear and plant substation is serviced by outside contractors every three years. Maintenance consists of checking for proper operation and repairing if necessary, cleaning, and lubricating of equipment.

### 4.4 TROUBLESHOOTING AND REPAIR

### 4.5 REPORTING REQUIREMENTS

This section provides a list of annual operational reporting requirements and commitments.

**Table 12 List of annual operational reporting requirements**

| Report | Author | Submit To | Submission Date |
|---|---|---|---|
| Third party Engineering Inspection | External Engineer | BC Hydro | *March 1* |
| 5 year Environmental Monitoring Plan (OEMP) | External Monitor | DFO,MLFNRO | December 31 2011-2015 |

# Section 5.0 - OPERATING STAFF

### 5.1 STAFFING LEVELS

The plant is currently staffed with a plant manager and a plant administrator, as well as one certified electrician and two certified millwrights. The Electrician and Millwrights also operate the plant as necessary. Plant staff normally work Monday to Friday 8 hours per day during normal business hours. During the off hours and weekends one operator is always on call on a rotating basis.

### 5.2 TRAINING

The plant has a detailed annual training plan for health, environment and safety. Typically 20 in-house or outside training courses per year are completed annually as required by corporate policy or regulatory agencies. On the job mentoring is performed by experienced operators to less experienced workers, and procedures have been developed for more complicated processes. Each new hire required is required to go through a thorough corporate orientation.

### 5.3 SAFETY

Safety is addressed by monthly safety meetings, and weekly safety inspections. There is an annual plant safety audit to ensure the plant is up to current regulatory standards. Plant visitors and contractors are required to go through a thorough corporate orientation as well as a site specific orientation. All contract work requires a safe work plan before starting work and daily tail gates talks with all details recorded

# Section 6.0 - SAFETY PROCEDURES

## 6.1 EMERGENCIES

### 6.1.1 General

An emergency may be potential, imminent or realized failure of some component of the Project. This section provides details on how to respond to potential emergencies, such that personnel can be prepared in the remote chance that such a situation does occur.

*Emergency numbers:*

**Table 13 Emergency Numbers**

| Mamquam Emergency Telephone List<br>Powerhouse 604 898 2761 Intake 604 898 1736 | | |
|---|---|---|
| **Contact** | **Phone Number** | **Emergency Type** |
| Connections Call Centre | **604 815 6090** | Working Alone |
| **Ambulance** | 911 | Medical Emergency |
| BCTC | **1 604 455 1710** | Outage/Isolation |
| **Fire** | 911 | Fire |
| Hospital - Squamish | **604 892 5211** | Medical Emergency Alert |
| **RCMP** | 911 | Security |
| Hazco | **1 800 327 7455** | Spill Response |
| **Plant & Atlantic Power Contacts** | **Cell** | **Home** |

| | | |
|---|---|---|
| Marc Nering | s.22 | |
| David Carlin | | |
| David Griffioen | | |
| Wayne Moffatt | | |
| Elspeth Miller | | |
| Mike Rafferty | | |

| Contact | Phone Number | |
|---|---|---|
| Pete Convery - VP Western Operations | s.22 | Work 617 977 8231 |
| Terry Shannon - EHS | | |
| **Other** | **Cell** | **Other** |
| PLC Support- Brad Ingram<br>-Ken Hanson | s.22 | Work 604 210 9617 |
| **Regulatory Agencies** | **Phone Number** | **Emergency Type** |
| Fisheries & Oceans | 1 800 465 4336 | Fishery Regulation Reporting |
| Ministry of Environment | 1 250 387 1161<br>1 800 663 9453 | Regulatory Issue Reporting<br>Dangerous Wildlife |
| Transport Canada (TDG) | 1 613 996 6666 | Emergency Involving Dangerous Goods |
| WorkSafe BC M-F 8:30-4:30<br>After Hours | 1 888 621 7233<br>1 866 922 4357 | Serious Injury or Fatality Reporting |

**Emergency contacts In the case of a dam failure:**

***Provincial Emergency Program*** *http://embc.gov.bc.ca/em/index.html*

***Water Management Branch*** *http://www.pep.bc.ca*

***Dam Safety Branch*** ***1-800-663-3456***

### 6.1.2 Notification

## 24 Hour Access Telephone Numbers

The following is a list of 24 hour telephone numbers that may be applicable for the activation of the emergency plan. The site's emergency plan administrator is responsible for maintaining this list.

***Telephone numbers in this emergency response plan must be reviewed every 6 months***

**Table 14 Mamquam Generating Station Internal Contact Numbers - 24 HRS**

| Mamquam Generating Station<br>1 604 898 2761<br>39241 Powerhouse Springs Rd, Squamish, BC<br>Intake | | |
|---|---|---|
| **Internal Contacts** | **Type of Emergency** | **Phone Number** |
| Connections Call Centre<br>**24 Hours** | As Indicated in Procedures | 604-815-6090 |
| **Plant Manager**<br>Marc Nering | All | Work: 604 898 2761<br>Cell: s.22<br>Home: |
| **Plant Operators:**<br>David Carlin<br>David Griffioen<br>Wayne Moffatt<br>Mike Rafferty | As Needed | s.22<br>Cell:<br>Cell:<br>Cell:<br>Cell: |
| **Senior Advisor, Health & Safety**<br>Vacant | Occupational Health & Safety & Environment | Cell<br>Home: |
| **Environmental Health & Safety**<br>Terry Shannon | Environmental spills, releases, permit violations | Work 1 858 492 5484<br>Cell: s.22 |
| **VP, Operations - West**<br>Pete Convery | As per notification guidelines | Work 1 617 977 8231<br>Cell: s.22 |
| **COO**<br>Ned Hall | As per notification guidelines | Work 1 617 977 8230<br>Cell s.22 |
| **Human Resources:**<br>Erica Ryan | | Work: 1 617 977 2495<br>Cell: s.22 |
| **Information Technology**<br>Manny Reyes | | Work: 1 630 427 6436<br>Cell: s.22 |
| **Computer Support – Helpdesk** | Computers | 1 877 832 3695 |

#### 6.1.3 Emergency Conditions and Response

This section describes emergency events and necessary course of action (response). Emergencies are defined as unusual situations that can lead to one or more significant consequences. A list of potential emergencies and appropriate responses is provided in Table 15.

**Table 15 Potential Emergencies and Response**

| Event | Response |
|---|---|
| Excessive leakage at diversion structures | Call plant manager<br>Plant manager to determine next actions |
| Movement or severe cracking of concrete diversion structures | Report to Dam safety officer.<br>If necessary, start to gradually lower head pond |
| Rupture of penstock, surge tank or tunnel | Call<br>Provincial Emergency Program<br>http://embc.gov.bc.ca/em/index.html<br><br>Water Management Branch http://www.pep.bc.ca<br><br>Dam Safety Branch 1-800-663-3456 |
| Equipment Fire/explosion | Squamish Fire Department (911) |
| Forest Fire | 911 |

#### 6.1.4 Loss of Control or Failure of the Works

Procedures are located in the Operations Manual, with additional information within the Operations, Maintenance and Surveillance (OMS) Manual .

**NOTE**: In the event that the works are damaged or operation controls are damaged and non-functional, the operator must contact the FLNRO Regional Water Manager within 24 hours.

In the event that the works are damaged, or operational controls are damaged as to be non-functional, The Lower Mamquam Hydroelectric project shall contact the Regional Water Manager [Remko Rosenbloom @ 604 586 5629 within 24 hours (see Section 6.1.2).

The Lower Mamquam Hydroelectric project provides the following commitment:

”if the loss of control or failure of the works increases the potential for additional damage, or become potentially hazardous to public safety, the licensee or his operators shall contact the RWM, the Regional Dam Safety Officer and the Provincial Emergency Program within Emergency Management British Columbia (PEP-EMBC) within 24 hours, The incident report shall clearly state that there has been a failure of the works, or that operational controls for the facility have been damaged, and what emergency procedures are underway”.

### 6.2 WARNING SYSTEMS

***This section describes the safety measures and procedures required and committed to, to ensure public safety including navigational safety, warning systems, or other.***

An air powered fog horn at both the intake and the powerhouse provides a very loud audible warning to recreational users of the river to warn them of possible changes in river flow. These devices are tested annually

# Section 7.0 - KEY CONTACTS

### 7.1 PROJECT OWNERS

Table 16 provides the key contact information for the Project owners.

**Table 16 Contact Information for Project Owners**

| Title | Name | Contact Numbers |
|---|---|---|
| Vice-President Operations | Pete Convery | Work: 617 977 8231<br>Cell: s.22 |
| Environmental | Terry Shannon | Work: 858 492 5484<br>Cell: s.22 |
| Safety | Roger Bresden | Work: 250 586 7788<br>Cell: s.22 |

## 7.2 PROJECT OPERATORS

Table 17 provides contact details for the key Project operational staff.

[Table 14 should provide contact information for:

- Plant control room;
- Plant Operators; and
- Operations Manager (if available).]

**Table 17 Contact Information for Project Operators**

| Title | Name | Contact Numbers |
|---|---|---|
| Control Room | Operations | 604 898 2761 |
| Plant Manager | Marc Nering | Work: 604 898 2761<br>Cell: s.22 |
| Plant Foreman | Dave Griffioen | Work: 604 898 2761<br>Cel s.22 |
| Operator | Dave Carlin | Work: 604 898 2761<br>Cell s.22 |
| Operator | Wayne Moffatt | Work: 604 898 2761<br>Cell: s.22 |
| Plant Administrator | Elspeth Miller | Work: 604 898 2761<br>Cell s.22 |

## 7.3 PROVINCIAL AND FEDERAL AGENCIES

**Table 18 Contact Information for provincial and federal agencies**

| Title | Name | Contact Numbers |
|---|---|---|
| FLNRO Regional SDM | Remko Rosenbloom | 604 586 5629 |
| FLNRO Regional Dam Safety Officer | Mike Bristol | 604 582 5200 |
| DFO | Murray Manson | 604 666 0129 |

7.4 **OTHER STAKEHOLDERS**

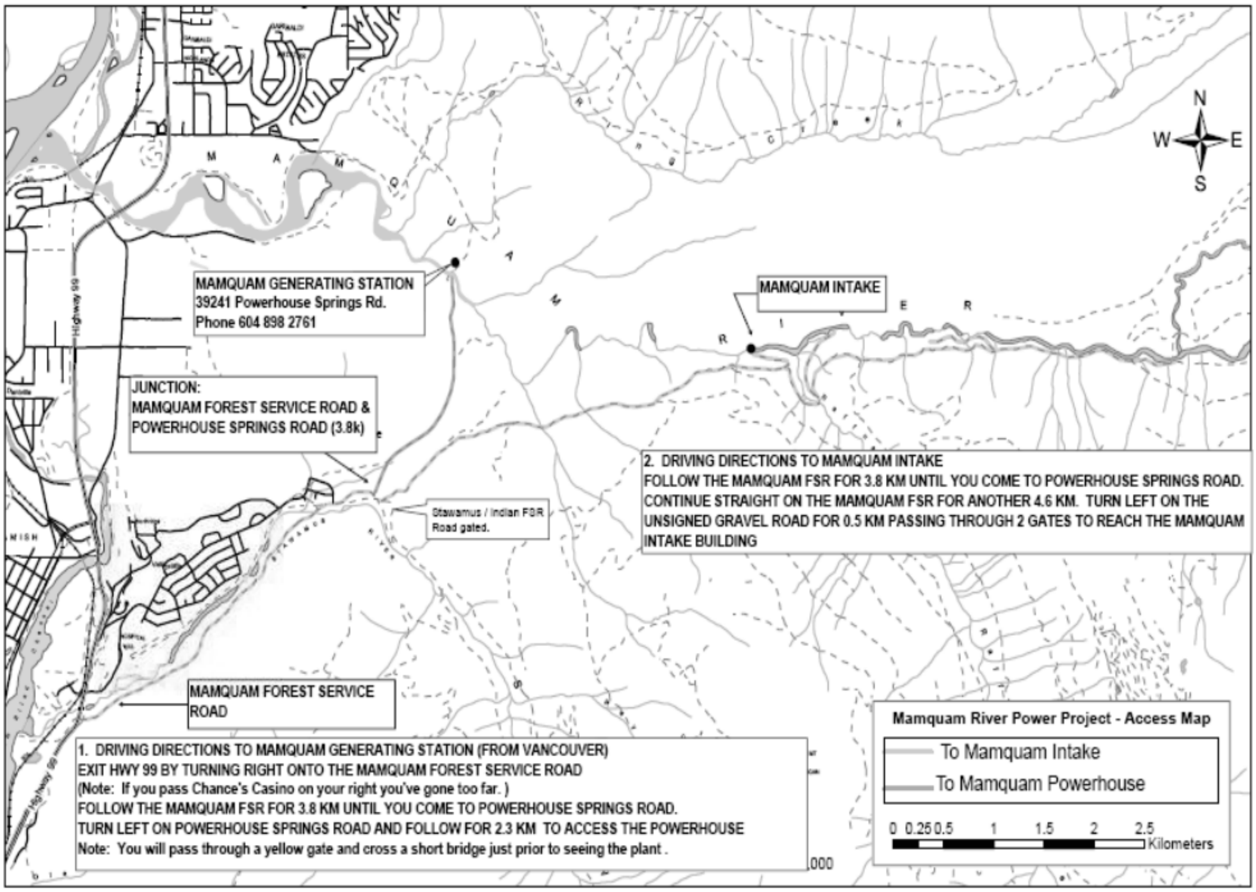
Table 19 provides the key contact information for the key Project operational staff.

**Table 19 Contact Information for Other Stakeholders**

| Stakeholder Name & Contact Title | Name | Contact Numbers |
|---|---|---|
| Upper Mamquam Hydroelectric | Sal Luengo | Work: 604 898 8297<br>Cell: s.22 |
| District of Squamish Public Works | Foreman | Work: 604 815 6868 |
| Skookum Creek Power | Steve McKay | Cell s.22 |

# APPENDICES

## Appendix A – General Access Map



TransAlta    AtlanticPower Corporation    SKOOKUM CREEK POWER PROJECT

# Appendix B River Gauging Locations

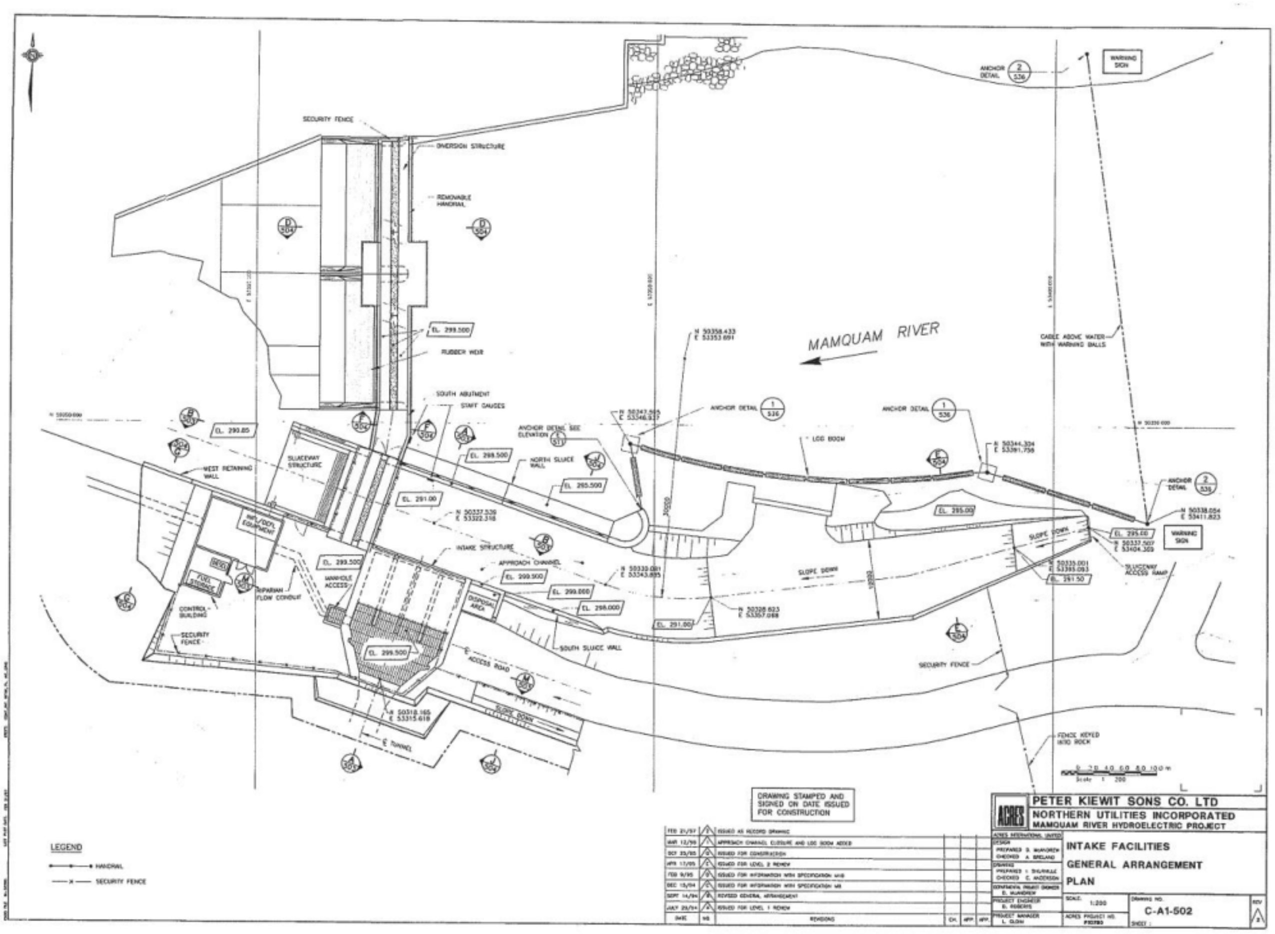
Lower Mamquam Hydroelectric Project Year 3 Flow Monitoring Report    Page 2

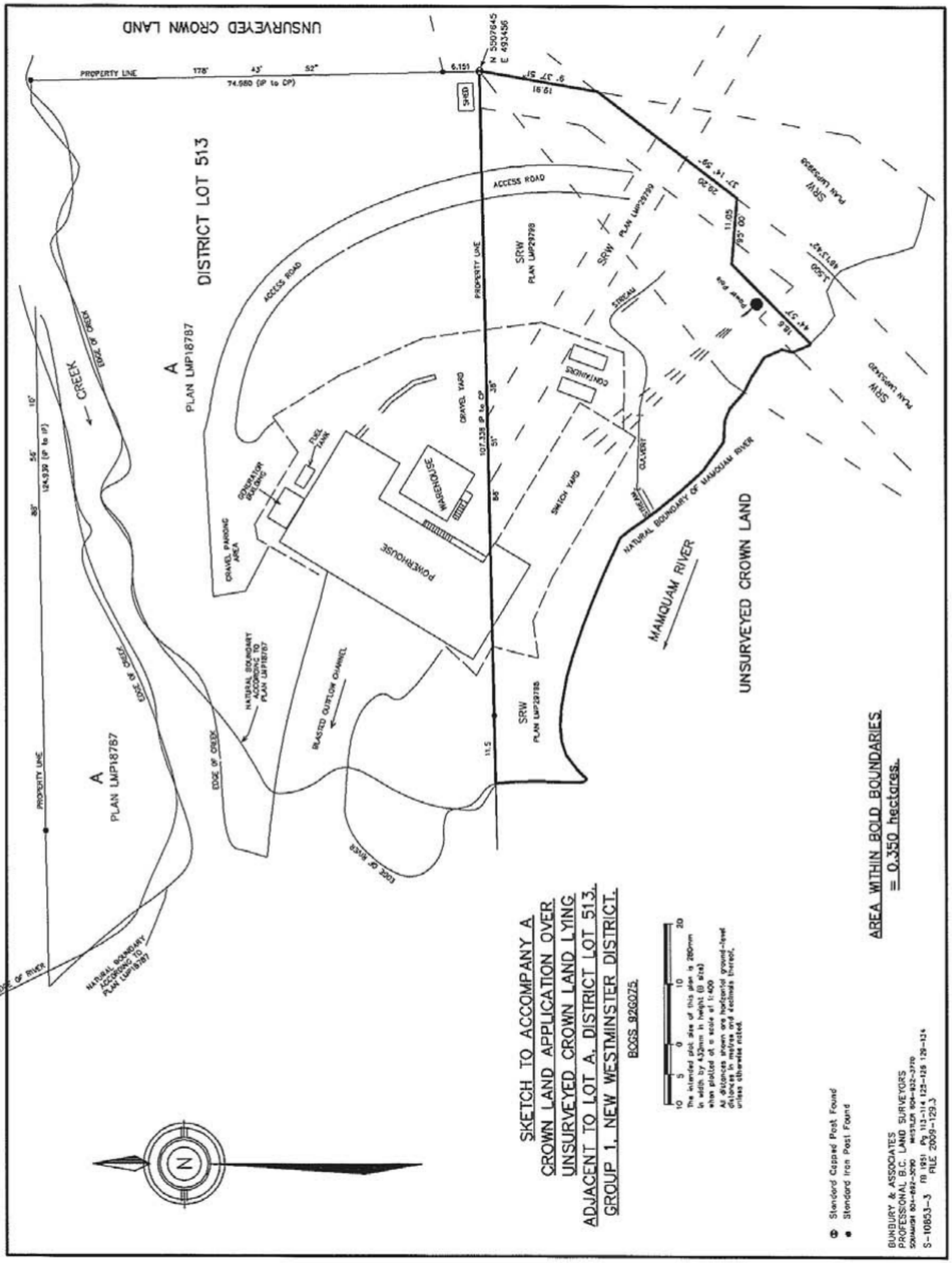
**Map 1.** **Location of the Lower Mamquam River Hydroelectric Project, showing project infrastructure and gauging stations.**


1071-07    ECOFISH RESEARCH

# Appendix C – General

# Arrangement Drawings




UNSURVEYED CROWN LAND
PROPERTY LINE
DISTRICT LOT 513
A
PLAN LMP18787
CREEK
ACCESS ROAD
SRW
POWERHOUSE
SWITCH YARD
CONTAINERS
GRAVEL YARD
EDGE OF CREEK
EDGE OF RIVER
MAMQUAM RIVER
UNSURVEYED CROWN LAND
AREA WITHIN BOLD BOUNDARIES
= 0.350 hectares.
SKETCH TO ACCOMPANY A
CROWN LAND APPLICATION OVER
UNSURVEYED CROWN LAND LYING
ADJACENT TO LOT A, DISTRICT LOT 513,
GROUP 1, NEW WESTMINSTER DISTRICT.
BCGS 92G075
Standard Capped Post Found
Standard Iron Post Found
BUNBURY & ASSOCIATES
PROFESSIONAL B.C. LAND SURVEYORS
S-10853-3
FILE 2009-129.3

In

## Appendix D – Conditional Water License

TransAlta AtlanticPower Corporation SKOOKUM CREEK POWER PROJECT

BRITISH COLUMBIA
The Best Place on Earth

March 5, 2009 File: 2003040

Coastal Rivers Power Limited Partnership
c/o Kelly Lail, Regional Director
EPCOR Power L.P.
215 – 10451 Shellbridge Way
Richmond, BC V6X 2W8

Dear Mr. Lail:

**Re: Conditional Water Licence 123692 on Mamquam River**

Enclosed please find a copy of Conditional Water Licence 123692. Please make careful note of its conditions. Any error in the licence should be brought to the attention of the issuing office as soon as possible.

If additional fees are required, you will be advised by our Victoria office, in due course.

You are hereby informed that the Water Act does not guarantee quality or quantity of water.

Please note the following:

1. Water licences do not authorize entry on privately owned land for the construction of works. Permission of the affected landowner must be obtained or an easement expropriated. For your protection, permission should be in writing and registered with the appropriate Land Title Office.

2. Permission for crossing roads or lands under the jurisdiction of any Government agency must be obtained from the agency concerned.

3. In order for you to keep your water licence in good standing, the following must be observed:
   a) continued beneficial use of water, as authorized under your licence;
   b) payment of annual rentals;
   c) compliance with the terms of your licence;
   d) compliance with the terms of the Water Act.

Ministry of Environment
Water Stewardship Division
Management & Standards Branch
Mailing Address/Location
10470 – 152nd Street, 2nd Floor
Surrey BC V3R 0Y3
Telephone: 604-582-5200
Fax: 604-582-5235
Web Address:
http:\\www.env.gov.bc.ca

4. In order to protect your interests, please notify the Regional Water Manager, in the event of any of the following:
   a) there is any change in your mailing address;
   b) you sell the land to which the licence is appurtenant;
   c) you propose to subdivide the land to which the licence is appurtenant; and/or
   d) you propose to alter the works authorized under the licence.

5. In accordance with condition (j) of your license, an In-stream Flow monitoring program and Operational Environmental Monitoring Plan shall be submitted to and approved by the Ministry of Environment within 6 months of the date of this letter (September 5, 2009).

You have the right to appeal this decision to the Environmental Appeal Board. Notice of any appeal must (1) be in writing, (2) include grounds for the appeal, (3) be directed by registered mail or personally delivered to the Chair, Environmental Appeal Board, 4th Floor, 747 Fort Street, Victoria BC V8W 9V1, (4) be delivered within 30 days from the date notice of the decision is given, and (5) be accompanied by a fee of $25.00, payable to the Minister of Finance and Corporate Relations.

If you have any questions or concerns please contact the Portfolio Administrator, Water Stewardship Division, at 604-582-5200.

Yours truly,

Julia Berardinucci

Julia Berardinucci
Regional Water Manager

Enclosure

pc: Water Revenue, Ministry of Environment, Victoria

06/01JUN 01 '94 04:55PM Q C POWER CORP P.2

WATER MANAGEMENT DIVISION

MINISTRY OF ENVIRONMENT, LANDS AND PARKS

THE PROVINCE OF BRITISH COLUMBIA—WATER ACT

# CONDITIONAL WATER LICENCE

The owners of the land to which this licence is appurtenant are hereby authorized to divert and use water as follows:

(a) The stream on which the rights are granted is Mamquam River.

(b) The point of diversion is located as shown on the attached plan.

(c) The date from which this licence shall have precedence is May 26, 1994.

(d) The purpose for which this licence is issued is power (general).

(e) The maximum quantity of water which may be diverted is 23.45 cms (828.1 cfs) for use in a powerplant with an authorized capacity of 50 MW, subject to a water reserve established by Order in Council No. 0714 dated, May 25, 1994.

(f) The water may be used throughout the whole year.

(g) The land within which the water is to be diverted and to which this licence is appurtenant is the intake site situated on that parcel of land in the vicinity of Raffuse Creek held under Licence of Occupation No. 235520 on Lands file 2406037. The water is to be used for the power undertaking of the licensee.

(h) The works authorized to be constructed are diversion weir, intake structure, stream gauges, tunnel, powerhouse, tailrace, transmission works, access roads and bridge, which shall be located approximately as shown on the attached plan. Works shall be installed to measure and record the flow of water diverted under this licence and instream flow in the Mamquam River immediately below the point of diversion.

(i) The construction of the said works shall be completed and the water beneficially used prior to the 31st day of December, 1997. Thereafter, the licensee shall continue to make a regular beneficial use of water in the manner authorized herein.

(j) Design plans for the works authorized by this licence must be prepared by a professional engineer registered in British Columbia and submitted to the Comptroller of Water Rights.

(k) Construction of the works authorized shall not be commenced until leave is given in writing by the Comptroller of Water Rights.

(l) An interim Operation Plan must be submitted to and leave in writing received from the Comptroller of Water Rights for interim commissioning of the powerplant prior to start-up of power production.

(m) As-built drawings must be submitted to the Comptroller of Water Rights within one year of interim commissioning.

(n) Within two years of interim commissioning an Operation and Maintenance Plan must be submitted to and leave in writing received from the Comptroller of Water Rights prior to final commissioning of the powerplant.

J. E. Farrell
Deputy Comptroller of Water Rights

File No. 2000966 Date issued: May 26, 1994 Conditional Licence 102850

## Appendix E – 5 Year Environmental Monitoring Program

Included with Hard Copy due to length

### Appendix F – Ramping Parameters

Table 23. Recommended ramping rates for the Lower Mamquam Hydroelectric Project (as per Lewis *et al.* 2011).

| MQM-DVLG01 Discharge ($m^3/s$) | Maximum recommended stage change rate (cm/hr) at MQM-DVLG01 during flow | MQM-DSLG01 Discharge ($m^3/s$) | Maximum recommended stage change rate (cm/hr) at MQM-DSLG01 during flow |
|---|---|---|---|
| ≤ 10 | -7.5 | ≤ 30 | -3.6 |
| > 10 to ≤ 24 | -19.9 | > 30 to ≤ 50 | -9.9 |
| > 24 | unrestricted | > 50 | unrestricted |

## Appendix G – Integrated Incident Management Plan

# Integrated Incident Management Plan
# Between
# Skookum Power Plant
# Upper Mamquam Hydro Facility

# Lower Mamquam Hydro Facility

## August 12, 2014

## Introduction:

The report describes the communication protocol and procedures between the three hydro electric generating facilities that operate in the Mamquam River watershed. These being, in order of flow, the Skookum Creek Plant (Skookum), the Upper Mamquam hydro facility (Upper Mamquam) and the Lower Mamquam hydro facility (Lower Mamquam).

Skookum, owned by SCPP Holdings Inc. is a 25 MW run-of-the-river hydropower project with a design flow of 9.9 m3/s. Upper Mamquam, owned by Transalta, is a 49 MW powerplant with a 27 m3/s design flow. Lower Mamquam, owned by Atlantic Power Corp., is a 60 MW powerplant with a 30 m3/s design flow.

The Skookum has the potential to impact both Upper Mamquam and Lower Mamquam operations and consequently related sensitive downstream fish habitat for both of these facilities. Upper Mamquam has the potential to impact Lower Mamquam and consequently related sensitive downstream fish habitat for this facility.

## Overview

1. Skookum Creek flows into the Mamquam River at approximately the "9-Mile bridge" on the Mamquam Forest Service Road (FSR).
2. Plant shutdown scenarios that have the potential to impact downstream facilities include an emergency unit or full plant shutdown (ESD) in which ramping protocol are not followed.
3. Mitigation measures pertaining to the Operations of the facilities have been incorporated into the design and reduce the potential magnitude and probability of an ESD (Unit ESD more likely than a Full Plant ESD).
4. The communication and emergency response protocol between the three facilities has been implemented to further reduce the potential effects of an ESD and forms the core of this document.
5. The impacts to fish that may be experienced in downstream habitats include the possibility of temporary stranding of fish to mortality due to dewatering. The impacts are dependent on time of year of the event, habitat, species present, magnitude and duration of the event. The highest likelihood of impacts resulting from an ESD is during the late summer. The greatest potential impacts are to fry followed by parr. Impacts to eggs in gravel and adult salmon are considered low.
6. During the commissioning of Skookum an increased potential for an emergency shutdown exists that could impact Mamquam and Lower Mamquam.

## Shutdown Scenarios

The probability of a cascading emergency shutdown scenario is extremely low with only a serious earthquake scenario being a plausible cause. The reason for this is that both facilities on the Mamquam are equipped with turbine bypass valves that permit the controlled release of water during shutdown of the facilities, even under low water conditions that have a low probability of being induced by an emergency shutdown at the Skookum facility. In addition, none of the facilities share transmission line infrastructure prior to interconnecting with the BC Hydro electrical grid. Even in the extremely unlikely case of a load rejection from BC Hydro or transmission line trip to all three facilities would result in all of the facilities shutting down in a controlled fashion.

Please note that instream flow requirements (IFR) are maintained through Skookum Creek and each of the downstream diversion reaches under all operating scenarios described below.

## 1. Normal Operation

Normal operation for a run-of-river hydroelectric facility is defined as generation at a facility based on available flows in excess of instream flow requirements and not more than the stipulated maximum diversion rates.

## 2. Controlled Shutdowns

A controlled shutdown of any of the facilities is initiated for scheduled maintenance, during most plant trips, errors and malfunctions. Potential events that could lead to a controlled shutdown of a unit or entire plant include a transmission line outage, load rejection, equipment malfunction, sensor error, minor equipment failure or operator error.

In the event of a controlled shutdown, flow to the units is redirected away from the turbine to allow immediate de-energization of the generator without cessation of flow to the tailrace and downstream reaches. Flow from the tailrace is gradually reduced at predetermined increments such that licensed ramping rates are maintained downstream and through the diversion reaches.

Any impact to downstream facilities is expected to be of short duration and allow them to continue to operate within the terms of their water licenses so long as their respective controls systems do magnify and operational anomaly. .

## 3. Skookum Unit Emergency Shutdowns

A unit emergency shutdown at Skookum is initiated by an equipment failure/malfunction, sensor error from a critical operating element or critical operator error on one of the two turbine-generator units. There are a limited number of elements that force an emergency unit trip. These include the following:

- A serious plant electrical or control system malfunction
- Activation of the emergency stop button
- Catastrophic failure of a generating unit and failure of the deflectors to engage

During a unit emergency trip a single unit is affected and shut down using emergency measures (i.e. fast nozzle closure or TIV closure) which halts flow through the unit in approximately 2-5 minutes. This will alter the downstream flow by the amount previously being used by the shutdown unit.

The loss of flow from one unit will reduce flow by up to 4.95 $m^3/s$ in Skookum Creek immediately below the powerhouse until the flows from the intake catch up. This flow reduction will persist until flows from the intake have reached the powerhouse which is expected to take 60 – 80 minutes depending on flow conditions.

## 4. Skookum Full Plant Emergency Shutdowns

An emergency shutdown that influences the entire plant is initiated by an event that places significant risk to the facility, its occupants or the environment. For example a penstock rupture or major electrical failure of components common to both units may initiate this. As with a unit shutdown, a full plant shutdown can also be caused by equipment failure/malfunction, sensor error from a critical operating element or operator error. In the event of an emergency shutdown flow from the facility is ceased in approximately 2-5 minutes. During a plant wide emergency shutdown a flow reduction of up to 9.9 $m^3$/s will occur in Skookum Creek immediately downstream of the powerhouse. This flow reduction will persist until flows from the intake have reached the powerhouse which is expected to take 60 – 80 minutes depending on flow conditions.

5. **Earthquake**

An earthquake event would probably trip the units offline under a controlled shutdown but may induce an emergency shutdown of the facilities depending on the magnitude of the event. The seismic event used for the design of the Project has a 2% probability of exceedance in 50 years (equivalent to a typical return period interval of 1 in 2,475 years). Damage to the facility also could occur during a lesser event. Due to the widespread influence of an earthquake on infrastructure this is likely a scenario in which all facilities will be tripped offline by their internal protection and control systems or due to interruptions in BC Hydro's transmission system. It is anticipated that an event of this magnitude would also trigger natural events that would have significant impacts on the both Skookum Creek and the Mamquam river.

# Mitigation Measures

**SKOOKUM MITIGATION MEASURES**

There are several design features that have been incorporated into the Project to reduce the potential for an ESD and particularly a full plant ESD.

Pelton units – Deflectors at the end of each nozzle have the ability to redirect water away from the turbine to allow immediate de-energization of the generator without cessation of flow to the tailrace and downstream reach. The nozzles are then gradually closed such that flow from the tailrace is gradually reduced at predetermined increments such that licensed ramping rates are maintained downstream and through the diversion reaches.

Two turbines – Using two turbines allows flows to be transferred from one to the other in the event of a single unit failure. In the case of Skookum having two units limits the maximum flow reduction caused by a single unit failure to half of the full design flow as a worst case scenario. Both downstream facilities also operate with multiple units.

Independent TIV/HPU – Having independent turbine inlet valves (TIV) and hydraulic power units (HPU) reduce the potential impact of an ESD associated with equipment failures or sensor malfunctions by limiting the flow reduction to a single unit.

Independent transmission line – An independent transmission line following an alternate alignment alleviates the potential for a multi-facility trip caused by localized line faults or load rejections.

**UPPER MAMQUAM AND LOWER MAMQUAM MITIGATION MEASURES**

The downstream facilities also have attributes that could be used to mitigate the downstream propagation of a Project ESD that are still to be explored as part of the Operating Protocol agreement and acceptance by the respective Agencies because they may cause short term violation of ramping and other permitted operating criteria.

Headpond – Both downstream facilities have headponds that can be drawn down to allow them some time to ramp down plant operations in a controlled manner and buffer potential impacts from incoming flow changes.

A rough approximation using measurements taken from orthophoto images and allowing for sedimentation of the upstream headpond / river interface suggests the upper facility has about 6,000 $m^3$ of active storage (approximate headpond dimensions: 150m x 40 m x 1m) while the lower facility has about 8,500 $m^3$ (approximate headpond dimensions: 65 m x 70 m x 1 m + 130 m x 30 m x 1 m). In the event of an ESD at Skookum, a coordinated response from the downstream facilities that utilized this stored volume could largely mitigate the impact of an ESD originating at Skookum. The details around this plan will be developed as the dynamics of the river system are better understood with some real time historical operating data.

Bypass Valves – Downstream plants are equipped with bypass valves that redirect water away from the turbine to allow de-energization of the generator without cessation of flow to the downstream reach. The bypass valves are then gradually closed such that flow from the tailrace is gradually reduced at predetermined increments such that licensed ramping rates are maintained.

# Potential Impacts to habitats downstream of Skookum Creek

Eggs and Alevin in Gravel

There is potential for eggs to be in gravel throughout the year. The hydrologic modeling exercise found that there were no instances where an ESD at the Skookum project would result in a reduction of flows below the IFR of either of the Mamquam sites. Since the range of flows in the diversion reaches is within the range which may be experienced under normal plant operations, there is likely limited additional risk to eggs or alevin in gravel due to an ESD event.

Downstream of the tailraces, during events which cause a shutdown of either of the downstream plants, the potential for dewatering of redds will depend on the depth of the water over the redd, the egg burial depth in the redd and the magnitude of the flow reduction.

For the salmonid species which may be present below the Lower Mamquam project tailrace, the water depths over the redd at time of spawning range from 15 cm to >24 cm (Bjornn and Reiser 1991). Most salmonids bury their eggs in gravel, typically 10 to 15 cm below the surface of the streambed for the top of the egg pocket and 25-50 cm below the surface of the streambed for the bottom of the egg pocket (DeVries 1997). Therefore stage changes would likely need to be in excess of 25 cm to cause dewatering of eggs in gravel, however this will vary depending on river stage, location and depth of the redd. Larger fish, such as Chinook, are more likely to utilize deeper and faster water for spawning than resident species (Beamish 1978) and thus may be less susceptible to dewatering of redds. Becker et al. (1986) found that eggs which were dewatered for 12 days had a 97% survival rate. This is attributed to the eggs ability to acquire oxygen via diffusion. Given the expected short duration of any dewatering which may result from a plant shutdown, mortality of eggs in gravel is unlikely.

Mortality rates of in-gravel eleutheroembryos or alevins are much higher than eggs due to their need for flowing water to provide their oxygen. Becker et al. (1986) found that eleutheroembryos had a 43% survival rate after 6 hour of dewatring and alevins had a 36% survival rate after 2 hours of dewatering. The potential for dewatering of alevins may be somewhat lessened by the downward movement of alevins through the substrate after hatching (Bams 1969; Dill 1969; Fast et al. 1981, Godin 1981). This may not occur until up to half way through their inter-gravel life history (Groot and Margolis 1991). Should an event occur from early February through late September after hatching, if inter-gravel alevins are dewatered for the expected period of an emergency plant shutdown some mortality would be expected.

Fry

Fry emergence from eggs in the downstream reach spans a considerable range given the numerous species that may spawn in the lower Mamquam River. Juvenile salmonids often take cover in the interstitial spaces between gravel and cobbles on the bed of the stream (Chapman 1966) and are known to occupy habitat with low velocities and depths during the early stages of their life. These areas are often found in stream margins and side channels. This increases the potential for impacts to young of the year fry from a large stage change in excess of permitted ramping rates or a full plant shutdown. Potential impacts to fry are greatest for resident species and salmon with longer stream rearing phases of their life histories including chinook and coho. Pink salmon, which outmigrate to Howe Sound upon emergence and chum which outmigrate within several days to weeks have a lower probability of being present during an ESD event. A dewatering event may result in the stranding of fry, which have lower swimming capabilities than latter life stages. Should the stranding occur in isolated pools of water, which persist until the lag time passes through the diversion reach and regular flow are restored (maximum estimated 142 minutes below the lower tailrace), survival is likely however there would be the increased potential for predation during that time. The pools must be of sufficient size to prevent excessive warming and oxygen deprivation of fry during the stranding. Mortality would be expected for dewatered fry.

Parr

Salmon, trout and char parr may occupy margin habitat susceptible to dewatering effects. Their presence in these habitats is more likely during the overnight period when they move into these habitats to feed (Needham and Jones 1959). They are also more likely to occupy these habitats in the summer growing season than in the winter (Bustard and Narver 1975, Cunjak 1996). Due to their improved swimming capabilities, parr will also have a higher potential to respond to dewatering events by moving away from margins as they are dewatering. As with fry, should an emergency shutdown result in stranding of parr in isolated pools, they may survive in isolated pools of sufficient size. The potential for mortality exists for fish which are not able to avoid stranding by moving into habitats which remain wetted.

Adult Salmon

Due to their high mobility and preference for deeper water habitats, adult salmon are less likely than other life stages, to be subject to stranding due to emergency shutdowns. Should dewatering occur while they are in shallow water habitats such as margins, they will likely react by moving to deeper water habitats. Studies have shown that if spawning salmon have to abandon an active redd site due to dewatering, they may attempt to return the site after the water levels recover (Smith 2010).

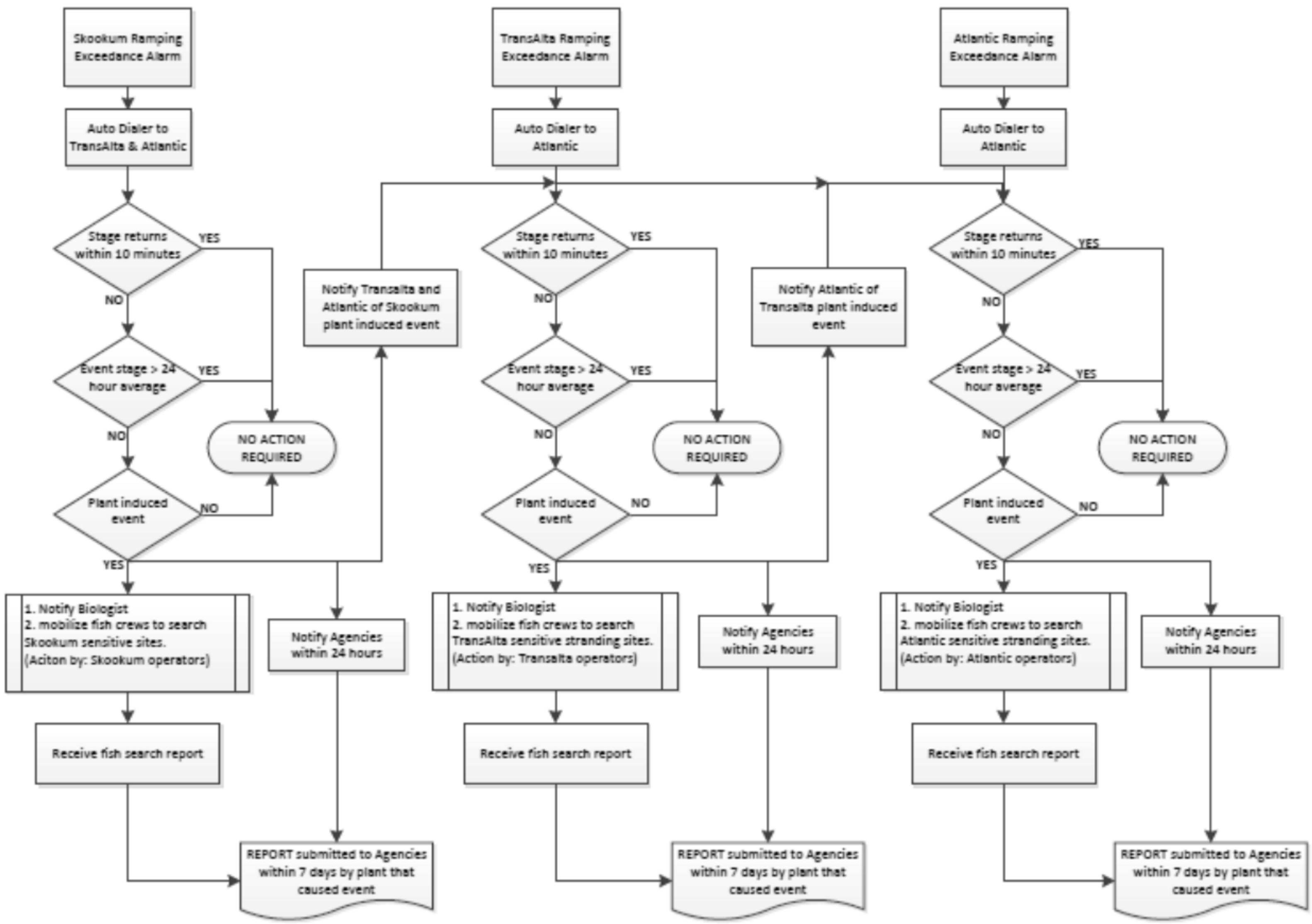
Downstream Impacts

The downstream extent below the Lower Mamquam tailrace which a ramping event and cessation to tailrace flows may be experienced is expected to be mitigated with distance downstream due to tributary inputs and dispersal of flows. The Mamquam and Blind channel habitat channels are not predicted to be subject to impacts due to their distance downstream and expected lack of hydrologic connectivity.

# Ramping and Emergency Event Protocol

The following flow diagram outlines the protocol that will be followed by the facilities in the event of a river incident that is caused naturally or is plant induced at any of the facilities. Contact names and numbers are provided in the section following the flow chart.

## Integrated Incident Management Plan Flow Chart



# Communication Contact Information

| | | |
|---|---|---|
| **SKOOKUM** | | |
| Skookum Power Plant (Skookum Creek Power Partnership) | Plant Operators (on site) - Spearhead Operating Services Ltd<br><br>Steve McKay<br><br><br><br>Cliff Bell<br><br><br><br>Patrick (Pat) Skinner | <br><br><br><br>Plant:<br>s.22<br><br><br>Plant:<br>s.22<br><br><br>Plant:<br>s.22 |
| | Plant Operations Manager – Lucas Paczek | Office: 604-940-0402<br>Cell: s.22<br>lpaczek@runofriverpower.com |
| **UPPER MAMQUAM** | | |
| | | |
| Upper Mamquam Hydropower Facility (TransAlta Corp) | Plant Operator – Salvadore (Sal) Luengo | Cell s.22<br>Power Plant: 604-898-8297 |
| | Environment - Glenn Isaac | 403-267-7273<br>Glenn_Isaac@transalta.com |
| | Plant Manager – Norris McLean | Office: 250 837 8754<br>Norris_mclean@transalta.com |
| **LOWER MAMQUAM** | | |
| Mamquam Power Plant – (Atlantic Power Corporation) | Plant Manager – Marc Nering | Cell s.22<br>Power Plant: 604-898-2761<br>mnering@atlanticpower.com |
| | Elspeth Miller | Power Plant: 604-898-2761<br>emiller@atlanticpower.com |
| Plant Operators | David Carlin<br><br>David Griffrioen | Office: 604 898 2761<br>Cell s.22<br>Office: 604-898-2761 |

| | | |
|---|---|---|
| | Wayne Moffatt | Cell: s.22<br>Office: 604 898 2761<br>Cell: s.22 |

# BIOLOGISTS

| | | |
|---|---|---|
| Ecofish | Ian Murphy | Phone:<br>Office: 778-346-3933<br>Office 2: 250-334-3042<br>Cell: s.22<br>Email: imurphy@ecofsihresearch.com |
| EDI Environmental Dynamics Inc. | Ian Redden | Phone: (250) 751-9070<br>Cell: s.22<br>Email: iredden@edynamics.com |

# PROVINCIAL AND FEDERAL AGENCIES

| | | |
|---|---|---|
| FLNRO Regional Water Manager<br>Regional Hydrologist<br>Regional Water Manager | James (Jim) Davies, Engineer Under the Water Act | Phone: (604) 586-5637<br>Fax: (604) 582-5235<br>email: James.Davies@gov.bc.ca |
| FLNRO Regional Dam Safety Officer | Mike Bristol | (604)586-5637 |
| Fisheries and Oceans Canada<br>Pacific Region HQ | | Phone: (604) 666-0384<br>Fax: (604) 666-1847<br>Phone: (604) 666-3491 (Habitat Branch) |
| Fisheries Protection Program<br>Fisheries and Oceans Canada | Murray Manson, MSc., R.P. Bio.<br>Fisheries Protection Program | Phone: (604) 666-0129<br>Email : murray.manson@dfo-mpo.gc.ca |
| | Don Knoop<br>(Compliance Occurrences) | Phone: (604) 666-0282<br>Email: don.knoop@dfo-mpo.gc.ca |
| Coast Forest Region<br>Squamish Forest District | | Phone: (604) 898-2100<br>email:<br>forests.squamishdistrictoffice@gov.bc.ca |
| Canadian Wildlife Service<br>Pacific Wildlife Research Centre | | Phone: (604) 940-4700<br>Fax: (604) 946-7022<br>Phone: (604) 940-4600<br><br>http://cwfis.cfs.nrcan.gc.ca/en/index_e.php |
| Severe Weather<br>Pacific Region | | Phone: 1-800-66STORM<br>1-800-667-8676<br>www.weatheroffice.ec.gc.ca/warnings/warnings_e.html |
| Transport Canada<br>Navigable Waters Protection Program<br>Regional Manager<br>Pacific Regional Office | | Phone: (604) 775-8867 |
| Ministry of Forests, Lands | | Phone: (604) 740-5858 |

| | | |
|---|---|---|
| and Natural Resource Operations<br>Conservation Officer | | |
| Water Allocation | Aman Ullah<br>Water Power Engineer | Phone: (604) 586-5636<br>Fax: (604) 586-4444<br>email: Aman.Ullah@gov.bc.ca |
| Report a Wildfire | | Phone: 1-800-663-5555 or<br>*5555 from cellular phone |
| Wildfire Information | | Phone: 1-888-3FOREST or<br>1-888-336-7378<br>http://bcwildfire.ca/ |
| Archaeology Branch | | Phone: (250) 953-3338<br>Fax: (250) 953-3340<br>Email: ARCWEBFEEDBACK@gov.bc.ca |

## SIGNATURES

This report was reviewed and approved by the undersigned.

______________________________________________

Skookum Power Plant Signatory

______________________________________________

Upper Mamquam Hydropower Facility Signatory

______________________________________________

Mamquam Power Plant Signatory

# Appendix H - Operation Maintenance and Surveillance Plan

### OPERATION, MAINTENANCE & SURVEILLANCE PLAN

| | |
|---|---|
| Dam Name | *Lower Mamquam* |
| Water Licence No.: | *102850* |
| Owner's Name | *Atlantic Power Preferred Equity Ltd*<br>Phone: *604 898-2761* |
| Stream Name: | *Mamquam River* |
| Reservoir Name: | *Run of River* |
| Dam Location: | *GPS Co-ordinates North 49 43 296, West 123 05 025*<br>*Latitude: N50358.000 Longitude: E53320.000* |

### LIST OF RESPONSIBLE INDIVIDUALS

| | Name | Title | Phone | Mobile |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| ***Operation*** | *Marc Nering* | Operations Manager | *604 898-2761* | s.22 |
| ***Maintenance*** | *David Griffioen*<br>*Wayne Moffatt* | Plant Operator<br>Plant Operator | *604 898-2761* | |
| ***Inspections*** | *David Griffioen*<br>*Wayne Moffatt* | Plant Operator<br>Plant Operator | *604 898-2761* | |
| ***Instrumentation*** | *David Carlin* | Plant Electrician/Operator | *604 898-2761* | |

**PHYSICAL DESCRIPTION**

Dam Height: *3.35m*

Dam Type: *Inflated Rubber Weir*

Length: *48.3m*

Crest Width: *Approx. 1.0m*

Reservoir Capacity: *6,375 cubic metres*

Reservoir Area: *4,800 square metres*

Spillway Capacity: *600 cubic metres/second*

Design Flood Inflow: *1:500 Year*

Watershed Area: *260 square kilometres*

Purpose of Dam: *Power Generation*

Consequence Classification: *MEDIUM*

**ACCESS TO DAM:** *(describe road access to dam from nearest center, attach map to this Plan)*

Access is from Highway 99 south of Squamish via Mamquam Forest Service Road, East on Mamquam Forest Service Road for 5.5 miles. Turn left at 5.5 Miles onto Intake access road (see attached map).

**LIST SIGNIFICANT STRUCTURES DOWNSTREAM OF DAM*:*** *(i.e. access road, railroad)*

None

**LIST ALL HYDRAULIC WORKS*:*** *(i.e., spillway, outlet, stop-logs, gates, valves etc. (include capacity, dimensions, locations etc.)*

- *Inflatable Weirs*

- *1 Radial Sluicegate*
- *1 Riparian Bypass Sluicegate*
- *1 Tunnel Adit*
- *1 Stop-log Set (performs isolation for tunnel, radial sluicegate and inflatable weirs)*
- *1 Intake Screen*
- *1 Sluiceway/Intake Channel*
- *1 Spillway*

**LIST PROCEDURES FOR RESERVOIR OPERATION*:*** *(i.e., how is Reservoir level controlled? what is the anticipated reservoir level for any given time of year? when are the drawdown and filling periods? what are the operation procedures during floods?)*

The intake PLC maintains reservoir elevation at 297.10 metres (+ 0.20/-0.02). The inflatable weirs are inflated or deflated to maintain the reservoir level within that range, regardless of river flows.

There are no draw-down or filling periods as the reservoir level remains constant.
The PLC controls the two inflatable weirs and the radial sluicegate as required during flood events. If required, the weirs and radial sluicegate can be manually controlled.

**LIST ALL ITEMS REQUIRING ROUTINE MAINTENANCE*:*** *(include type of maintenance to be performed, scheduling of maintenance, record keeping, etc.)*

| | |
|---|---|
| Back-up diesel generator | – inspected weekly, serviced annually or more often if required |
| Blowers | – inspected weekly, serviced annually |
| Trash-rack Cleaner | – inspected weekly, serviced annually |
| Radial Gate | – inspected weekly, full inspection annually, serviced every 3 years |
| UPS Batteries | – serviced quarterly, full service annually |
| Weirs | – inspected weekly, inspected semi-annually |
| Fire Detection Equipment | – serviced annually |
| Riparian Bypass | – inspected weekly, full inspection semi-annually |
| HVAC | – inspected weekly |
| MCC | – inspected every 2 years |

All weekly inspection items are recorded on Weekly Intake Inspection Forms.
Semi-annual inspections are recorded on the Dam Inspection Checklists.
Maintenance records are kept in the Preventative Maintenance Plan binder for the year during which the service work was performed.

**LIST ALL INSTRUMENTATION, FREQUENCY OF MONITORING, AND METHOD OF RECORD KEEPING:** *(i.e., seepage measurement weir, reservoir level gauge, piezometers, etc.)*

Headpond/Forebay level – continuously monitored

Upstream Sluiceway (before trash-rack) – continuously monitored
Downstream Sluiceway (after trash-rack) – continuously monitored
Trash-rack differential (Upstream-Downstream readings) – continuously monitored
Radial Sluicegate position – continuously monitored
Riparian Flow measurement – continuously monitored
Approximately 2 weeks of the most recent trending data is available at all times, before being overwritten.

**LIST OF EQUIPMENT TO BE PERIODICALLY TEST-OPERATED:** *(i.e., gates, valves, hoists, etc., include frequency of test operation)*

Radial Gate – tested during sluicing operations (minimum semi-annually)
Diesel generator – tested weekly
Communications systems – tested weekly

**LIST ALL COMPONENTS REQUIRING ROUTINE VISUAL INSPECTIONS:** *(include schedule) (e.g. weekly, monthly, quarterly, annually etc.)*

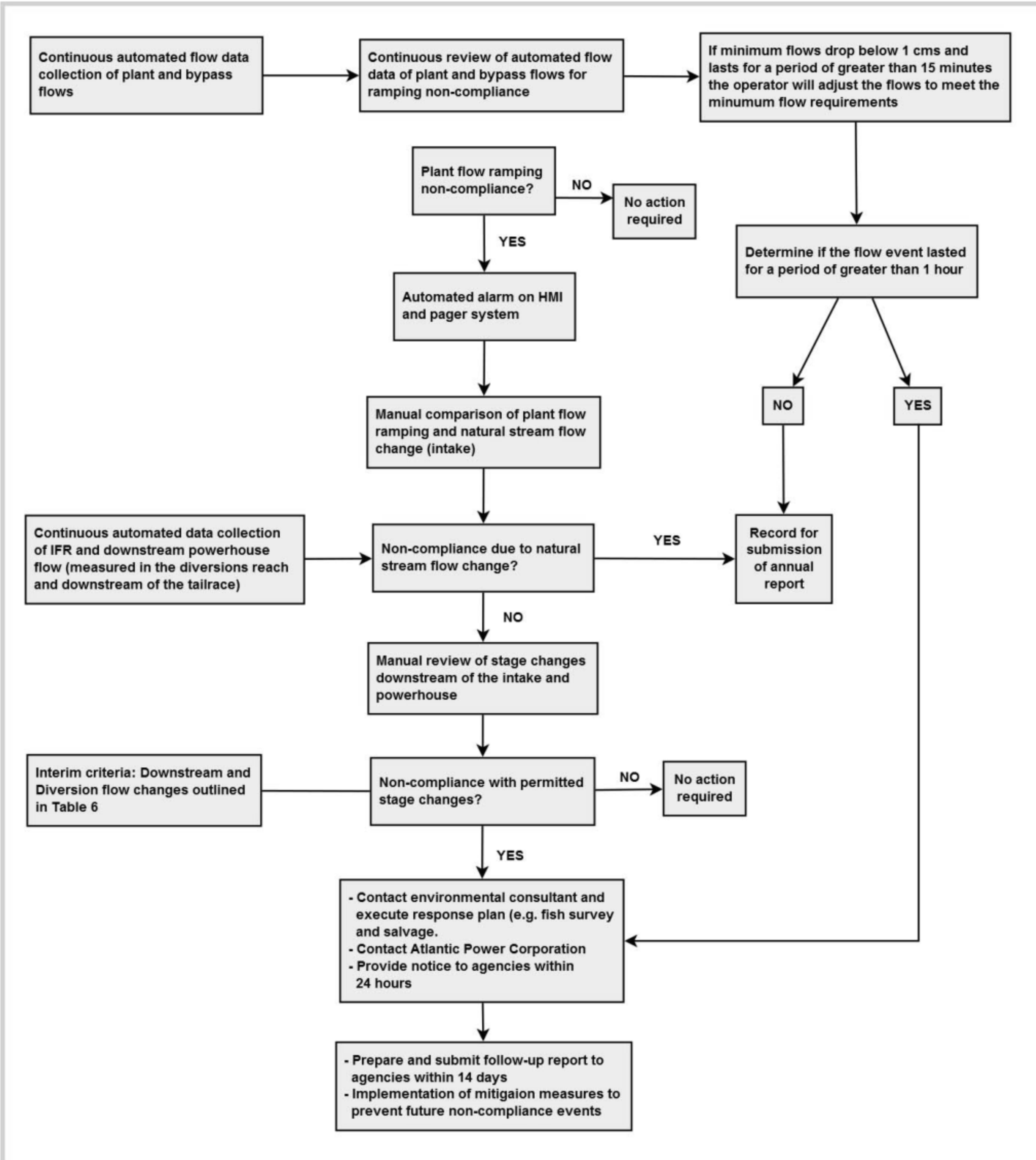
Weirs – inspected weekly
Radial Gate – inspected weekly
Spillways and structures – inspected semi-annually
Powerline – inspected annually

**ANNUAL FORMAL INSPECTIONS BY OWNER*:*** *(include; time of year when performed, special items to be examined, reviewed, and/or test operated)*

The BC Dam Inspection Checklist is completed by a professional engineer. This is normally performed in the summer months when there are no access restrictions. Any deficiencies are closely monitored (eg., spillway erosion).

# ADDENDUMS

**ADDENDUM A – Ramping Rate Compliance Monitoring Flow Chart**




**ADDENDUM B –Calculations of Ramping Rate Exceedances**

1. Determine if ramping rate criteria were exceeded (Rule 1, the exceedance rule):

Ramping rates will be calculated for each data point in the time series as the maximum stage change in the preceding hour. If the difference between a data point and the maximum stage observed in the previous hour exceeds the Project's recommended ramping criterion (e.g., -2.5 cm), the ramping event is flagged. The two-minute average data from the hydrometric compliance point should be used to undertake the calculations, as follows:

a) Calculate the maximum stage observed over the past hour for each data point $i$ as:

$$hmax(t_i) = \max\left(h(t_{i-k}), \dots, h(t_{i-1})\right)$$

where $h$ is stage, $k$ is the number of data points recorded per hour, and $t$ is time.

b) Calculate the maximum stage decrease over the past hour relative to time $t_i$, $\Delta hmax(t_i)$, as:

$$\Delta hmax(t_i) = h(t_i) - hmax(t_i)$$

c) Determine if the ramping criteria was exceeded (Rule 1, the exceedance rule):

$$if\ \Delta hmax(t_i) < -2.5,\ \ exceedance = 1, else\ exceedance = 0$$

2. Determine if the habitat was dewatered (Rule 2, the dewatering rule):

If the stage returns to within the ramping criterion (e.g., -2.5 cm) of the previous maximum stage within 10 minutes of the moment it was in exceedance of the criterion, the event is not flagged. Habitats will not instantly dewater following a significant decline in stage, and fish will survive when stranded for such a short period of time. The time to asphyxiation has been estimated to be 10 minutes considering both air exposure and the time needed for the substrate to drain. This is the dewatering rule (Rule 2) and is evaluated as follows:

a. Calculate the maximum value of $\Delta hmax$ over the next 10 minutes as:

$$max(\Delta hmax) = max(\Delta hmax(t_{i+1}), \Delta hmax\left(t_{i+\left(\frac{k}{6}\right)}\right))$$

b. Determine if this maximum value of $\Delta hmax$ is in compliance (e.g. ≥ -2.5 cm):

$$if\ (\max(\Delta hmax)) < -2.5, \quad dewatering = 1, \quad else\ dewatering = 0$$

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# MEMORANDUM

**TO:** Marc Nering and Terry Shannon, Atlantic Power Corporation
**FROM:** Ian Murphy, B.Sc., EP and Sean Faulkner, M.Sc., R.P.Bio., Ecofish Research Ltd.
**DATE:** April 2, 2015
**FILE:** 1071-09
**RE:** Lower Mamquam River – Ramping Incident Response Monitoring

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# Lower Mamquam Hydroelectric Project

## Year 5 Annual Monitoring Report



Prepared for:

**Atlantic Power Corporation**
**PO Box 5383**
**Squamish, BC, V8B 0C2**

December 18, 2015

Prepared by:

**Seana Buchanan, M.Sc., Abul Baki, Ph.D., P.Eng., David West, M.Sc., P.Eng., Matthew Sparling, M.Sc., Sarah Kennedy, B.Sc., Xuezhong Yu, Ph.D., Adam Marriner, M.Sc., Kevin Ganshorn, M.Sc., R.P.Bio.[1], Nicole Wright, Ph.D. AScT[1], and Adam Lewis, M.Sc., R.P.Bio.[1]**

**Ecofish Research Ltd.**

[1] Certifying professional

Published by Ecofish Research Ltd., Suite F, 450 8th St., Courtenay, B.C., V9N 1N5

**Citation:**

Buchanan, S, A. Baki, D. West, M. Sparling, S. Kennedy, X. Yu, A. Marriner, K. Ganshorn, N. Wright, and A. Lewis. 2014. Lower Mamquam Hydroelectric Project Year 5 Annual Monitoring Report. Consultant's report prepared for Atlantic Power Corporation by Ecofish Research Ltd., December 18, 2015.

**Certification:**

*Certified: stamped version on file*

Kevin Ganshorn, M.Sc., R. P.Bio. No. 2448

Nicole Wright, Ph.D., AScT. No. 30520

Adam FJ Lewis, M.Sc., R. P.Bio. No. 494

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# Lower Mamquam Hydroelectric Project

## Operational Environmental Monitoring Program Summary Report



Prepared for:

**Atlantic Power Corporation**
**PO Box 5883**
**Squamish, BC, V8B 0C2**

May 6, 2016

Prepared by:

**Ecofish Research Ltd.**

Published by Ecofish Research Ltd., Suite F, 450 8th St., Courtenay, B.C., V9N 1N5

**Citation:**

Buchanan, S, I. Girard, D. West, J. Romano, J. Ellenor, A. Baki, H. Regehr, N. Swain, K. Ganshorn, K. Lyle, D. LaCroix and A. Lewis[1]. 2016. Lower Mamquam Hydroelectric Project Operational Environmental Monitoring Program Summary Report. Consultant's report prepared for Atlantic Power Corporation by Ecofish Research Ltd., May 6, 2016.

[1] Certifying professional

**Certification:**

*Certified: stamped version on file*

Adam FJ Lewis, R. P. Bio. No. 494

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# 3. FLOW COMPLIANCE

## 3.1. Instream Flow Requirements

### 3.1.1. Background

The Project has an instream flow requirement (IFR) of 1.0 $m^3/s$ year-round to maintain fish and fish habitat (Lewis *et al.* 2010a). River stage and real-time instantaneous flow data at the MQM-DVLG01 hydrometric gauge, in combination with annual discharge measurements, are used to determine IFR compliance below the Project intake when the plant is operating.

### 3.1.2. Methods

In order to assess the Project's compliance with the IFR during the monitoring period, discharge data were derived for MQM-DVLG01, using RC9. Rating Curve 9 has been developed from 19 discharge measurements across a range of flows, and is considered well established. The root mean square error of RC9 is 8.4%; this margin of error has been applied to the discharge data derived from the rating curve for the purpose of IFR compliance monitoring. Further details on RC9 development are found in Section 4.3 of this report.

Mean hourly flows at MQM-DVLG01 were used, in order to account for noise in the two-minute interval time series. The water surface elevation is subject to small high frequency fluctuations. When operating at flows near the IFR, these fluctuations may cause data to be flagged as out of compliance, even though sufficient water is being released. By calculating the hourly average, these fluctuations are eliminated. The hourly data are provided in a separate data file accompanying this report ("MQM-DVLG01_Hourly Flow_01Sep15 to 31Aug16_IFR Compliance.xlsx") and correspond to the average discharge derived from RC9, during the hour immediately preceding that time.

The IFR compliance assessment takes into account the potential error in the derived discharge time series, which is based upon the root mean square (RMS) percentage error of the rating curve (8.4%). Confirmed IFR excursions are defined as those where the upper error bound of the derived hourly discharge is below the IFR. A summary of those occasions when the lower error bound of the derived hourly discharge is below the applicable IFR, but the upper error bound is above the IFR, is also provided here.

### 3.1.3. Results

There were no confirmed IFR excursions recorded during the monitoring period (September 1, 2015 to August 31, 2016). Monthly plots of derived hourly average discharge data (derived from RC9) are displayed relative to the applicable IFR of 1.0 $m^3/s$, in Appendix A.

There were 41 occasions (total duration 8 days, 14 hours) when the lower error bound of the hourly discharge (derived from RC9, RMS 8.4%) was below the applicable IFR; although all of time instream flows were clearly above the IFR. A table of possible excursions is provided in the data file accompanying this report ("MQM-DVLG01_Hourly Flow_01Sep15 to 31Aug16_IFR Compliance.xlsx"). The average difference between the IFR and instream flows for all potential occasions was 0.015 ± 0.008 $m^3/s$; and the maximum difference was 0.043 $m^3/s$, which occurred over 8 hours on May 13, 2016 (from 09:00 PST to 16:00 PST). The discharge grade during all potential excursions was RISC Grade B.

## 3.2. Ramping Rate

### 3.2.1. Background

Water flow changes can impact aquatic life, potentially violating sections of the *Fisheries Act*. For example, rapid flow reductions can lead to fish stranding or isolation in small pools, leading to mortality from suffocation, desiccation, freezing or predation. These conditions directly violate Section 32 of the *Fisheries Act*. Presently, the Department of Fisheries and Oceans' (DFO) generic standard ramping rate limits are 2.5 cm/hr when fry are present and 5.0 cm/hr at all other times; although no ramping may be allowed under some conditions (Hunter 1992 and Higgins 1994).

Ramping compliance was assessed for the period between September 1, 2015 and August 31, 2016. Following the commissioning work, discharge dependant ramping rates were used (Table 16), Justification for these criteria may be found in the Project's Commissioning Monitoring Report (Lewis *et al.* 2011).

**Table 16. Recommended ramping rates for the Lower Mamquam Hydroelectric Project (as per Lewis *et al.* 2011).**

| MQM-DVLG01 Discharge ($m^3/s$) | Maximum recommended stage change rate (cm/hr) at MQM-DVLG01 during flow | MQM-DSLG03 Discharge ($m^3/s$) | Maximum recommended stage change rate (cm/hr) at MQM-DSLG03 during flow |
|---|---|---|---|
| ≤ 10 | -7.5 | ≤ 30 | -3.6 |
| > 10 to ≤ 24 | -19.9 | > 30 to ≤ 50 | -9.9 |
| > 24 | unrestricted | > 50 | unrestricted |

### 3.2.2. Methods

#### 3.2.2.1. Ramping Event Assessment

Ramping monitoring methods are detailed in Lewis *et al.* (2010b) and included use of permanent hydrometric gauges as well as manual stage measurements and portable pressure transducers placed in sensitive fish stranding areas. Refer to Section 2 of Lewis *et al.* (2010b) for further details. Ramping rates were determined during commissioning activities in May 2011 (Lewis *et al.* 2011), and compliance with these rates is analysed for September 1, 2015 to August 31, 2016 using two-minute stage data from MQM-DVLG01 and MQM-DSLG03.

A ramping event occurs when the ramping rate, as calculated by a defined method under particular operating conditions, exceeds the ramping criterion for a specific site for a certain amount of time. Such events may be a result of project operations, or natural conditions. Such events may or may not result in fish stranding (a stranding incident). Ramping events are transient events typically lasting minutes.

The compliance point in the downstream reach is the permanent hydrometric gauge located downstream of the powerhouse (MQM-DSLG03), and in the diversion reach the compliance point is the permanent hydrometric gauge located below the intake (MQM-DVLG01). The recommended ramping rates are provided in Table 16.

Natural water level fluctuation cause by turbulence are detected as noise at the ramping monitoring gauges, which can create an uncertainty with respect to calculations of ramping rates. Because of the nature of the river at the diversion gauge location (MQM-DVLG01), this gauge is particularly sensitive to noise in stage readings (although typically less than ±0.5 cm at IFR). On occasion, this error in stage reading may result in the incorrect flagging those ramping events that are marginally less than ramping rate criteria. To address this issue, those ramping events at the diversion gauge that had a calculated ramping rate within 1.0 cm of the ramping rate criterion (i.e., Table 16), were flagged as a potential type I error (false positive).

In summary, the following criteria were used to evaluate ramping events for compliance:

1. Ramping rates were calculated using a moving average over the previous 10 minutes, if the difference between a data point and the maximum stage observed in the previous hour exceeded the Project's recommended ramping criterion (e.g., -3.6 cm), the ramping event was flagged. This is the exceedance rule (Rule 1).
2. If the stage returned to within the ramping criterion (e.g., -3.6 cm) of the previous maximum stage within 10 minutes of the exceedance of the criterion, the event was not flagged. Habitats are not expected to instantly dewater following a significant decline in stage, and fish will not immediately die when stranded for such a short period of time (Nagrodski *et al.* 2012). This is the dewatering rule (Rule 2).
3. The average stage over a period of time prior to a ramping event may be used to determine the likelihood of colonization by fish within the affected habitat. This comparison to the flow history is made to exclude events where fish would not have had time to colonize newly wetted habitat (e.g., exclusion of spike events). This is the wetted history rule (Rule 3).
4. Due to natural water level fluctuations the stage rate of change may fluctuate about the compliance level resulting in multiple exceedance events over a brief period of time. If this occurs during a steady decrease in water level these events will be considered a single exceedance.
5. To screen natural flow rate of change, ramping events were screened out if the plant was not operating or was confirmed to be operating within specified ramping parameters as defined in Table 16. In all cases these events were confirmed with plant operations staff and recorded in the ramping alarm log.

6. Events were not flagged in the diversion reach when a 'saw tooth' pattern was observed at the diversion gauge, located just downstream of the headpond. This type of pattern can be attributed to water level adjustments in the headpond which can occur in a jerky step-wise fashion; consequently inclusion of these events would exaggerate the extent of ramping non-compliance events.
7. Events resulting from the Upper Mamquam or Skookum project operation were screened and removed by evaluating against flow and stage records from the MQM-USLG01 gauge, located between the Upper Mamquam powerhouse and Lower Mamquam intake.

##### 3.2.2.2. Sensitive Stranding Site Selection

A total of five stranding search sites were selected in the downstream and diversion reach of the Mamquam River that were representative of high, moderate, and low risk stranding habitat (Map 6). The sites were located in natural stream habitats that represent areas that are most sensitive to fish stranding, based on the following criteria:

- Where the river cross-section had a relatively flat slope with large substrate that could strand fish, or finer substrate with depressions that could trap fish;
- Cobble and gravel bars, with roughness characteristics that created refuges that juvenile fish are known to prefer and may be reluctant to leave during a ramp down event. These micro-stranding sites were identified as "hotspots areas" prior to the beginning of testing; and
- Side channels or pools that are known to be preferred by juvenile fish for rearing.

One stranding site (MQM-DVSDS02) was established within the diversion reach of the Mamquam River, which coincided with MQM-DVEF02, approximately 7.6 km upstream from the confluence with the Squamish River. No fish stranding had been observed in the diversion during stranding searches over the previous five year monitoring period (Buchanan *et al.* 2016). These results, combined with the minimal stranding habitat, indicate low risk of fish stranding in the diversion reach.

Three sites were established within the downstream reach of the Mamquam River (MQM-DSSD01, MQM-DSSD02 and MQM-DSSD03) (Map 6). MQM-DSSD01 is located just downstream of the MQM-DSLG01 compliance gauge. MQM-DSSD02 is located where the Highway 99 Bridge crosses the river and is comprised of two sub-sites, MQM-DSSD02C and MQM-DSSD02B, located upstream and downstream of the highway bridge, respectively (Map 6). MQM-DSSD03 is located where the railroad bridge crosses the river and is consequently comprised of two sub-sites, MQM-DSSD03A and MQM-DSSD03B, located upstream and downstream of the bridge, respectively. MQM-DSSD04 is located east of the Squamish Valley Golf and Country Club and south of Mamquam Road, approximately 150 m upstream of the Mashiter Creek confluence (Map 6).

#### 3.2.2.3. Stranding Search Methods

Following a confirmed ramping event, where risk to fish was sufficient to warrant a stranding search, Ecofish staff were dispatched to conduct stranding searches at the respective established sites. The stranding searches involved two components: broad-based and hotspot searches (Lewis *et al.* 2011).

In the event that isolated fish (i.e., alive in wetted area but cut-off from mainstem of river) were identified during these stranding search, they were returned to the mainstem of the river near the stranding site but in a location that had low risk of stranding given further stage reduction. If stranded fish mortalities (or near mortality) were found, fish species were collected and preserved for analysis. At each site, the number of fish found was recorded, as well as the species and the fork length (mm) of each individual. Standing sites and fish were also photo-documented.

#### 3.2.2.4. Uncertainty of Plant Induced Stranding

Plant induced ramping events occur occasionally on the Mamquam River during periods of natural stage change. As a result, natural water levels may fluctuate substantially between the period of time when the ramping event occurred and when the stranding search is conducted. If fish are found stranded/isolated during the ensuing stranding searches, it can be difficult to make conclusive statements regarding whether fish stranding/isolation was a result of natural stage change in the river or of plant operation. Furthermore, the hydraulic geometry between, and even within, stranding locations can vary, making it difficult to predict the area of the river bank that was dewatered during the ramping event. Consequently, professional judgement is often used to infer whether fish were stranded as a result of a ramping event.

For each fish stranding/isolation event qualitative levels of certainty were assigned to evaluate the spatial and temporal uncertainty; i.e. were fish stranded due to plant-induced ramping events or as a result of natural stage change. The categorization used for this purpose is as follows:

- *Certain* – instances where fish stranding/isolation was directly observed during the ramping event.
- *Likely* – instances where fish were found within the believed spatial/temporal zone of the ramping event, however no conclusive evidence existed that the event caused the stranding/isolation.
- *Possible* – instances where it was unclear whether fish stranding/isolation resulted from the event (e.g., several water-level fluctuations, poor fish condition); the ramping event could not be eliminated as the cause.
- *Unlikely* – instances where fish were found outside the believed spatial/temporal zone of the ramping event (e.g., fish were found outside of the suspected dewatered area, fish were desiccated/decayed), however no conclusive evidence existed that the event did not cause the stranding/isolation.

- *Not possible* – instances where conclusive evidence indicated that fish were not stranded/isolated during the ramping event.

### 3.2.3. Results

#### 3.2.3.1. Ramping Rates

All ramping events calculated based on criteria 1 through 4 (described in Section 3.2.2.1) are reported in Appendix B, Appendix C, Appendix D, and Appendix E, regardless of whether the plant was operational or the ramping event was caused by the upstream plant. However, for the purpose of reporting ramping compliance here, only those events that have been screened against all seven criteria have been brought forward and are presented in Table 17 (diversion) and Table 18 (downstream). The total number of false alarms (those that violate the exceedance rule and the dewatering rule, but are also screened out against criteria 3 through 7 above) are summarized in Table 19 with their corresponding rationale.

Generation data for the period of analysis were provided to Ecofish in kilowatt hours (kWh), in hourly increments, and used to calculate the discharge diverted at the intake ($m^3/s$). Plots of diverted discharge, together with discharge calculated for the upstream (MQM-USLG01), diversion (MQM-DVLG01), and downstream (MQM-DSLG03) gauges are shown for each potential ramping event identified in Appendix B for MQM-DVLG01 and in Appendix D for MQM-DSLG03, including data for at least 20 hours prior to each event. These appendices provide two additional plots, showing the calculated discharge (from the rating curve) and the measured stage for each event (bottom left figure), and the calculated discharge together with the ramping rate at the applicable gauge for each event (bottom right figure). The ramping rate is the value calculated as per step No. 2 above; either the difference in stage between a particular point and the maximum stage during the previous hour or, if the maximum stage is greater than the 24 hour average, it is the difference between that average and the current stage.

Ramping events at the MQM-DVLG01 gauge, downstream of the intake are summarized for September 1, 2015 to August 31, 2016 in Table 17 and shown graphically in Appendix B. Events were only included if operational data indicated a significant increase in plant generation (based on hourly data), or if there was a corresponding rise in stage at the downstream gauge and no decrease in stage recorded at the gauge upstream of the intake. Table 17 includes the time the event started, maximum change in stage within one hour, maximum stage change upstream of the intake (within one hour) over the previous two hours, and the RISC grade of the stage data from MQM-DVLG01. Appendix C provides a list of all events after September 1, 2015 that exceeded the ramping rate criterion when the plant was operational. Appendix C includes events that were likely natural ramping events, and events caused by the Upper Mamquam Hydroelectric Project or Skookum Hydroelectric Project, whereas Table 17 includes only events that were attributable to the Lower Mamquam Project. The discharge at the start of each ramping event recorded at MQM-DVLG01 was also calculated, and is included in Table 17 and Appendix C.

Ramping events at the MQM-DSLG03 gauge, downstream of the powerhouse, are summarized in Table 18 and shown graphically in Appendix D. Table 18 includes events after September 1, 2015 when a change in plant operation (ramping) could have caused the exceedance of the ramping criterion. Events were only included if operational data indicated a significant decrease in plant generation (based on hourly data), or if there was a corresponding rise in stage at the gauge below the intake and no decrease in stage recorded at the gauge upstream of the intake.

Table 18 includes the time the event started, maximum change in stage within one hour, maximum stage change upstream of the intake (within one hour), and the RISC grade of the stage data from MQM-DSLG03. Appendix E provides a list of all events after September 1, 2015 that exceeded the ramping rate criterion when the plant was operational. Appendix E includes events that were likely natural ramping events, and events caused by the Upper Mamquam Hydroelectric Project or Skookum Hydroelectric Project, whereas Table 18 includes only events that were attributable to the Lower Mamquam Project.

In summary, between September 1, 2015 and August 31, 2016, four ramping events were detected in the diversion reach of Mamquam River (MQM-DVLG01) that were confirmed to be plant induced. An additional 97 false alarms on 72 separate days were recorded in the diversion reach during periods when the plant was confirmed to be operating within compliance (Appendix C). The events that resulted in false alarms can be characterized as follows (Table 19): 22 did not violate the wetted history rule (channel was not wetted long enough prior to the event for fish to have colonized dewatered areas), 61 were a result of rapid natural flow change when the plant was operating normally, five were the result of a sawtooth pattern in the diversion resulting in exaggerated ramping rates, and nine were caused by flow changes resulting at the Upper Mamquam or Skookum plants.

Two ramping events were recorded in the downstream reach of the Mamquam River (MQM-DSLG03) during periods when the plant was operational and flow was changing through the plant (Table 18). An additional 12 false alarms on 11 separate days were recorded in the downstream reach during periods when the plant was confirmed to be operating within compliance (Table 19). The events that resulted in false alarms can be characterized as follows: two did not violate the wetted history rule (channel was not wetted long enough prior to the event for fish to have colonized dewatered areas), six were the result of rapid natural flow change when the plant was operating normally, and four were caused by flow changes resulting at the Upper Mamquam plant or Skookum plant.

#### 3.2.3.2. Stranding Searches

Stranding searches were not conducted for the four ramping events detected in the diversion reach, as there was low probability of fish stranding due to the wetted history rule, timing of the events (fish are more mobile at night), and minimal stranding habitat (Table 17). This assessment of fish stranding risk is supported by results from the five year monitoring period (Buchanan *et al.* 2016). Stranding searches were conducted for both ramping events detected in the downstream reach. One search was conducted during the fry present period (August 4, 2016) and one search was conducted during parr present periods (November 28, 2015); no stranded or isolated fish were found during these stranding searches.

**Table 17. Ramping events recorded in the diversion (MQM-DVLG01) when the plant was ramping for the period September 1, 2015 to August 31, 2016.**

| Year | Date | Start Time | Duration of Stage Decline (min) | Maximum MQM-DVLG01 Ramping Rate (cm/hr) | MQM-DVLG01 Ramping Rate Relative to 24 hr avg Stage (cm/hr)[1] | MQM-USLG01 Ramping Rate (cm/hr) | MQM-DVLG01 Stage RISC Grade | Maximum MQM-DVLG01 Discharge ($m^3/s$) | Event Searched | Fish Found[2] | Rationale if the Event was not Searched |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2015 | 11-Nov | 4:52 | 226 | -14.0 | n/a | -1.4 | RISC Grade B | 3.9 | No | n/a | Low Probability[3] |
| | 29-Nov | 1:16 | 66 | -9.5 | -0.3 | -2.0 | RISC Grade B | 4.3 | No | n/a | Low Probability[3] |
| 2016 | 24-Mar | 2:00 | 430 | -24.4 | n/a | -1.9 | RISC Grade B | 10.8 | No | n/a | Low Probability[4] |
| | 18-Jul | 21:04 | 94 | -26.6 | 6.5 | -2.5 | RISC Grade B | 15.2 | No | n/a | Low Probability[3] |

[1] n/a means the stage at MQM-DVLG01 was below the 24 hr average

[2] n/a means the event was not searched

[3] Low probability of fish stranded due to short wetted history

[4] Low probability of fish stranded due to short wetted history, moderate flow, and the timing of the event was at night when fish are more mobile

**Table 18.** **Ramping events recorded downstream of the powerhouse (MQM-DSLG03) when the plant was ramping for the period September 1, 2015 to August 31, 2016.**

| Year | Date | Start Time | Duration out of Compliance (min) | Maximum MQM-DSLG03 Ramping Rate (cm/hr) | MQM-DSLG03 Ramping Rate Relative to 24 hr avg Stage (cm/hr)[1] | MQM-USLG01 Ramping Rate (cm/hr) | MQM-DSLG03 Stage RISC Grade | Maximum MQM-DSLG03 Discharge ($m^3/s$) | Event Searched | Fish Found | Rationale if the Event was not Searched |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2015 | 28-Nov | 14:34 | 56 | -27.0 | -26.9 | -0.2 | RISC Grade B | 8.0 | Yes | No | n/a |
| 2016 | 4-Aug | 14:22 | 20 | -9.2 | -6.6 | -0.4 | RISC Grade B | 12.6 | Yes | No | n/a |

[1] n/a means the stage at MQM-DSLG03 was below the 24 hr average



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**Table 19. Summary of false ramping alarms generated by events and rationale. Events that violate the exceedance rule and the dewatering rule are included, but for events in the Mamquam River diversions and downstream reaches are screened out against criteria 3 through 7.**

| Rationale for false alarm | Number of Diversion false alarms | Number of Downstream false alarms |
|---|---|---|
| 3. Wetted History | 22 | 2 |
| 5. Operating within parameters | 61 | 6 |
| 6. Sawtooth pattern | 5 | n/a |
| 7. Result of Upper Projects[1] | 9 | 4 |
| Total | 97 | 12 |

[1] Events due to either Upper Mamquam or Skookum Projects

# 4. SLUICING

## 4.1. Background

Annual sluicing prevents excess build-up of sediment, and serves to prevent head pond overflow of the intake structure which may cause severe damage. In addition, high flow events occasionally result in large trees/logs and other debris being transported into the sluiceway. Opening the sluice gates is the only way to flush these objects and prevent damage to trash rack cleaning equipment and intake screens (APC 2014).

Sediment and debris are expected to be flushed from the sluiceway through use of sluiceway radial gates during each operating year. Sluicing is timed to occur in the fall, coincident with high river flows (>80 $m^3/s$). Instream turbidity is naturally very high at these flows; levels approached 1000 NTU in fall of 2016.

The duration of headpond sluicing and turbidity levels prior to and during the sluicing event must be reported annually by APC (APC 2014).

## 4.2. Methods

To monitor turbidity levels during sluicing and non-sluicing conditions, in 2011 a turbidity meter was installed below the Lower Mamquam intake at MQM-DVLG01 (Map 1). This meter was damaged during a high flow event on January 28, 2016 and replaced following freshet during the summer low flow period on August 10, 2016. It is wired to a Unidata Neon data logger, which transmits the turbidity data to the Unidata server, via satellite or cell communications. The turbidity meter is calibrated annually in the field by immersing the sensor into solutions of known turbidity values. An offset that assumes a linear curve is then applied to turbidity values to account for sensor "drift".

### 4.3. Results

No active sluicing events occurred during the monitoring period, because the plant was shut down, the weir was deflated, and the headpond was dewatered during fall of 2015, the high flow period when sluicing would normally occur.

## 5. RECOMMENDATIONS

### 5.1. Hydrology

Additional discharge measurements would further validate the rating curves. Further measurements outside of the current range of measured flows would also verify the application of the rating curve to a greater range of stage data. Continued monitoring is recommended for this reason, and to monitor any shifts or changes to the stage-discharge relationship. Specific recommendations include more frequent discharge measurements following storm events at all gauges, and flow measurements near IFR (1 $m^3/s$) at MQM-DVLG01 following any headpond flushing event from the Lower Mamquam or either of the upstream projects. Specific flow measurement targets will be assessed during the 2016-2017 monitoring period.

### 5.2. Flow Compliance

No changes are recommended at this time.

### 5.3. Sluicing

The turbidity data offset assumes a linear curve between low and high turbidity values, but this assumption has not been tested. We therefore recommend a field calibration with a wide range of data points and calculation of a non-linear curve in 2017.

## 6. CLOSURE

This report has been prepared to meet hydrology, flow compliance, ramping, and sluicing monitoring requirements of the Project's OPPR. Gauge installation and maintenance data demonstrates adherence to proper QA/QC procedures. Discharge measurements at the four gauge locations were used to develop rating curves, and subsequent evaluation of derived discharge data shows that the Project was compliant with the minimum IFR (instream flow requirement) of 1.0 m3/s as required by the water license. Between September 1, 2015 and August 31, 2016 four ramping events were detected in the diversion reach, and two in the downstream reach of the Mamquam River. No stranding searches were conducted in the diversion because of the low risk of fish stranding in this reach. Stranding searches were conducted for both ramping events in the downstream reach on August 4, 2016 and November 28, 2015. No stranded or isolated fish were found during these stranding searches. No active sluicing occurred during the operational period from September 2015 to August 2016 and therefore no monitoring was required. This report is intended to be used as a demonstration of the Project's adherence to the OPPR.

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## PROJECT MAPS

Path: ...Projects-Active\1071-04-Mamquam\MXD\1071_MQM_GaugesAndDischarge_2012Oct29_EF.mxd


LOWER MAMQUAM RIVER HYDRO PROJECT
Discharge Measurement Locations
Gauge MQM-DVLG01
Legend
Discharge Measurement Location
Hydrometric Gauge
Infrastructure
Intake
Powerhouse
Penstock
Existing Transmission Line
Forest Tenure Road
Road
Parks and Protected Areas
100m Contour
MQM-TRQ09
MQM-DVMS01
MQM-TRQ06
MQM-TRQ02
MQM-DVMS03
MQM-DVLG01
MQM-INJ01
MQM-TRQ10
Mamquam River
Lower Mamquam Intake
RFE-USLG01
MQM-TRQ15
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493965
494465
494965
495465
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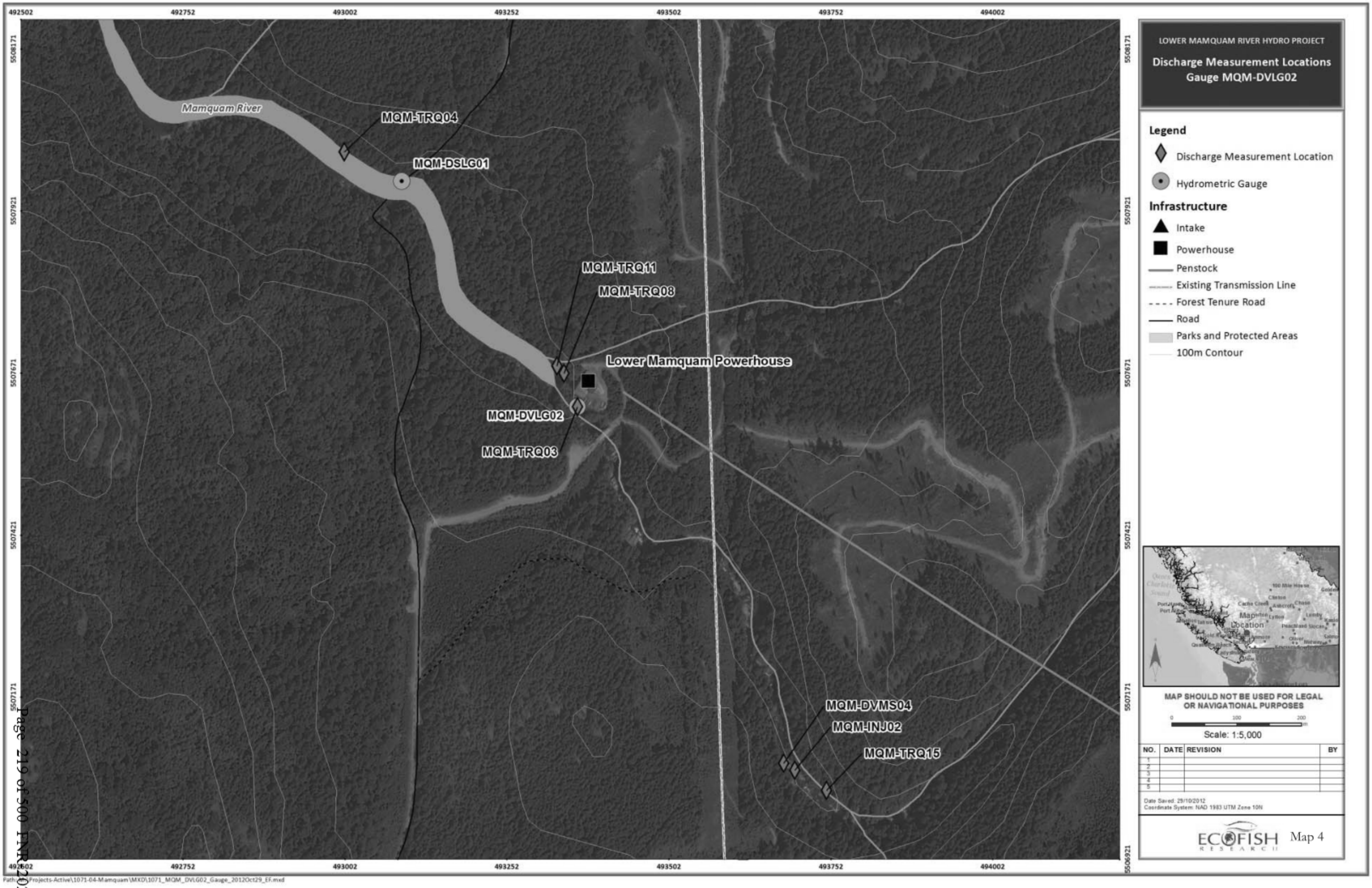
5507920
5507420
5506920
5506420
5505920
MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES
Scale: 1:10,000
NO.
DATE
REVISION
BY
Date Saved: 29/10/2012
Coordinate System: NAD 1983 UTM Zone 10N
ECOFISH RESEARCH
Map 3
Path: Projects-Active\1071-04-Mamquam\MXD\1071_MQM_DVLG01_Gauge_2012Oct29_EF.mxd


LOWER MAMQUAM RIVER HYDRO PROJECT
Discharge Measurement Locations
Gauge MQM-DVLG02
Legend
Discharge Measurement Location
Hydrometric Gauge
Infrastructure
Intake
Powerhouse
Penstock
Existing Transmission Line
Forest Tenure Road
Road
Parks and Protected Areas
100m Contour
Mamquam River
MQM-TRQ04
MQM-DSLG01
MQM-TRQ11
MQM-TRQ08
Lower Mamquam Powerhouse
MQM-DVLG02
MQM-TRQ03
MQM-DVMS04
MQM-INJ02
MQM-TRQ15
492502
492752
493002
493252
493502
493752
494002
5508171
5507921
5507671
5507421
5507171
5506921
MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES
Scale: 1:5,000
NO. DATE REVISION BY
Date Saved: 29/10/2012
Coordinate System: NAD 1983 UTM Zone 10N
ECOFISH RESEARCH
Map 4
Projects-Active\1071-04-Mamquam\MXD\1071_MQM_DVLG02_Gauge_2012Oct29_EF.mxd


LOWER MAMQUAM RIVER HYDRO PROJECT
Discharge Measurement Locations
Gauges MQM-DSLG01/MQM-DSLG03
Legend
Discharge Measurement Location
Hydrometric Gauge
Infrastructure
Intake
Powerhouse
Penstock
Existing Transmission Line
Forest Tenure Road
Road
Parks and Protected Areas
100m Contour
MSH-TRQ01
MQM-TRQ14
MQM-TRQ13
MQM-TRQ12
MQM-DSLG02
Mamquam River
MQM-TRQ05
MQM-TRQ04
MQM-DSLG01
Lower Mamquam Powerhouse
MQM-DSLG03
MQM-DVLG02
British Columbia
Map Location
MAP SHOULD NOT BE USED FOR LEGAL OR NAVIGATIONAL PURPOSES
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NO. DATE REVISION BY
Date Saved: 30/11/2015
Coordinate System: NAD 1983 UTM Zone 10N
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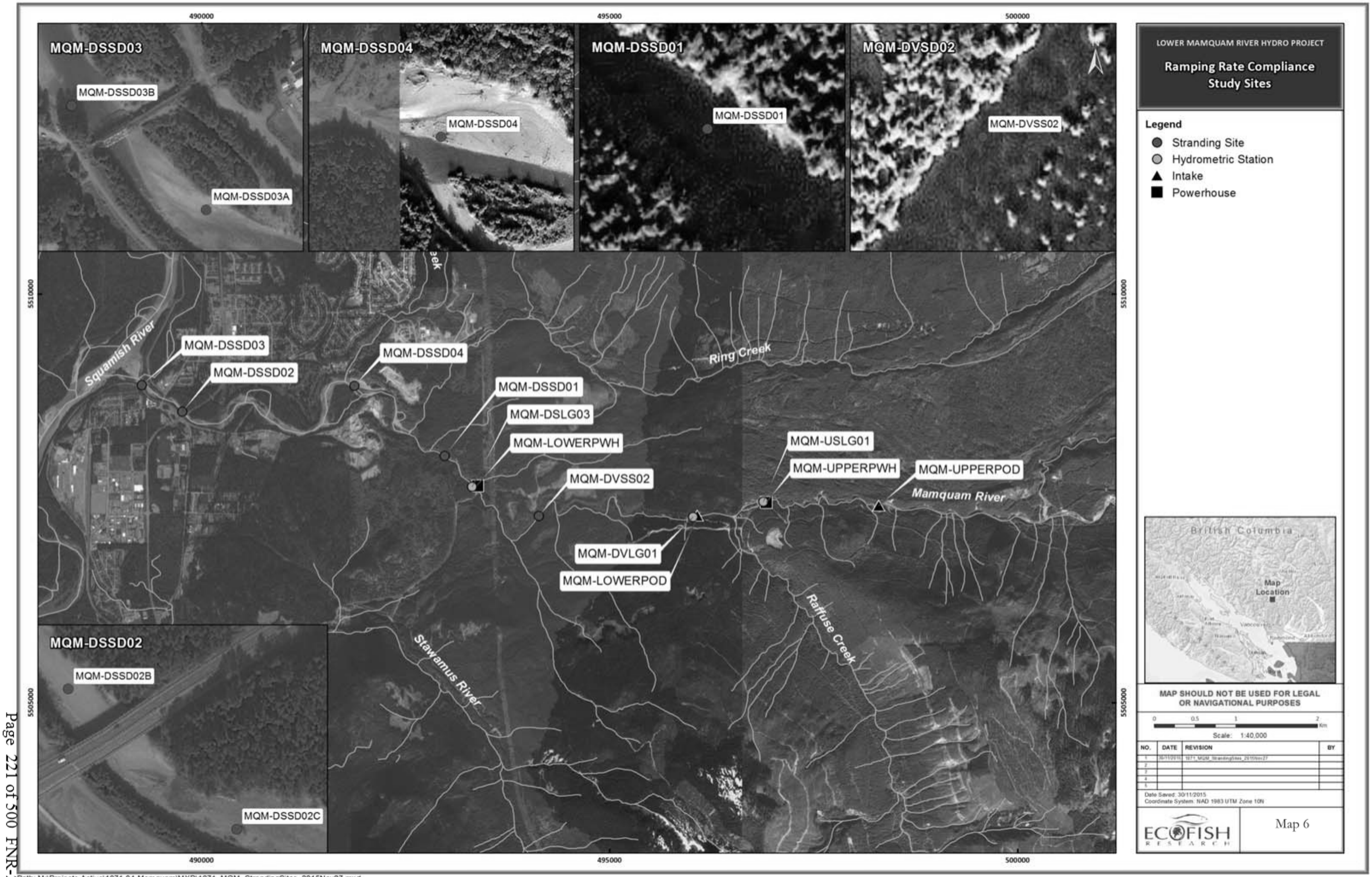
Map 5

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# APPENDICES

## Appendix A. Monthly plots for MQM-DVLG01, showing discharge calculated using RC9, compared to the IFR.

**Note: Plots for the months of September and October are not shown, as flow during these months exceeded 2.0 $m^3/s$ (the upper threshold of flow presented on IFR plots).**

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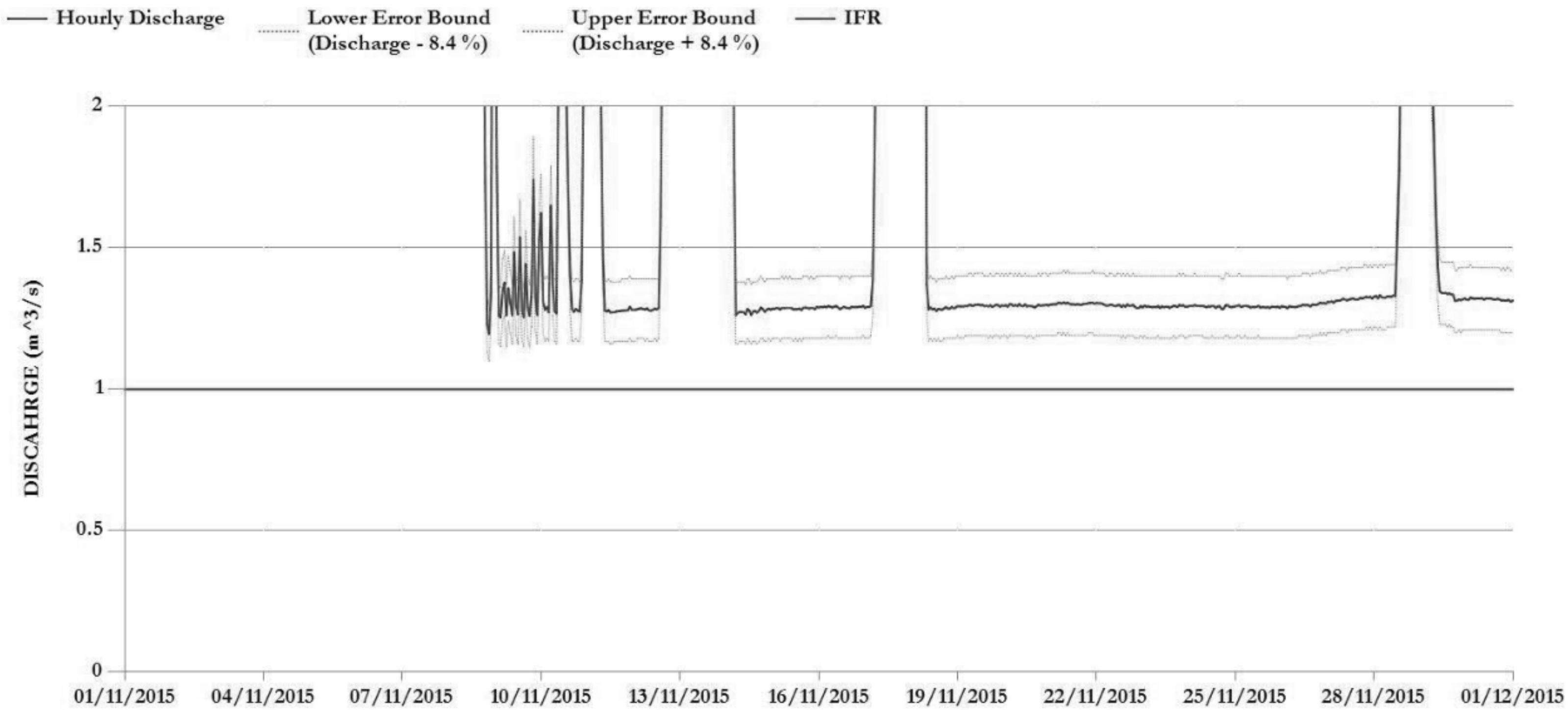
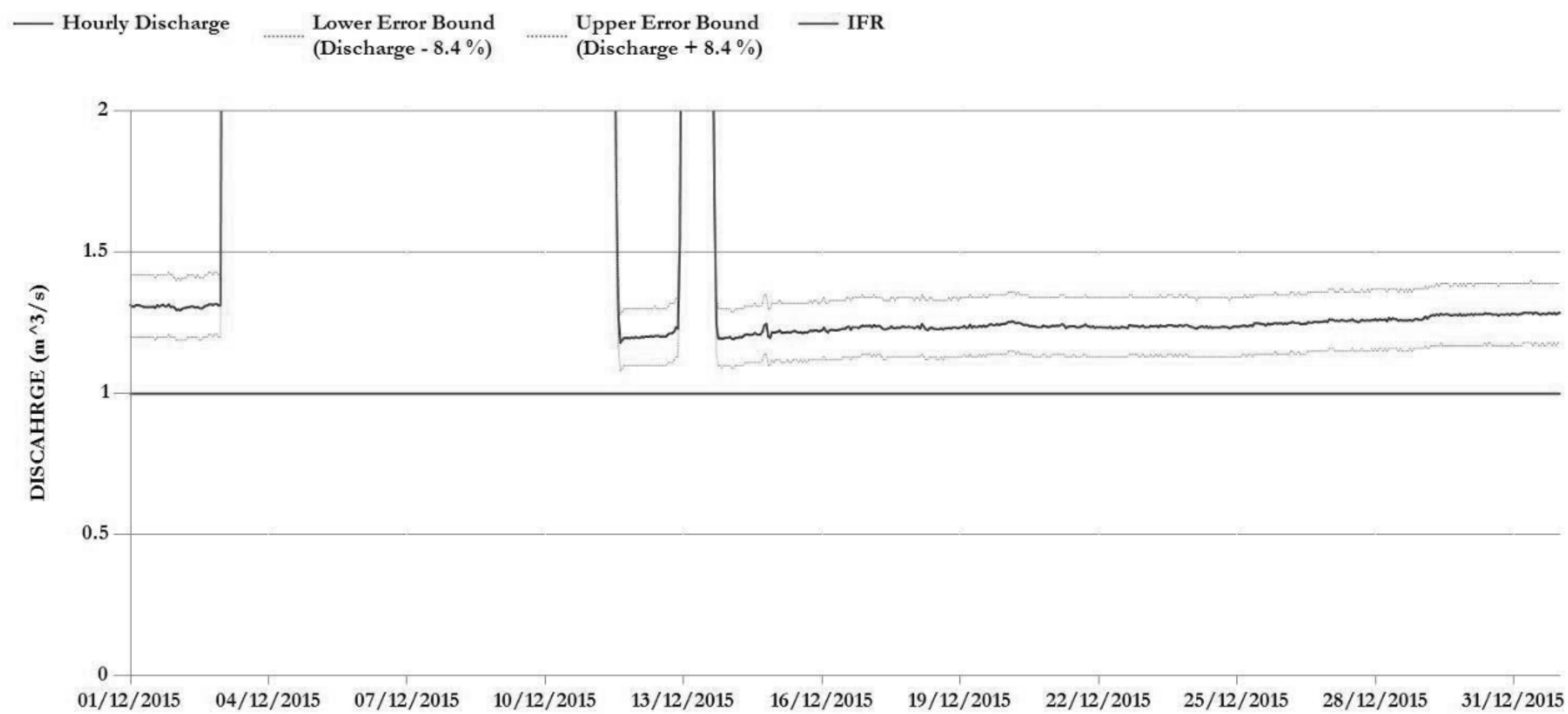
Figure 1. Hourly average discharge data from MQM-DVLG01, derived from RC9*: NOVEMBER 2015.



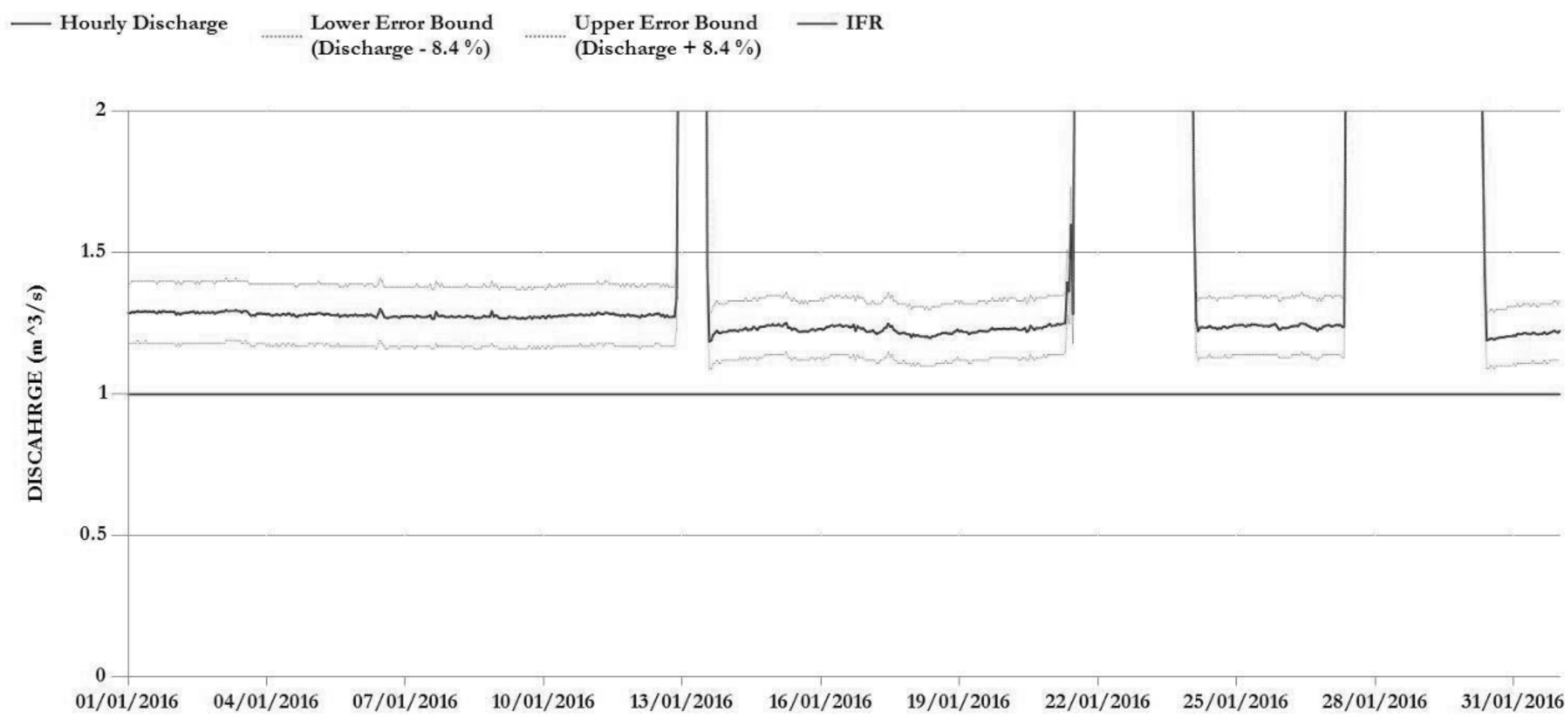

* Rating Curve 9 was used to derive flows from 7-May-2012 to 31-Aug-2016, and is based on measured flows 0.9 to 19.3 $m^3/s$. Flows outside of these measured flow ranges are estimates only, and subsequently fall under RISC Grade E. Flows above 2.0 $m^3/s$ are not shown.

Figure 2. Hourly average discharge data from MQM-DVLG01, derived from RC9*: DECEMBER 2015.



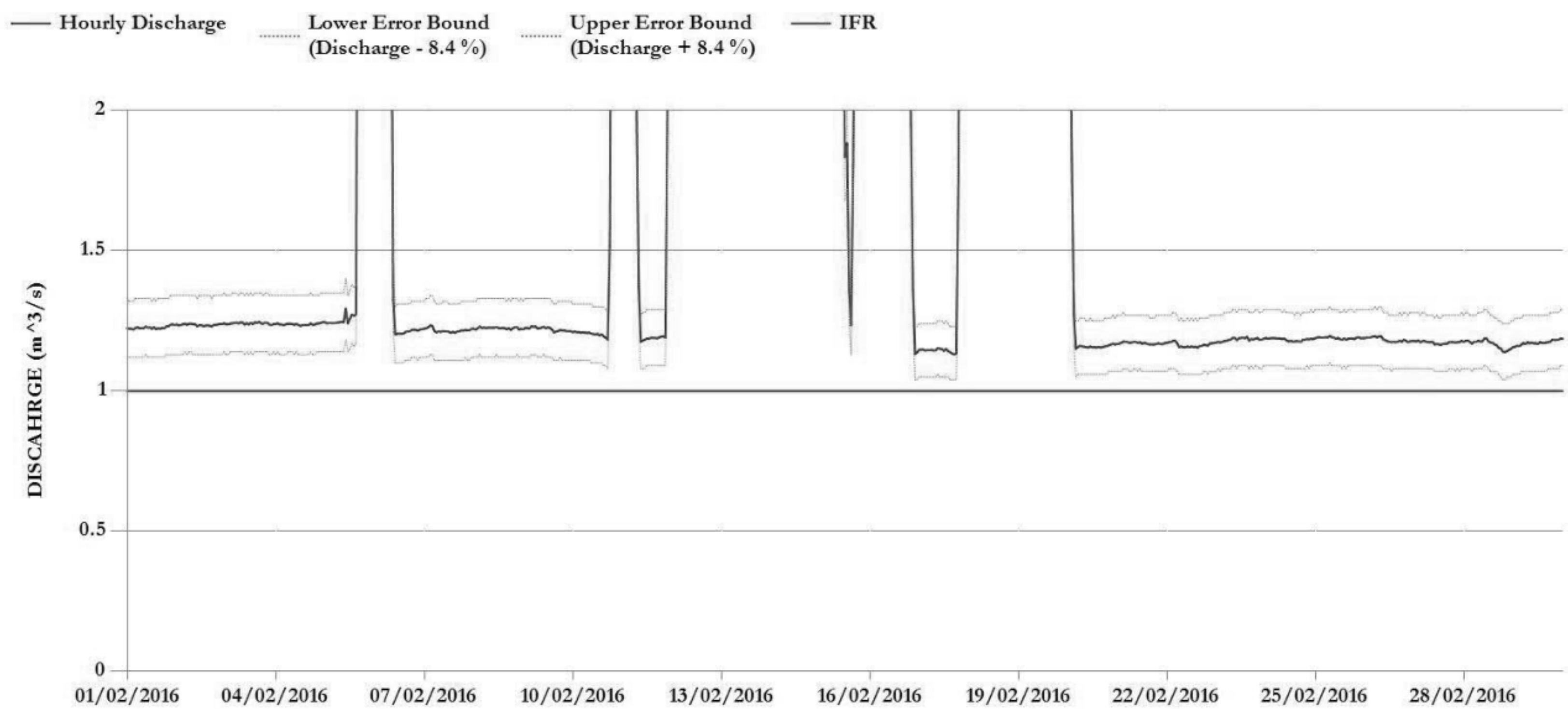

* Rating Curve 9 was used to derive flows from 7-May-2012 to 31-Aug-2016, and is based on measured flows 0.9 to 19.3 $m^3/s$. Flows outside of these measured flow ranges are estimates only, and subsequently fall under RISC Grade E. Flows above 2.0 $m^3/s$ are not shown.

**Figure 3. Hourly average discharge data from MQM-DVLG01, derived from RC9*: JANUARY 2016.**



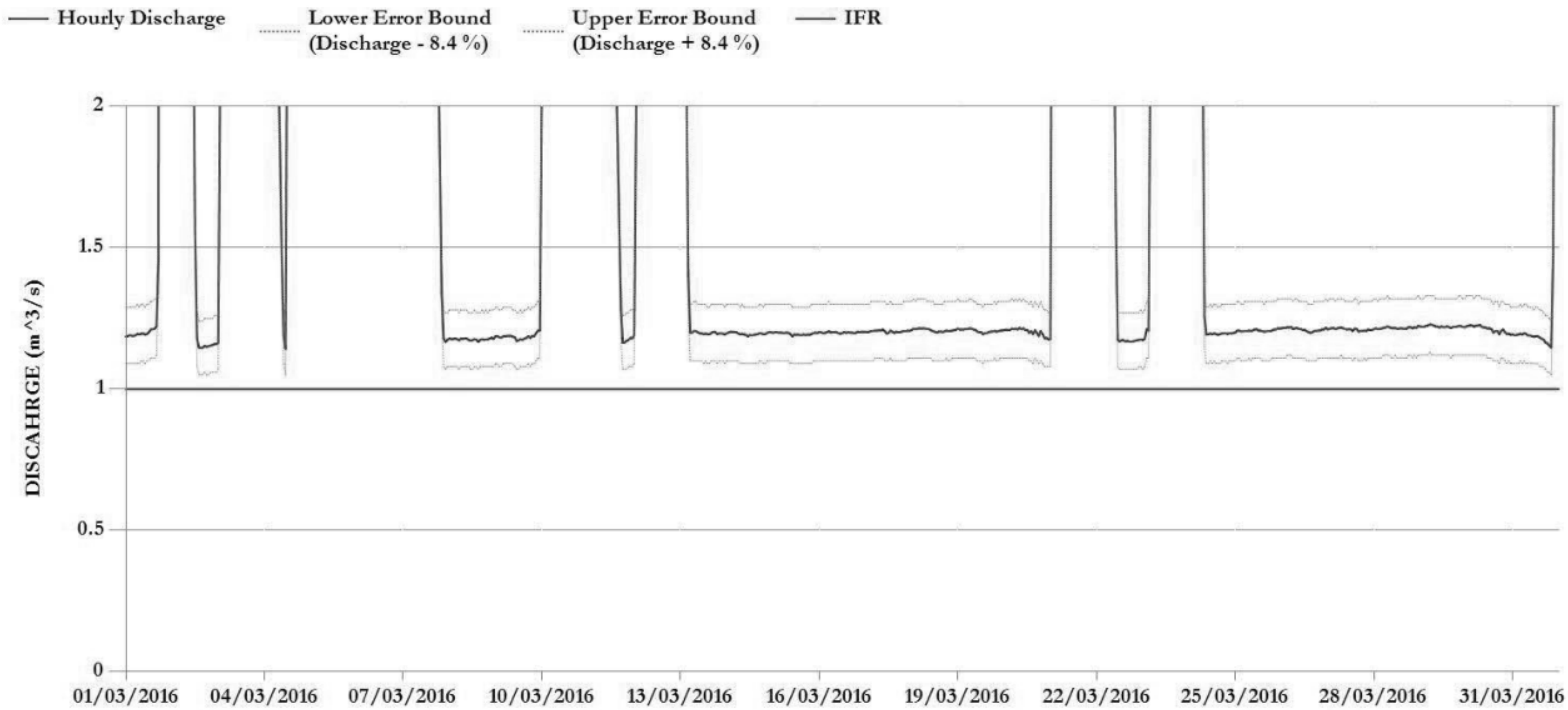

* Rating Curve 9 was used to derive flows from 7-May-2012 to 31-Aug-2016, and is based on measured flows 0.9 to 19.3 $m^3/s$.
Flows outside of these measured flow ranges are estimates only, and subsequently fall under RISC Grade E.
Flows above 2.0 $m^3/s$ are not shown.

**Figure 4. Hourly average discharge data from MQM-DVLG01, derived from RC9*: FEBRUARY 2016.**



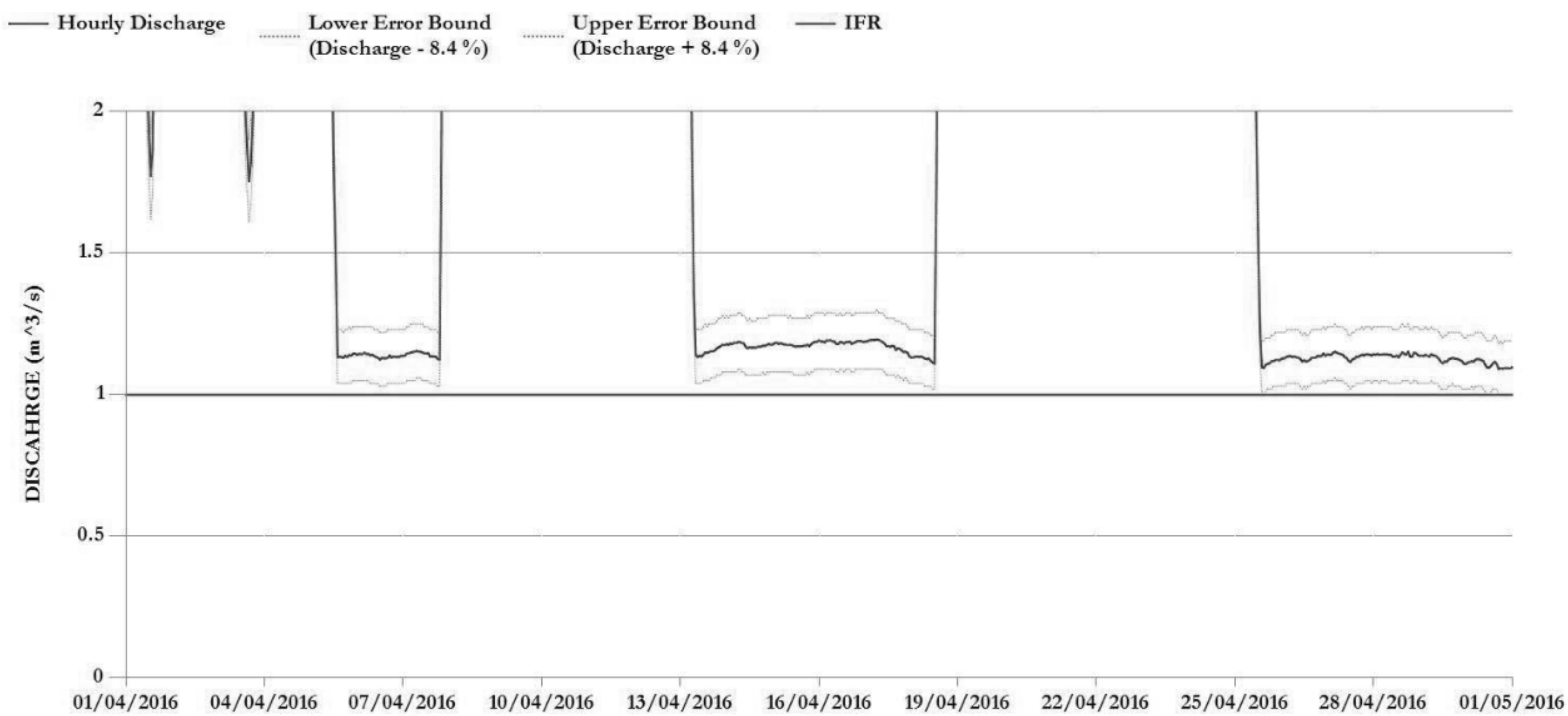

*Rating Curve 9 was used to derive flows from 7-May-2012 to 31-Aug-2016, and is based on measured flows 0.9 to 19.3 $m^3/s$. Flows outside of these measured flow ranges are estimates only, and subsequently fall under RISC Grade E. Flows above 2.0 $m^3/s$ are not shown.

**Figure 5. Hourly average discharge data from MQM-DVLG01, derived from RC9*: MARCH 2016.**



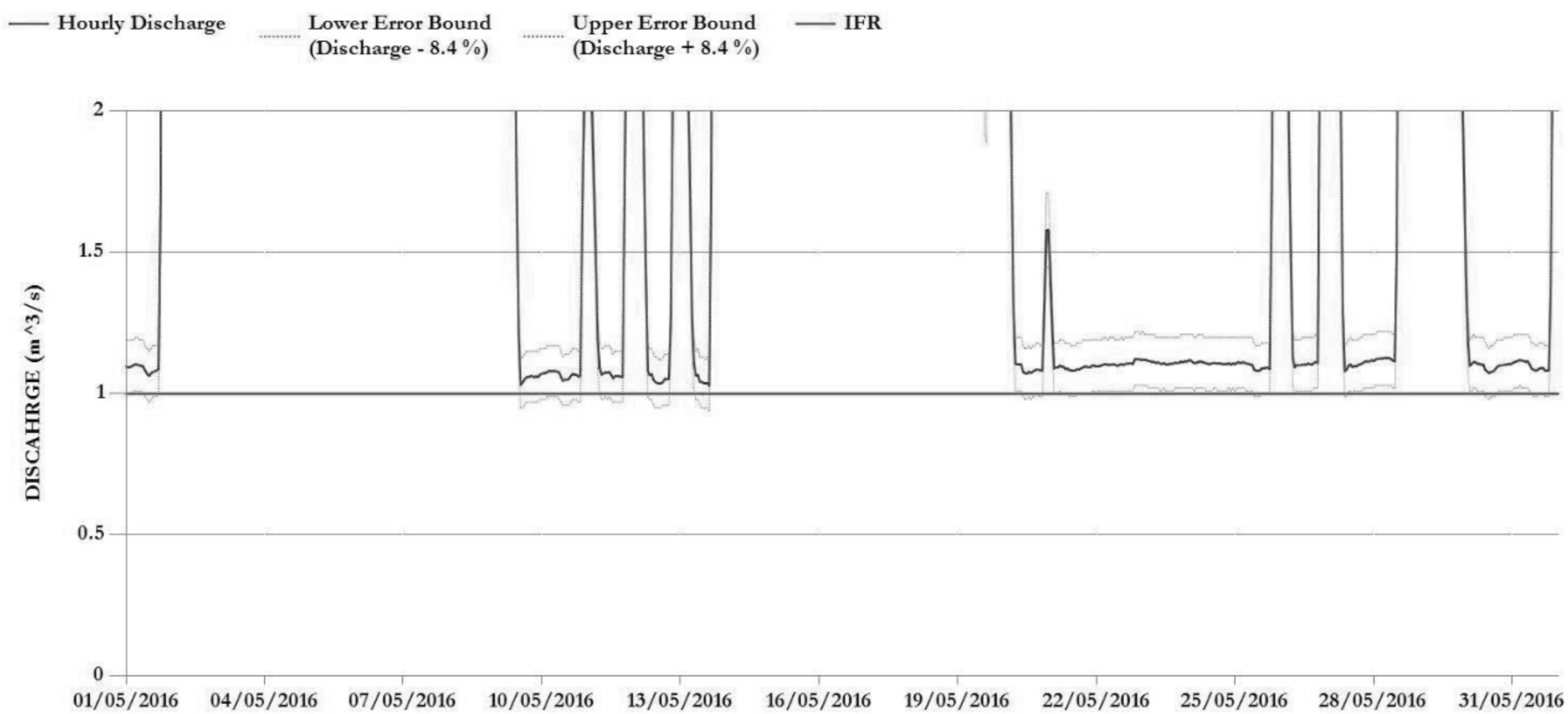

*Rating Curve 9 was used to derive flows from 7-May-2012 to 31-Aug-2016, and is based on measured flows 0.9 to 19.3 $m^3/s$. Flows outside of these measured flow ranges are estimates only, and subsequently fall under RISC Grade E. Flows above 2.0 $m^3/s$ are not shown.

**Figure 6. Hourly average discharge data from MQM-DVLG01, derived from RC9*: APRIL 2016.**



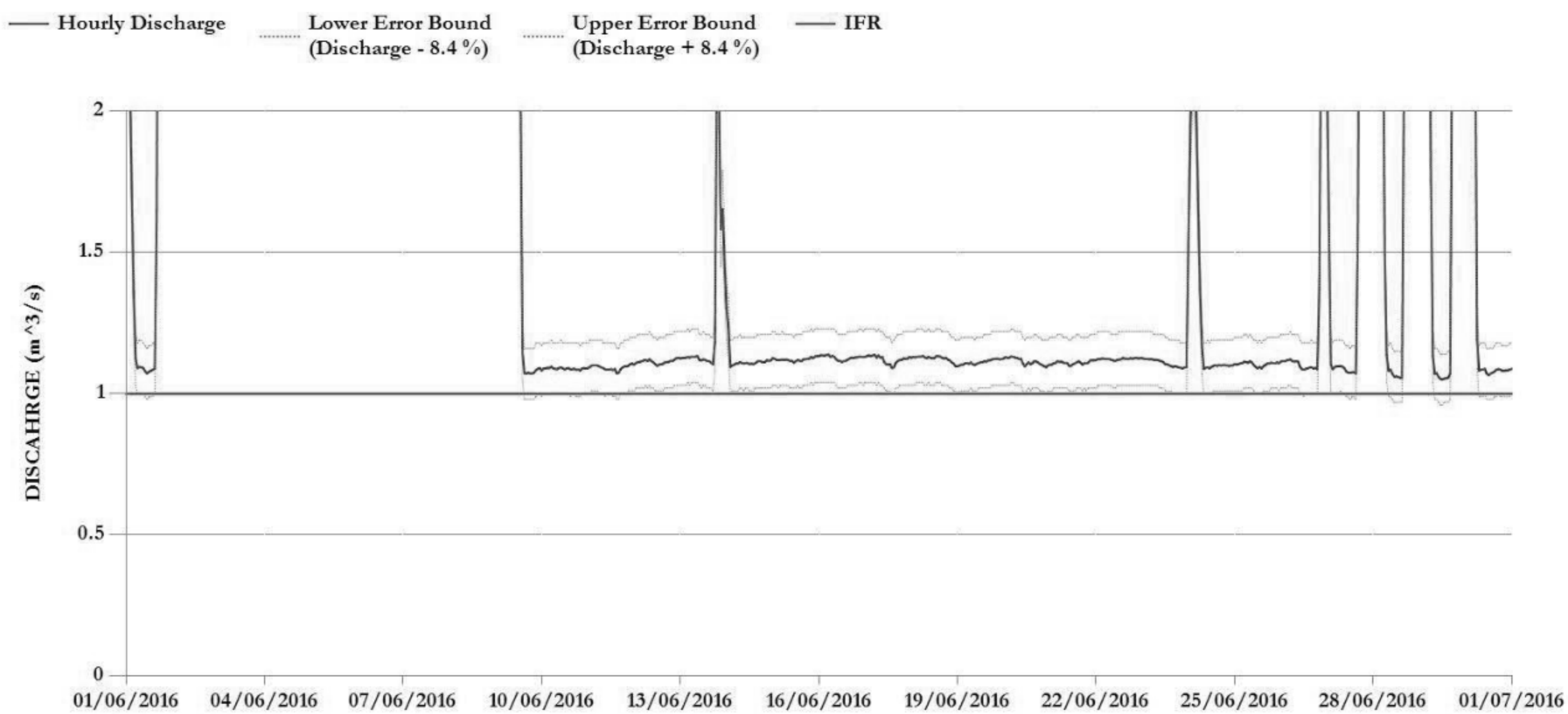

*Rating Curve 9 was used to derive flows from 7-May-2012 to 31-Aug-2016, and is based on measured flows 0.9 to 19.3 $m^3/s$. Flows outside of these measured flow ranges are estimates only, and subsequently fall under RISC Grade E. Flows above 2.0 $m^3/s$ are not shown.

Figure 7. Hourly average discharge data from MQM-DVLG01, derived from RC9*: MAY 2016.



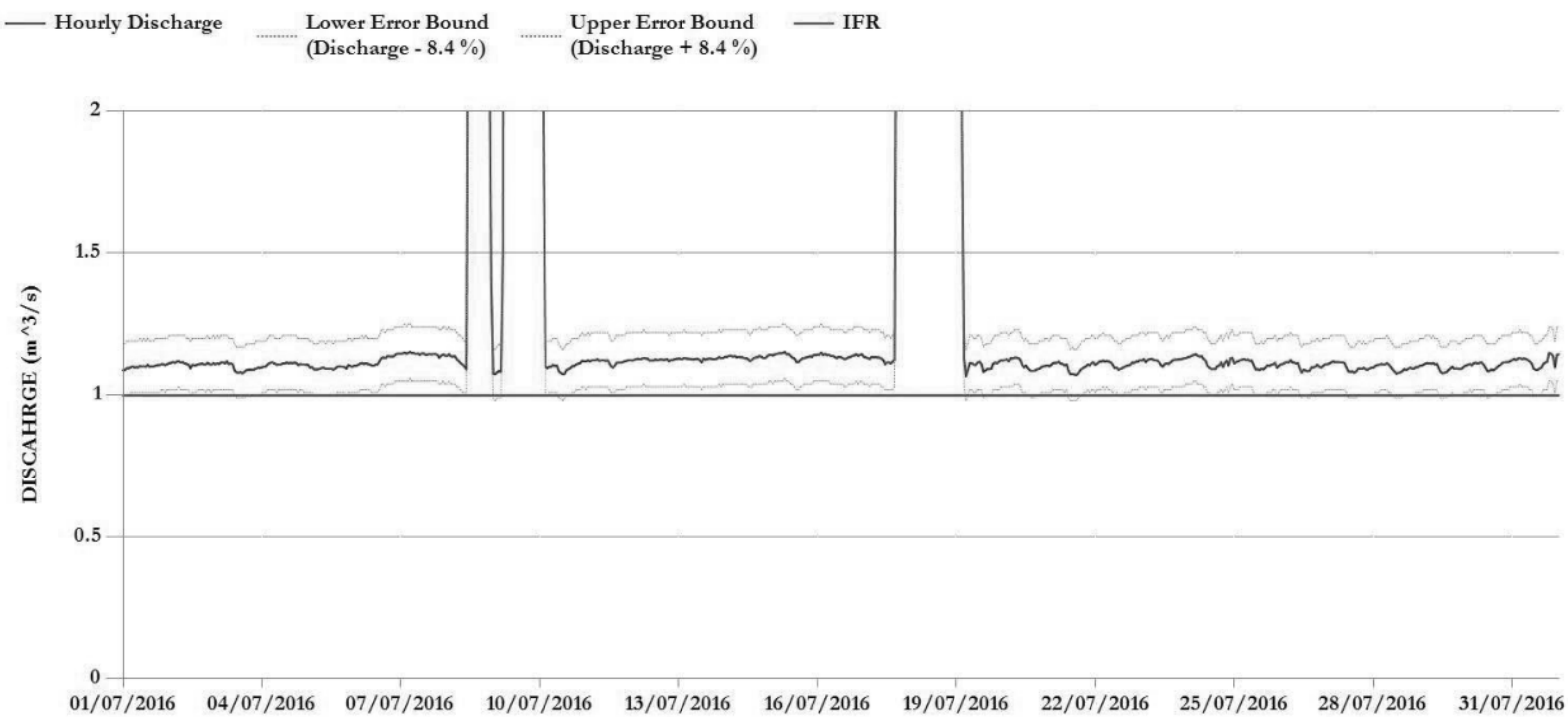

* Rating Curve 9 was used to derive flows from 7-May-2012 to 31-Aug-2016, and is based on measured flows 0.9 to 19.3 $m^3/s$.
Flows outside of these measured flow ranges are estimates only, and subsequently fall under RISC Grade E.
Flows above 2.0 $m^3/s$ are not shown.

Figure 8. Hourly average discharge data from MQM-DVLG01, derived from RC9*: JUNE 2016.



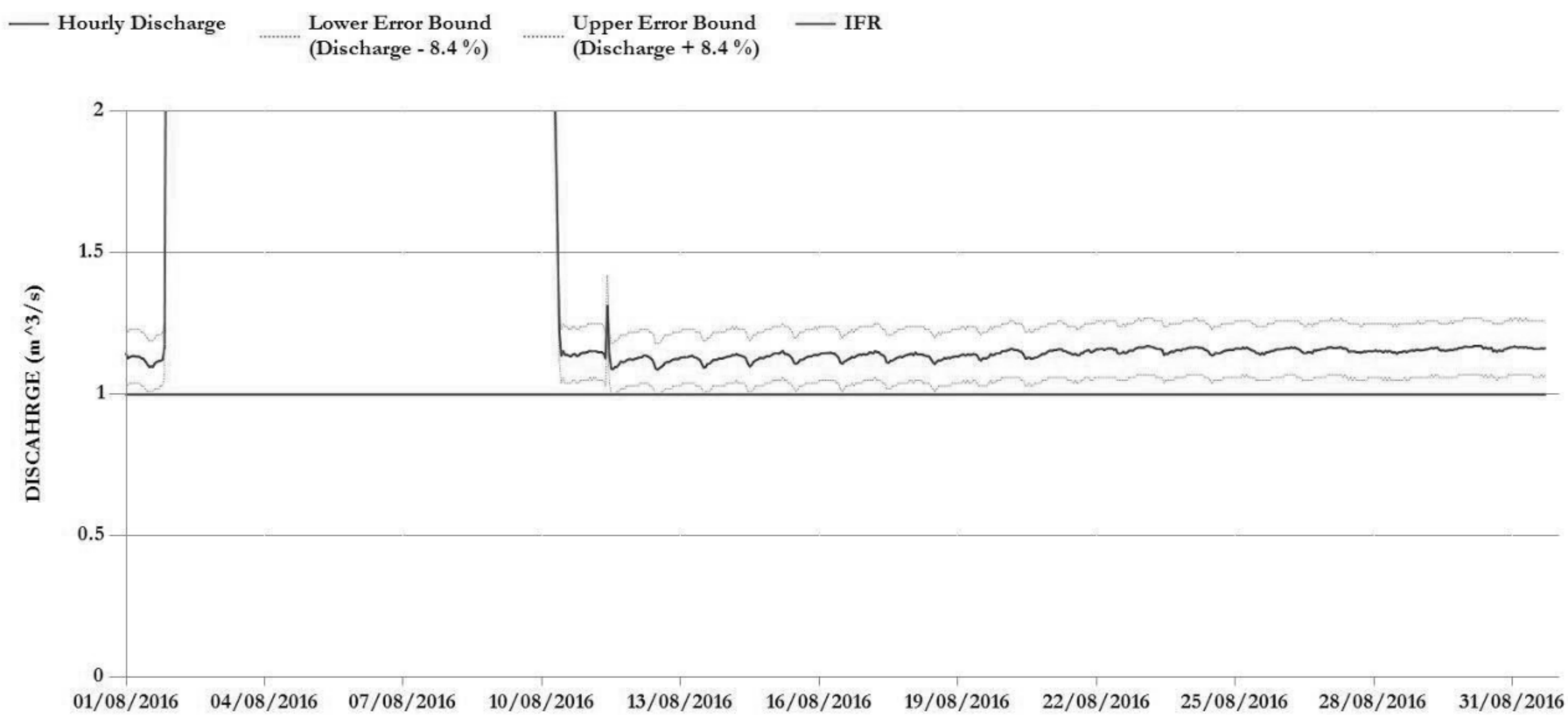

* Rating Curve 9 was used to derive flows from 7-May-2012 to 31-Aug-2016, and is based on measured flows 0.9 to 19.3 $m^3/s$. Flows outside of these measured flow ranges are estimates only, and subsequently fall under RISC Grade E. Flows above 2.0 $m^3/s$ are not shown.

**Figure 9. Hourly average discharge data from MQM-DVLG01, derived from RC9*: JULY 2016.**




* Rating Curve 9 was used to derive flows from 7-May-2012 to 31-Aug-2016, and is based on measured flows 0.9 to 19.3 $m^3/s$. Flows outside of these measured flow ranges are estimates only, and subsequently fall under RISC Grade E. Flows above 2.0 $m^3/s$ are not shown.

**Figure 10. Hourly average discharge data from MQM-DVLG01, derived from RC9*: AUGUST 2016.**




* Rating Curve 9 was used to derive flows from 7-May-2012 to 31-Aug-2016, and is based on measured flows 0.9 to 19.3 $m^3/s$. Flows outside of these measured flow ranges are estimates only, and subsequently fall under RISC Grade E. Flows above 2.0 $m^3/s$ are not shown.

## Appendix B. Plots of ramping events for MQM-DVLG01.

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**Figure 1. Discharges on November 7, 2015 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

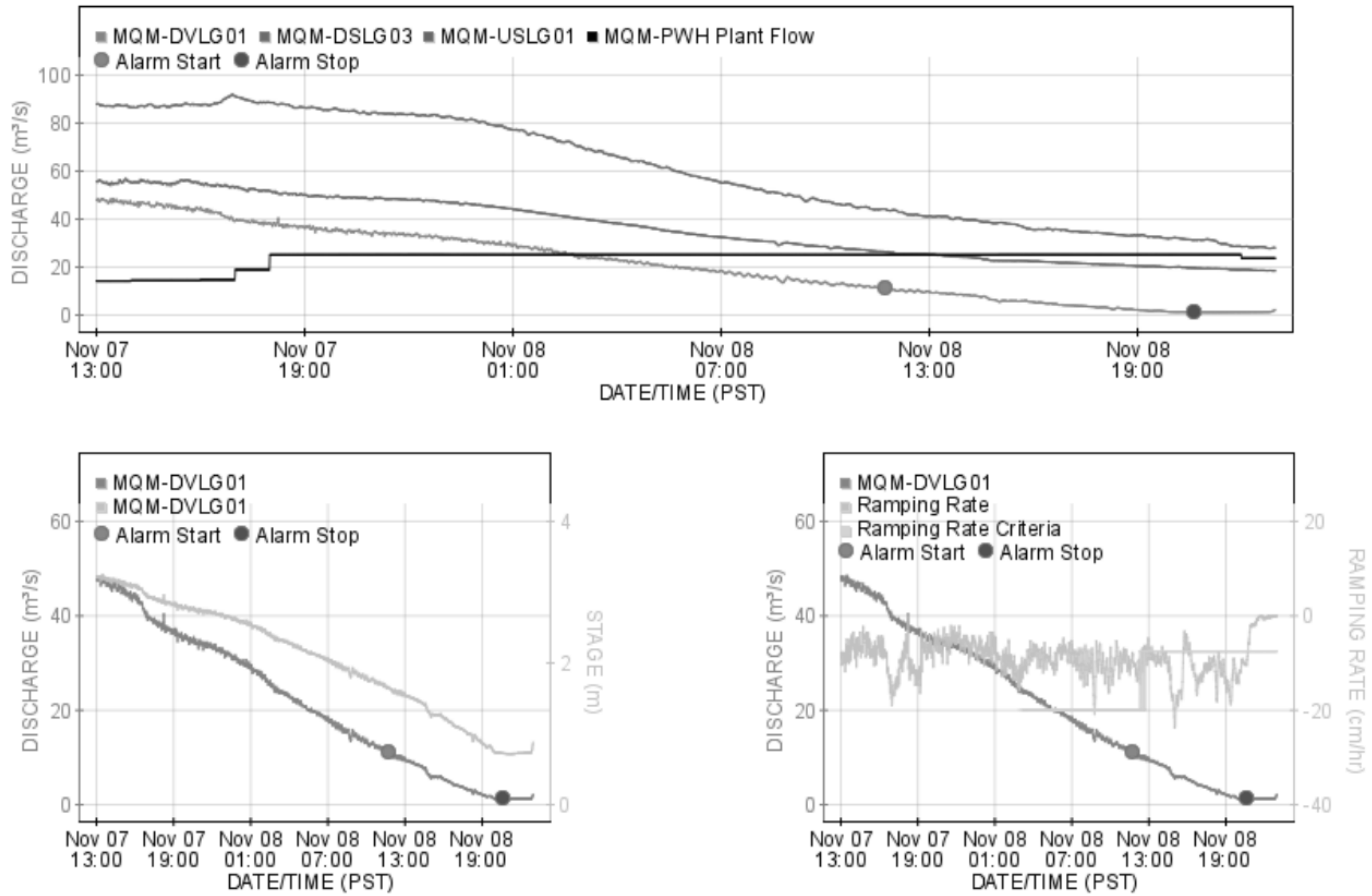
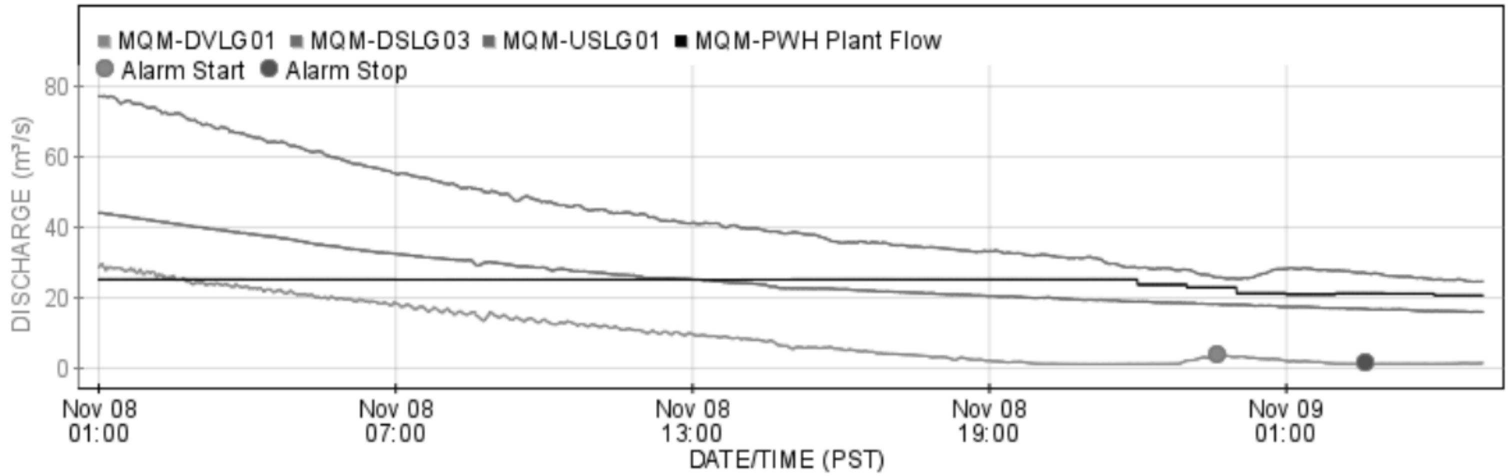
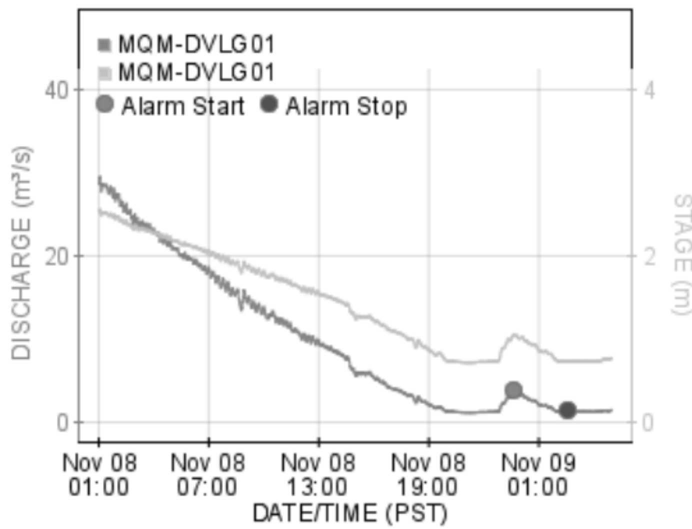


**Figure 2. Discharges on November 8, 2015 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**



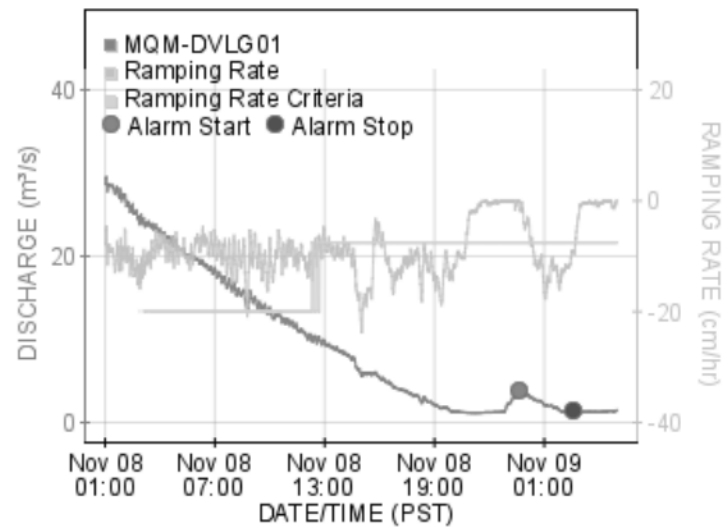



**Figure 3.** **Discharges on November 8, 2015 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

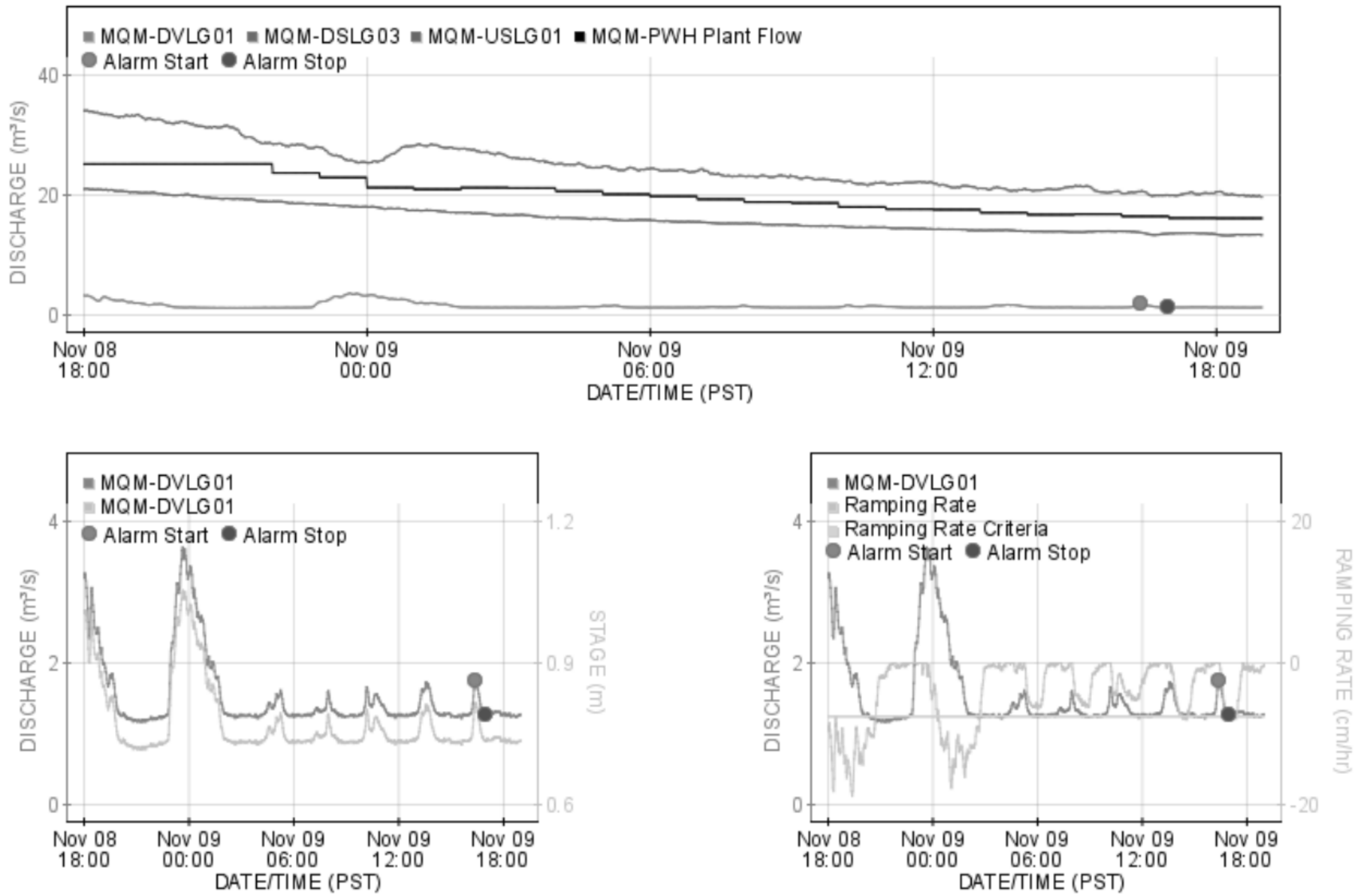
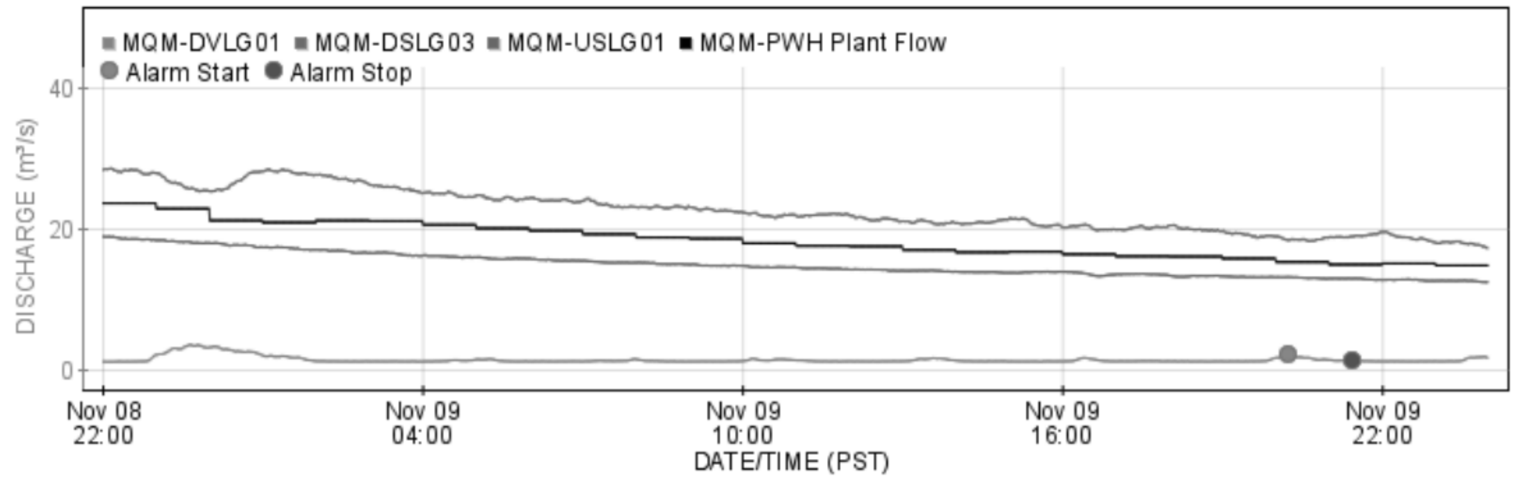
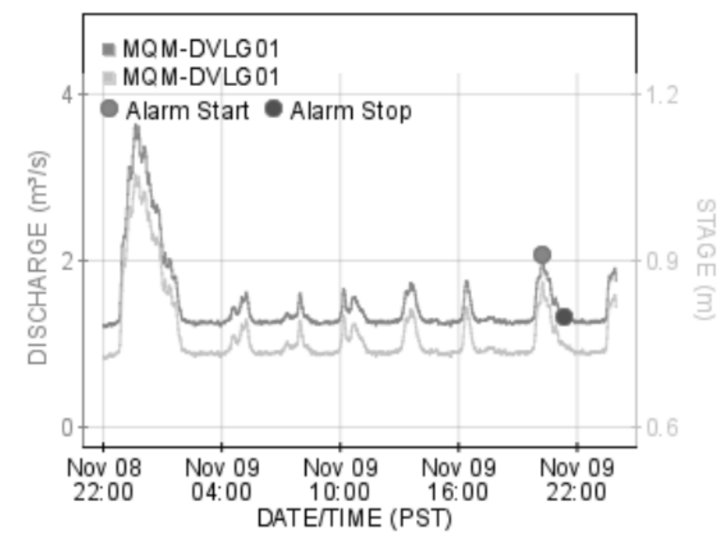


**Figure 4.** **Discharges on November 8, 2015 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**



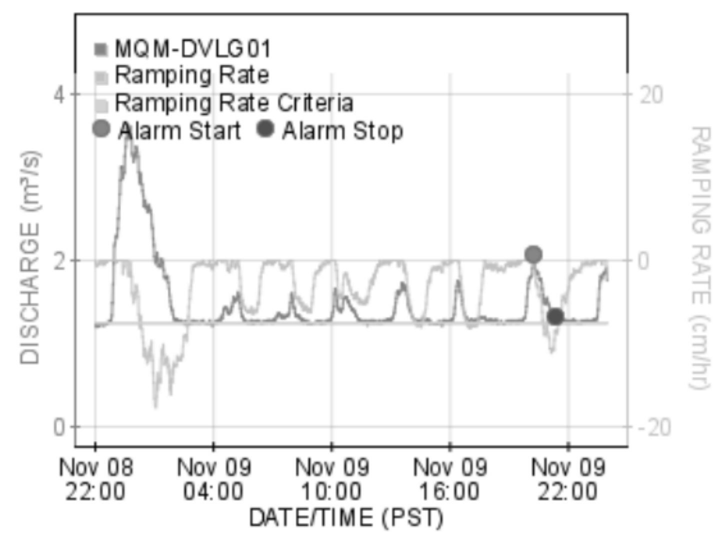



**Figure 5. Discharges on November 9, 2015 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

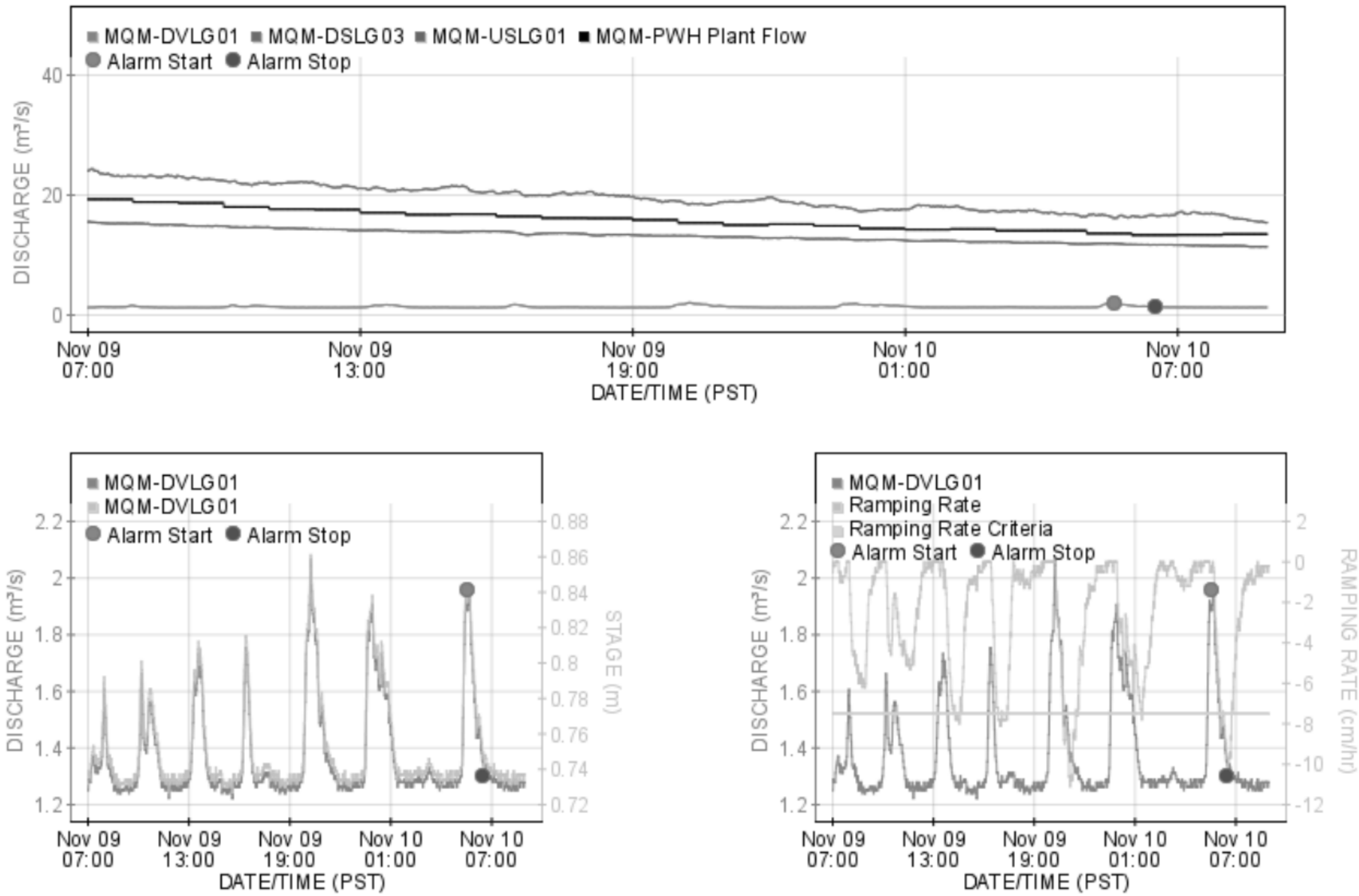


**Figure 6. Discharges on November 10, 2015 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

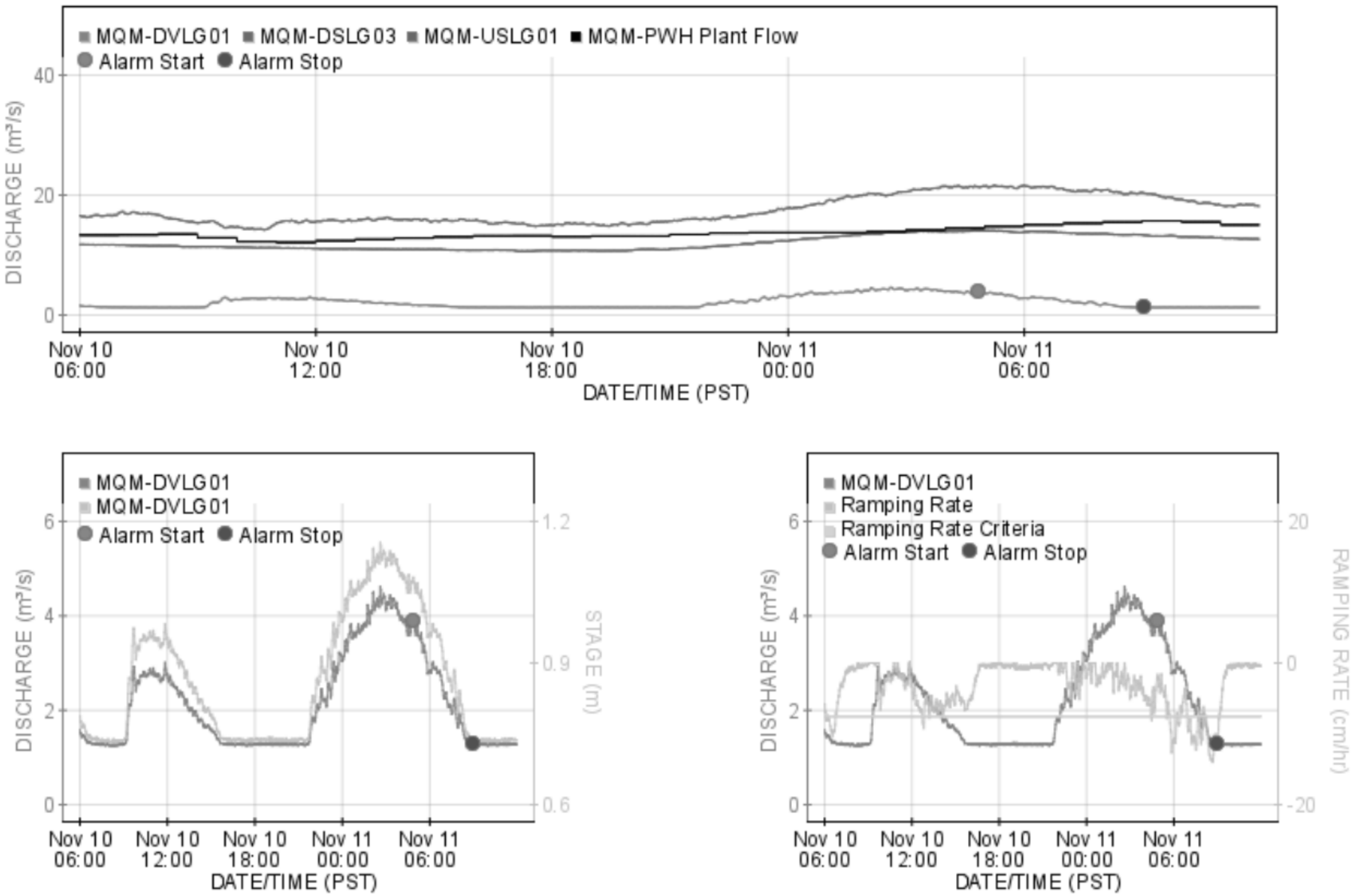


**Figure 7.** **Discharges on November 12, 2015 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

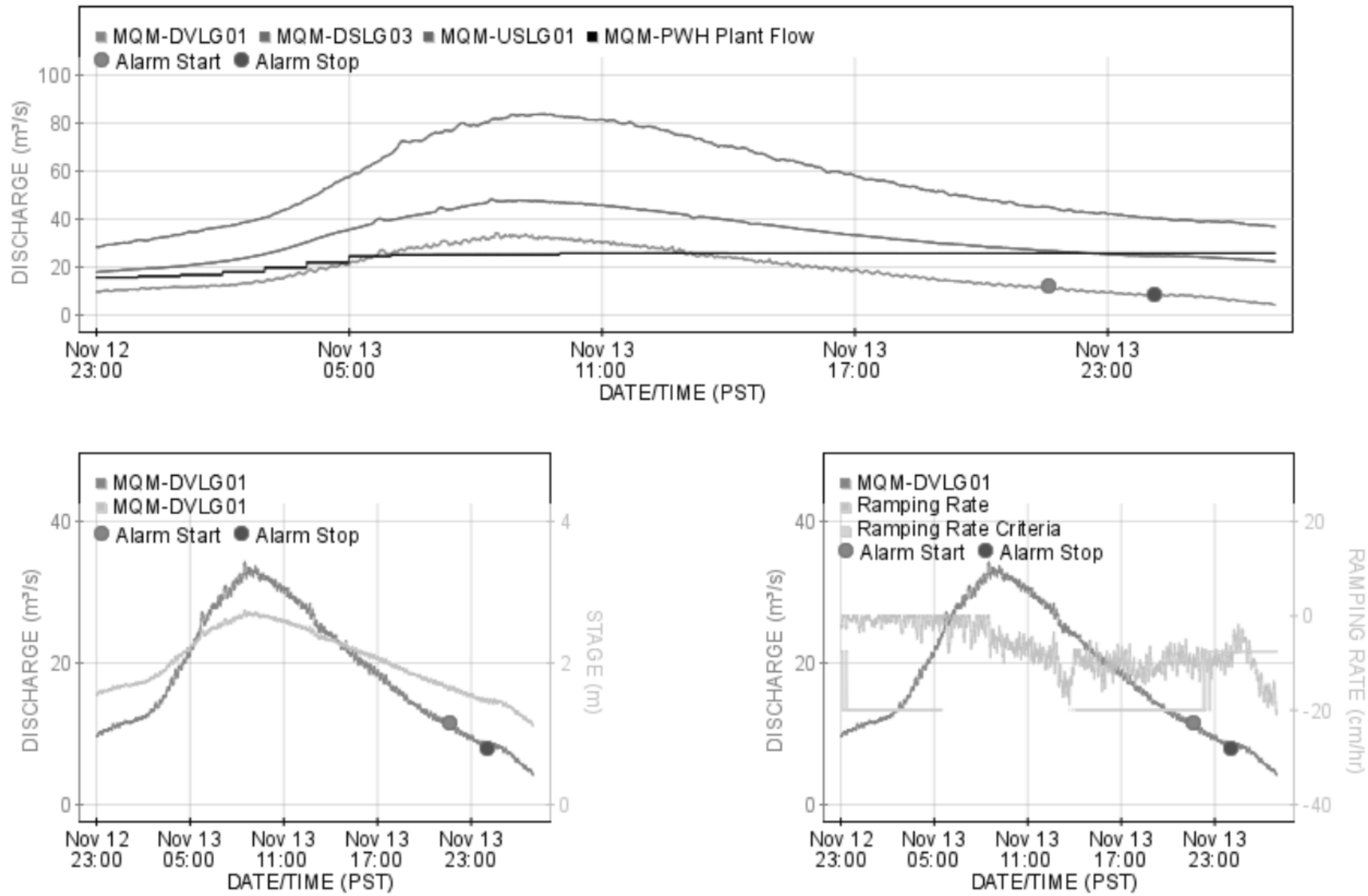
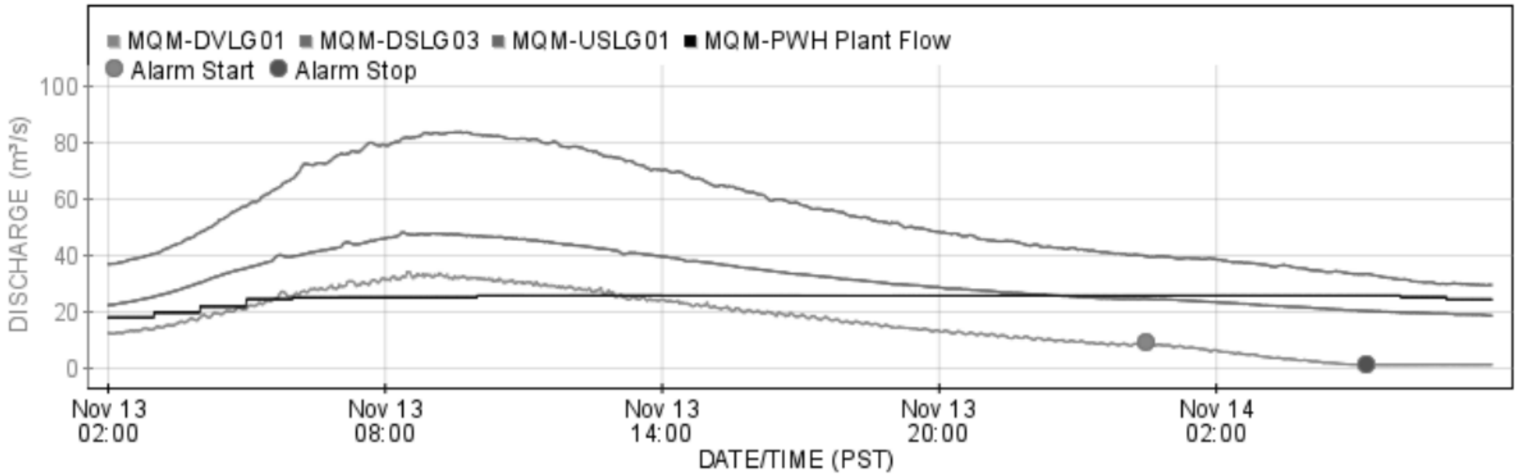
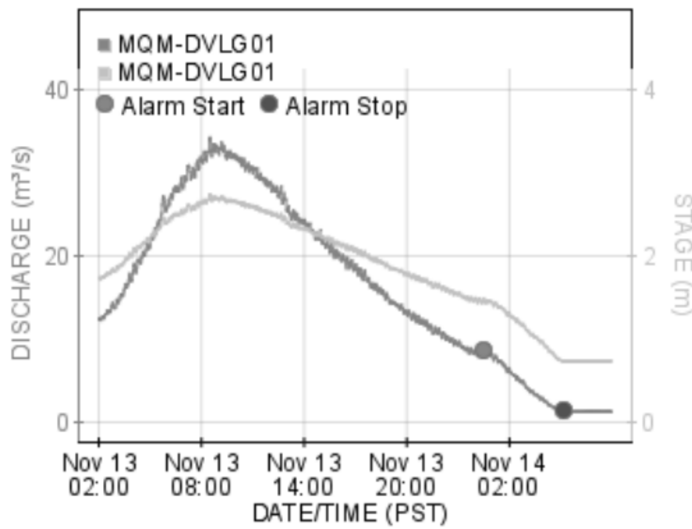


**Figure 8. Discharges on November 13, 2015 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**



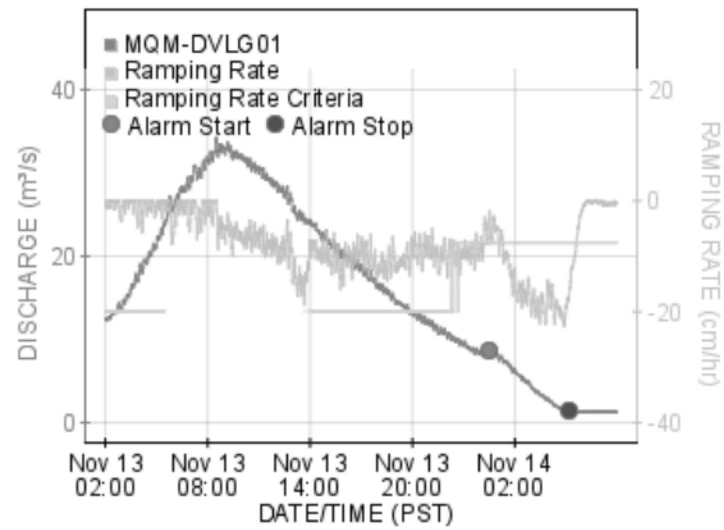
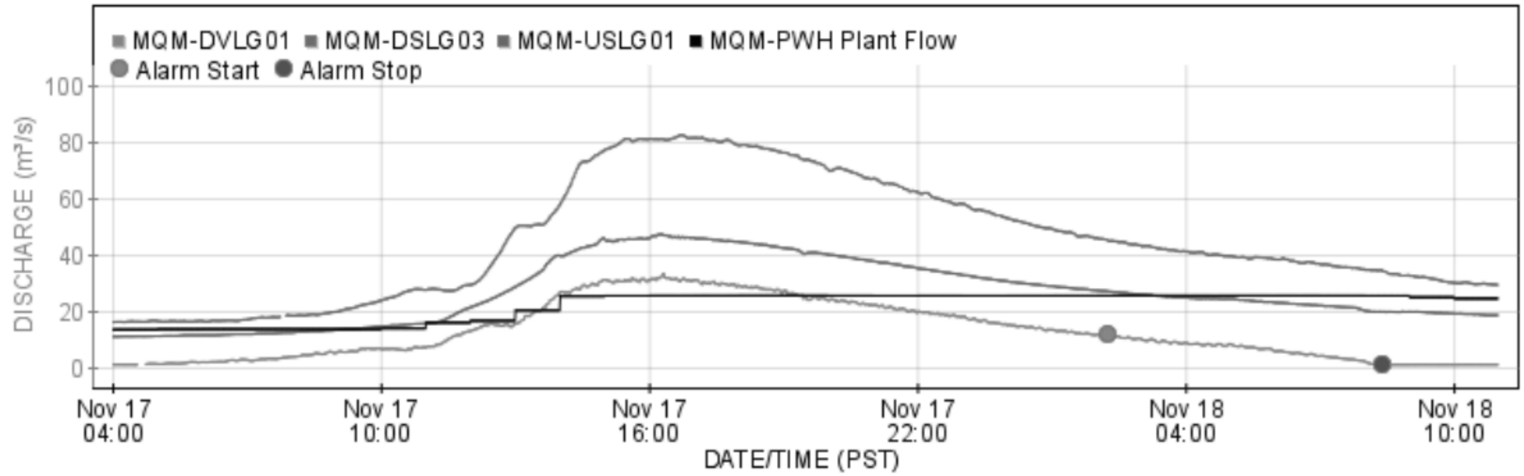
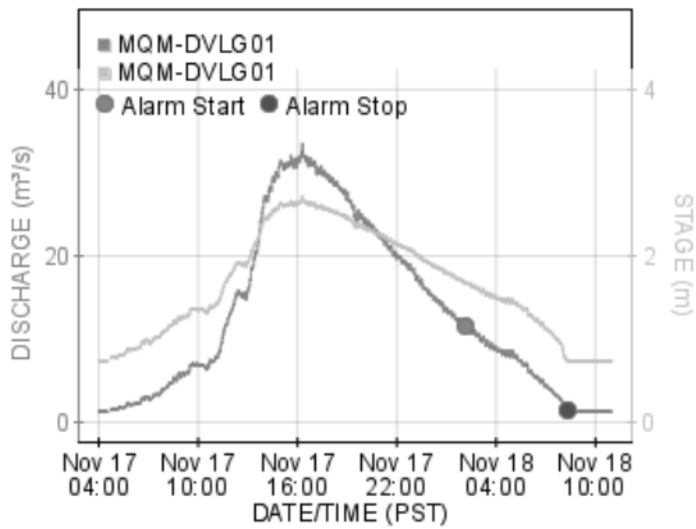



**Figure 9. Discharges on November 17, 2015 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**



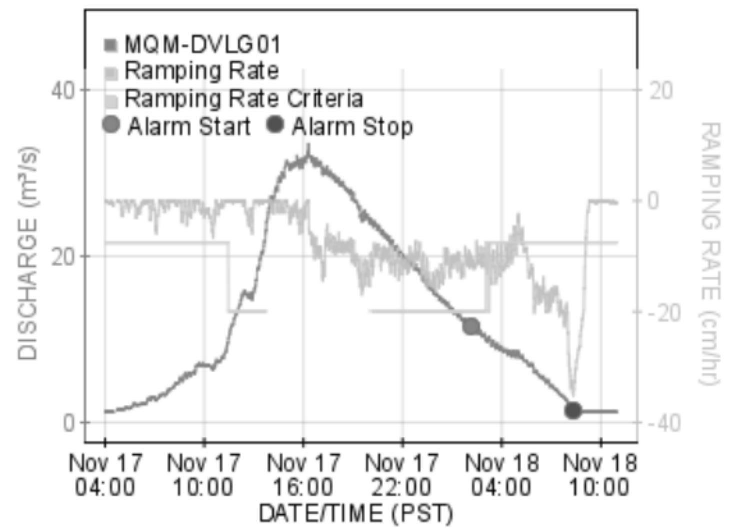



**Figure 10.** **Discharges on November 27, 2015 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

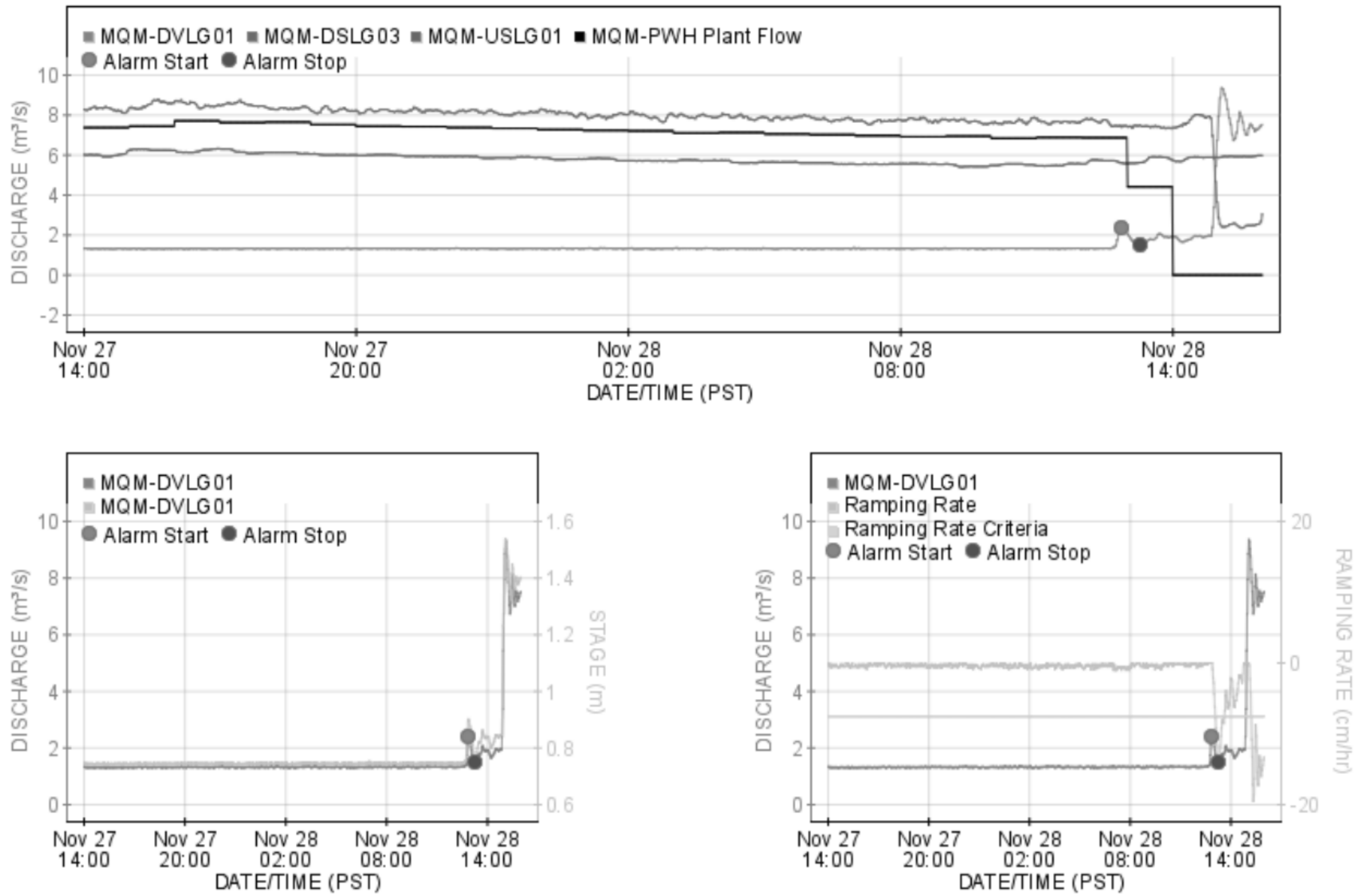


**Figure 11.** **Discharges on November 27, 2015 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

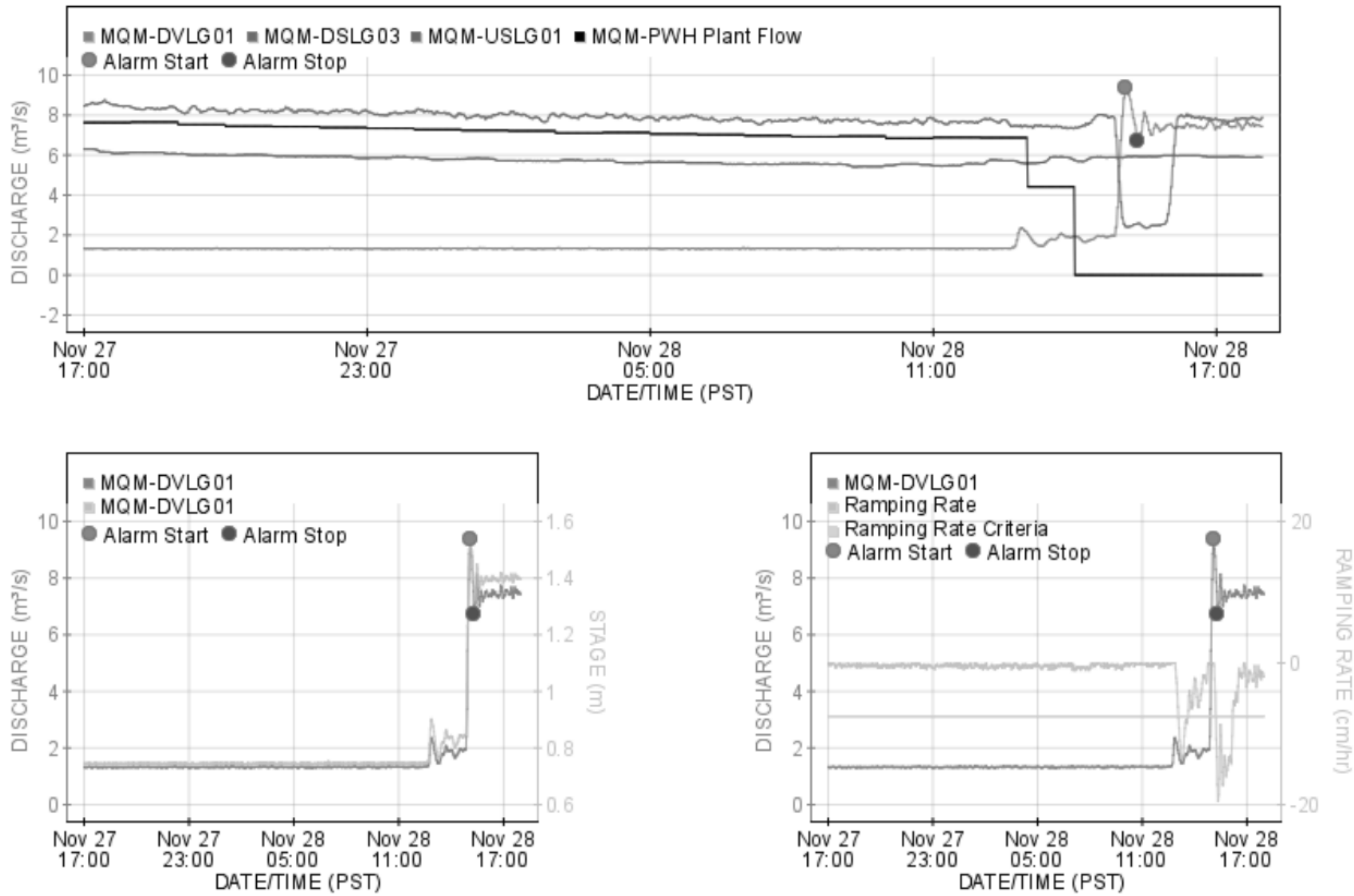


**Figure 12. Discharges on November 28, 2015 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

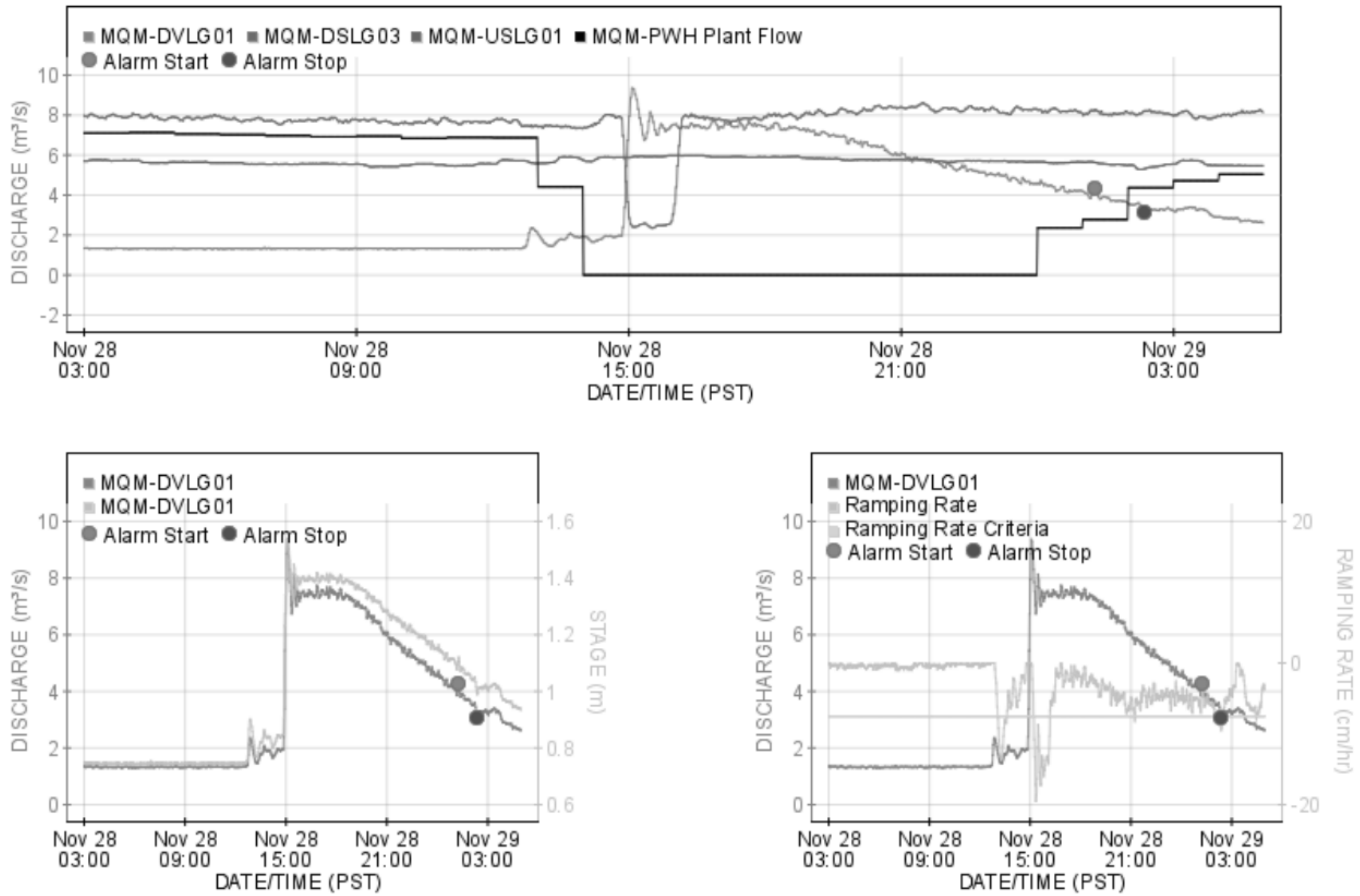


**Figure 13.** **Discharges on December 9, 2015 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

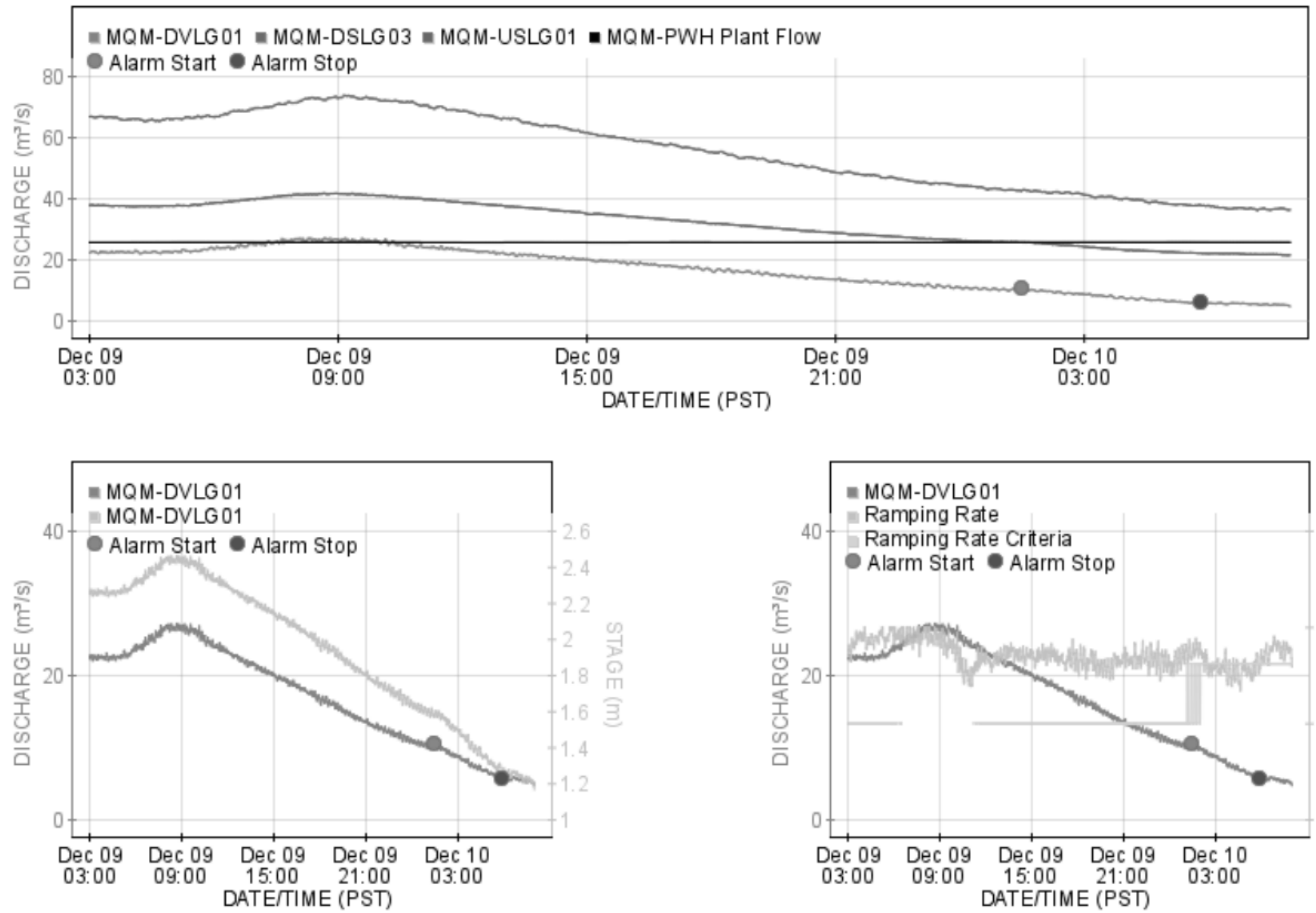


**Figure 14. Discharges on December 9, 2015 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

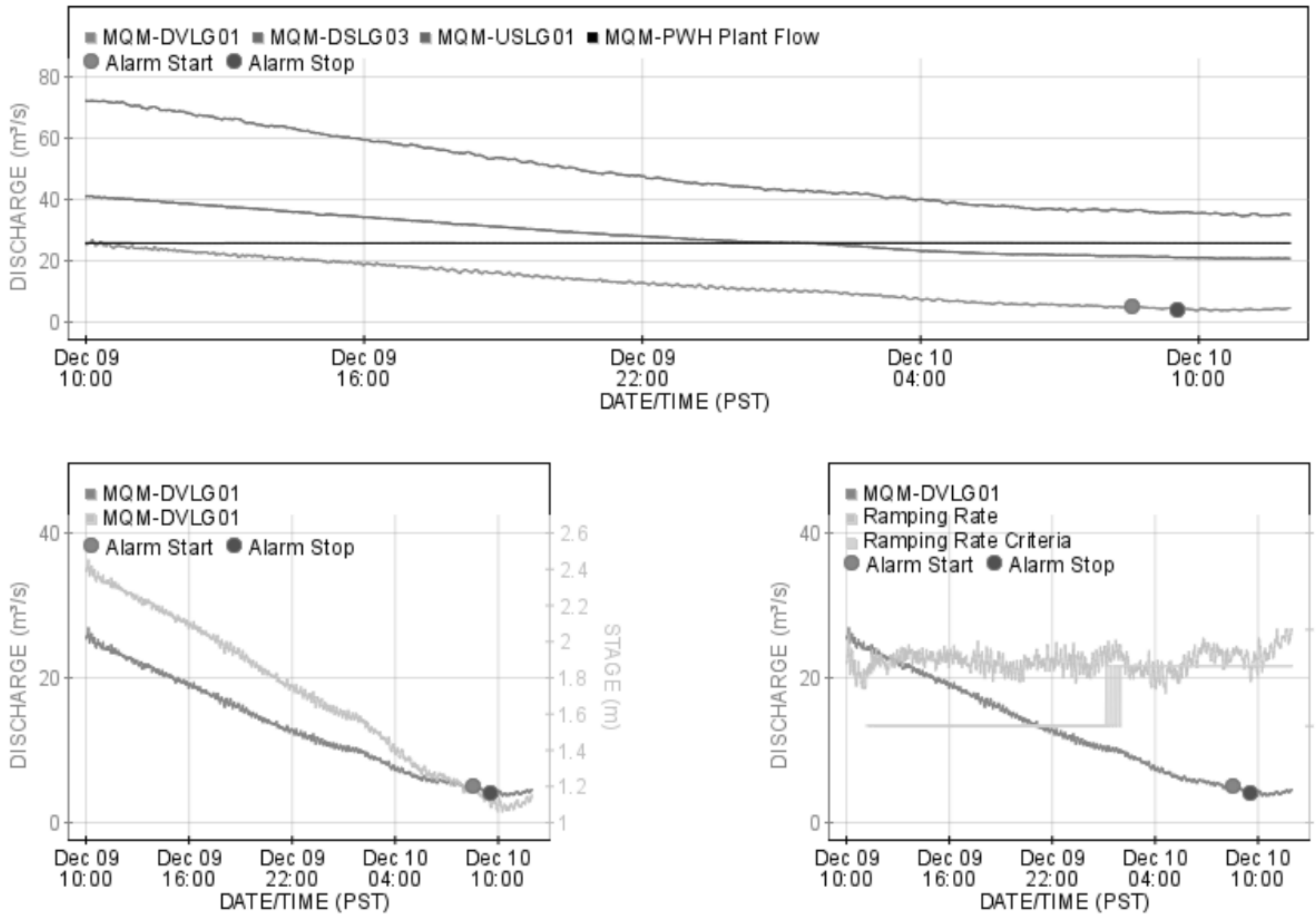


**Figure 15. Discharges on December 10, 2015 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

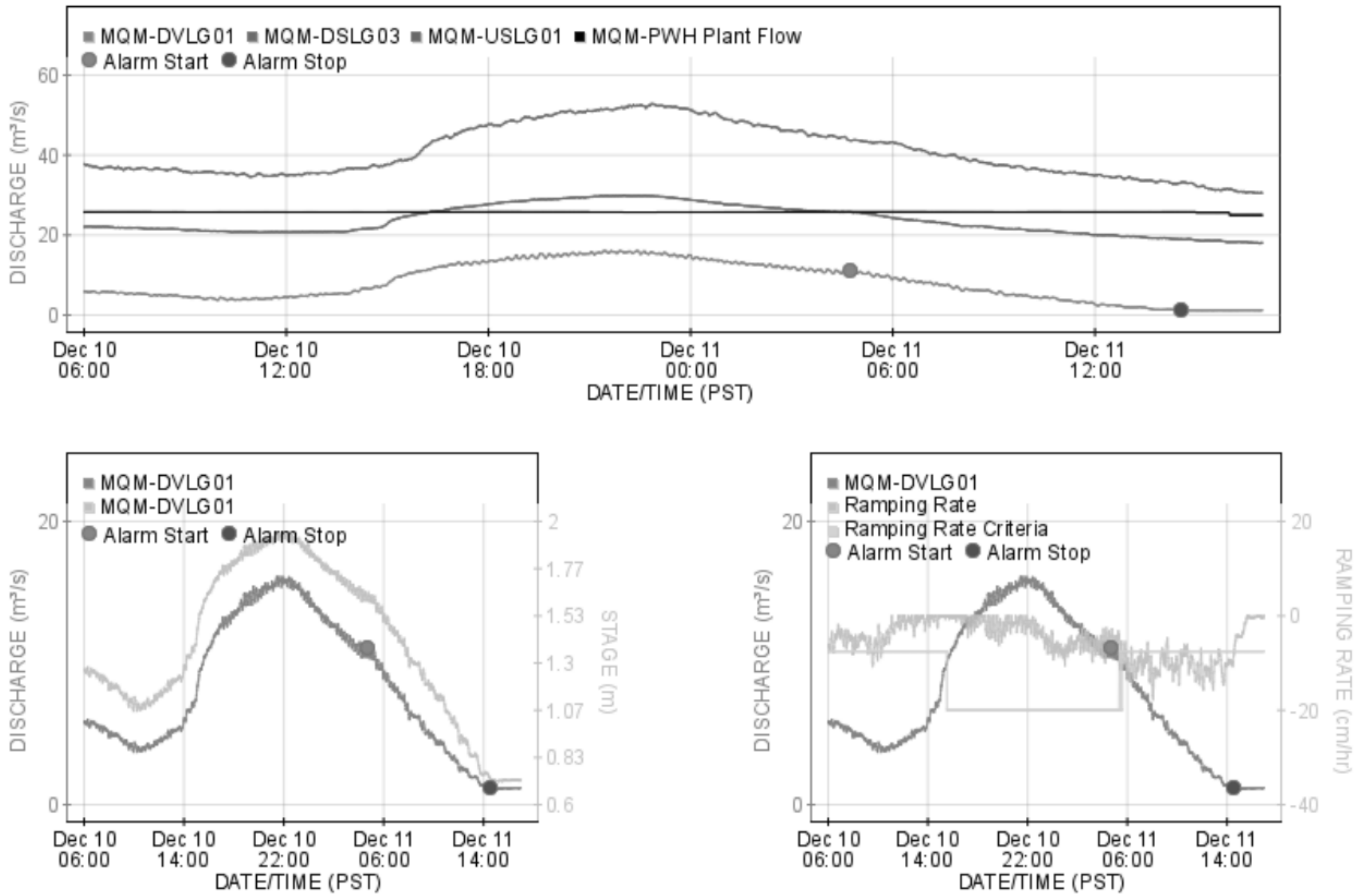


**Figure 16.** **Discharges on December 12, 2015 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

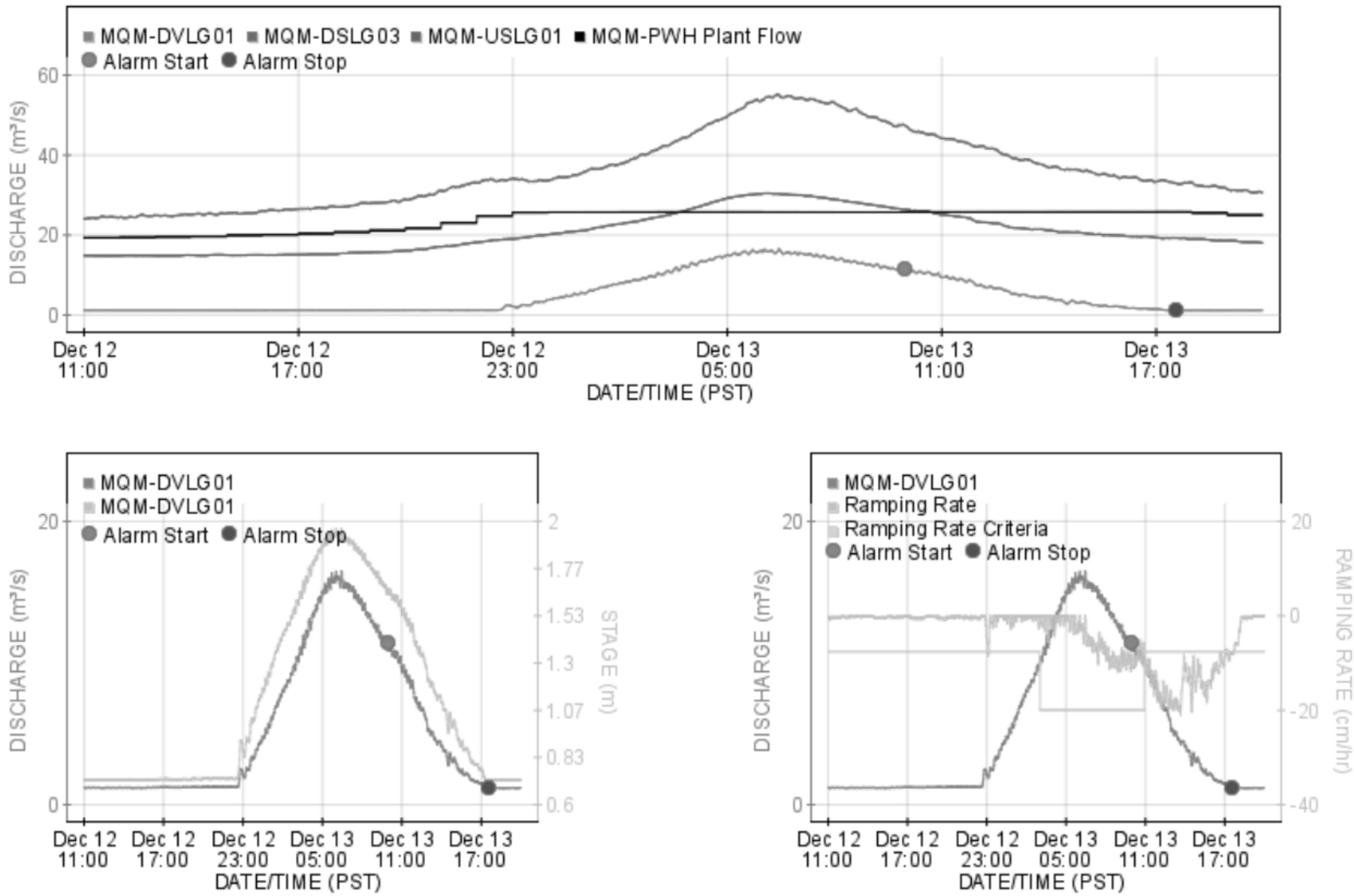


**Figure 17. Discharges on January 12, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

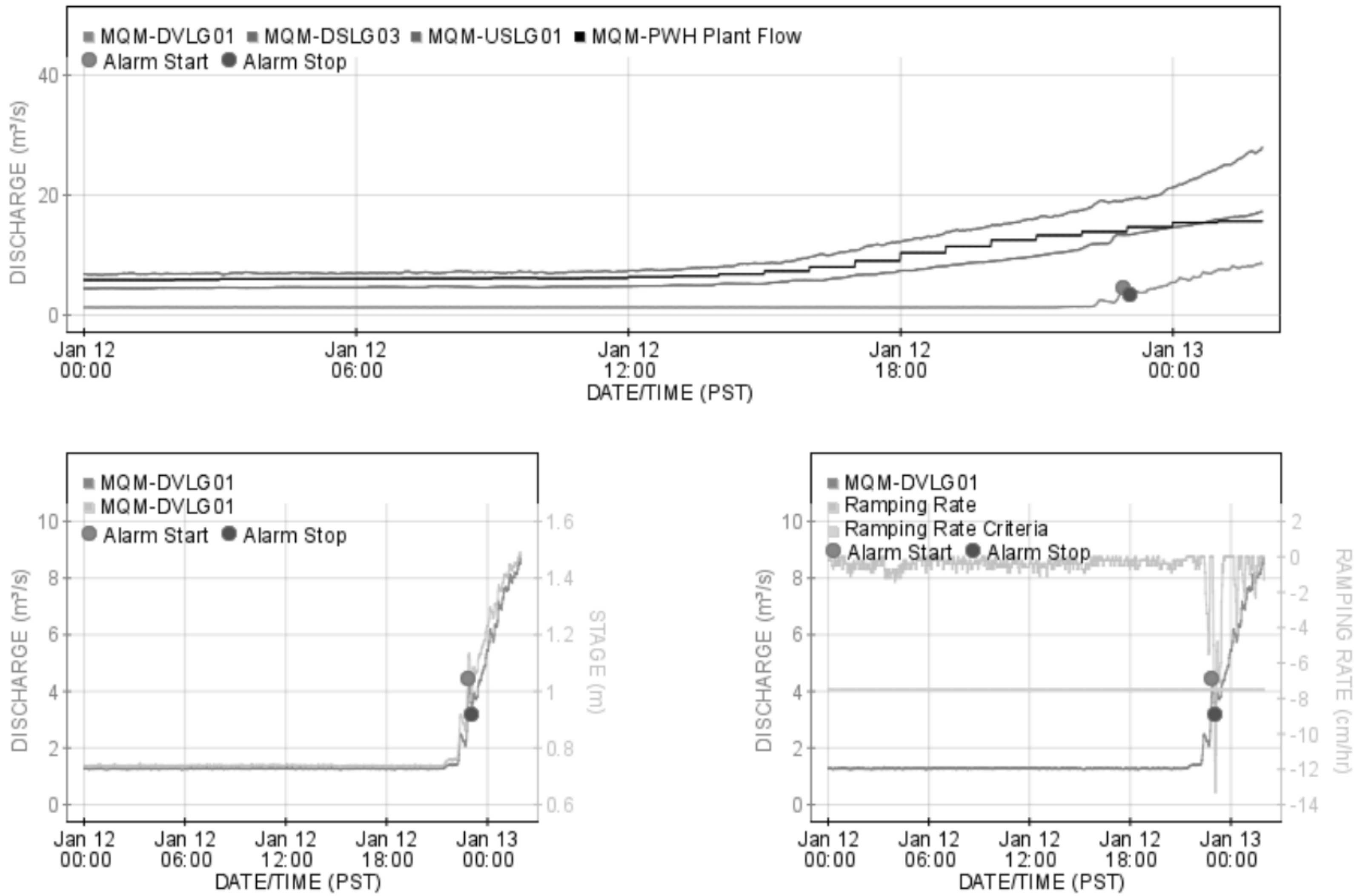





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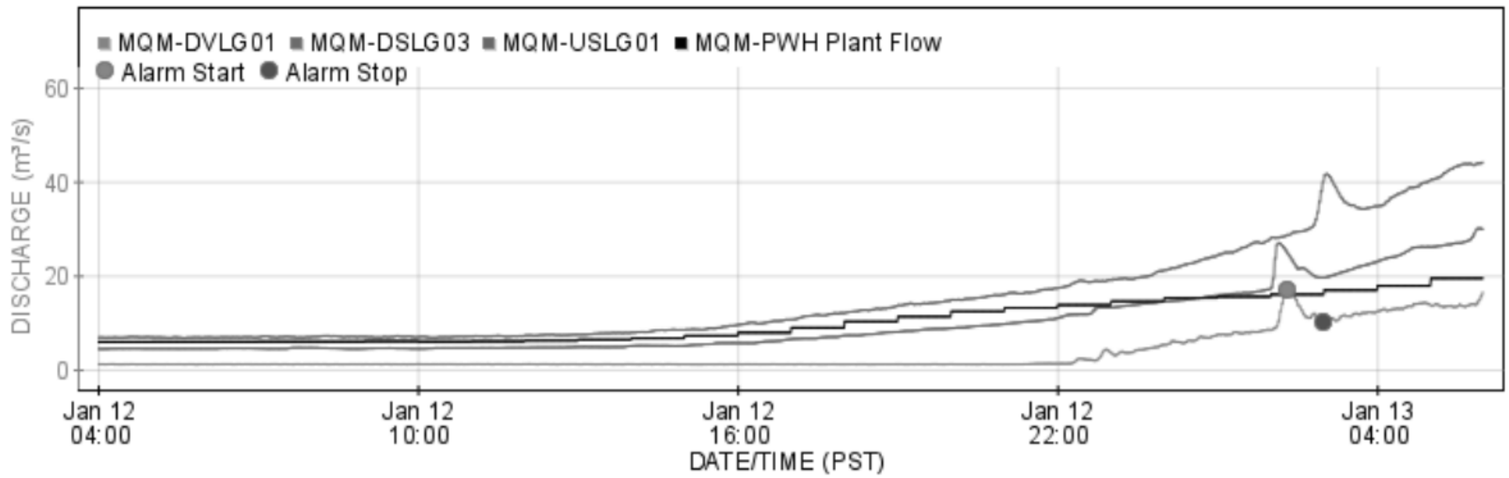
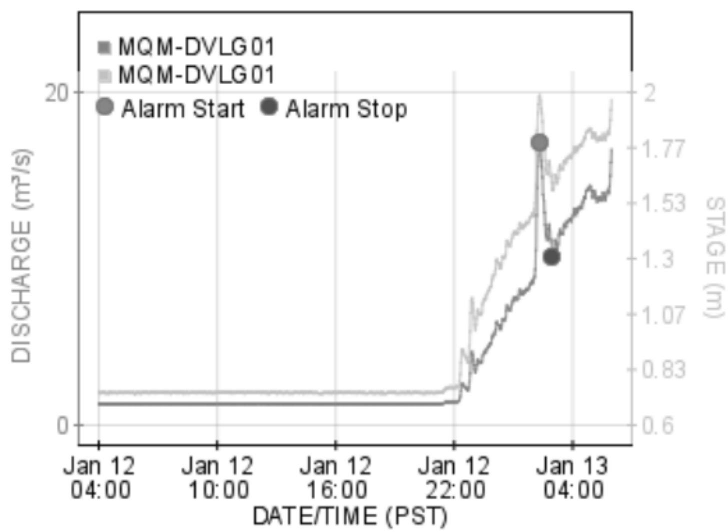
**Figure 18. Discharges on January 12, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**



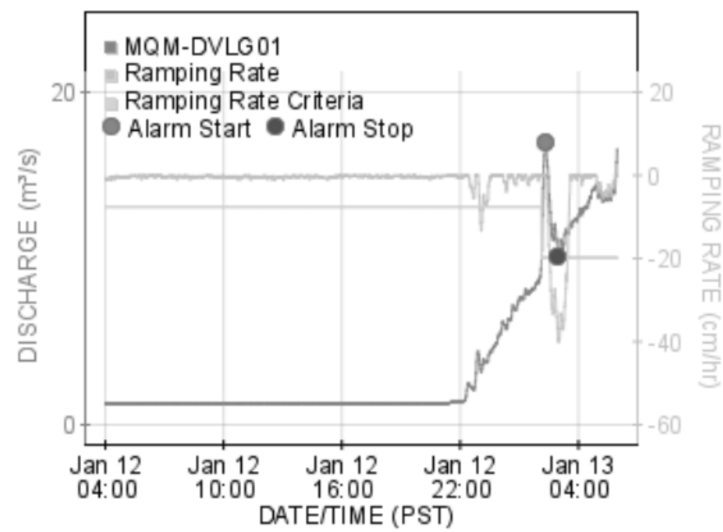



**Figure 19. Discharges on January 12, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

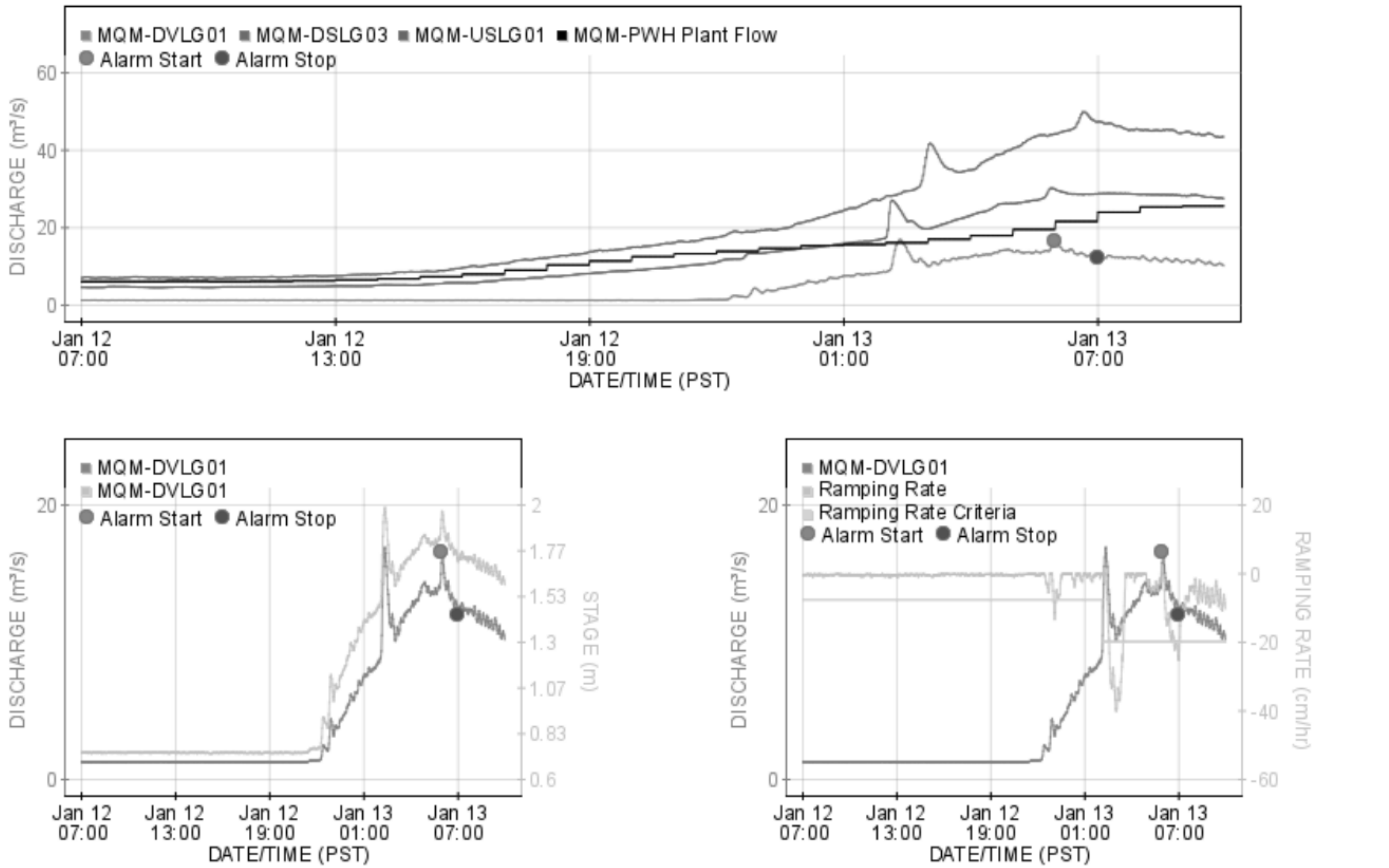


**Figure 20. Discharges on January 12, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

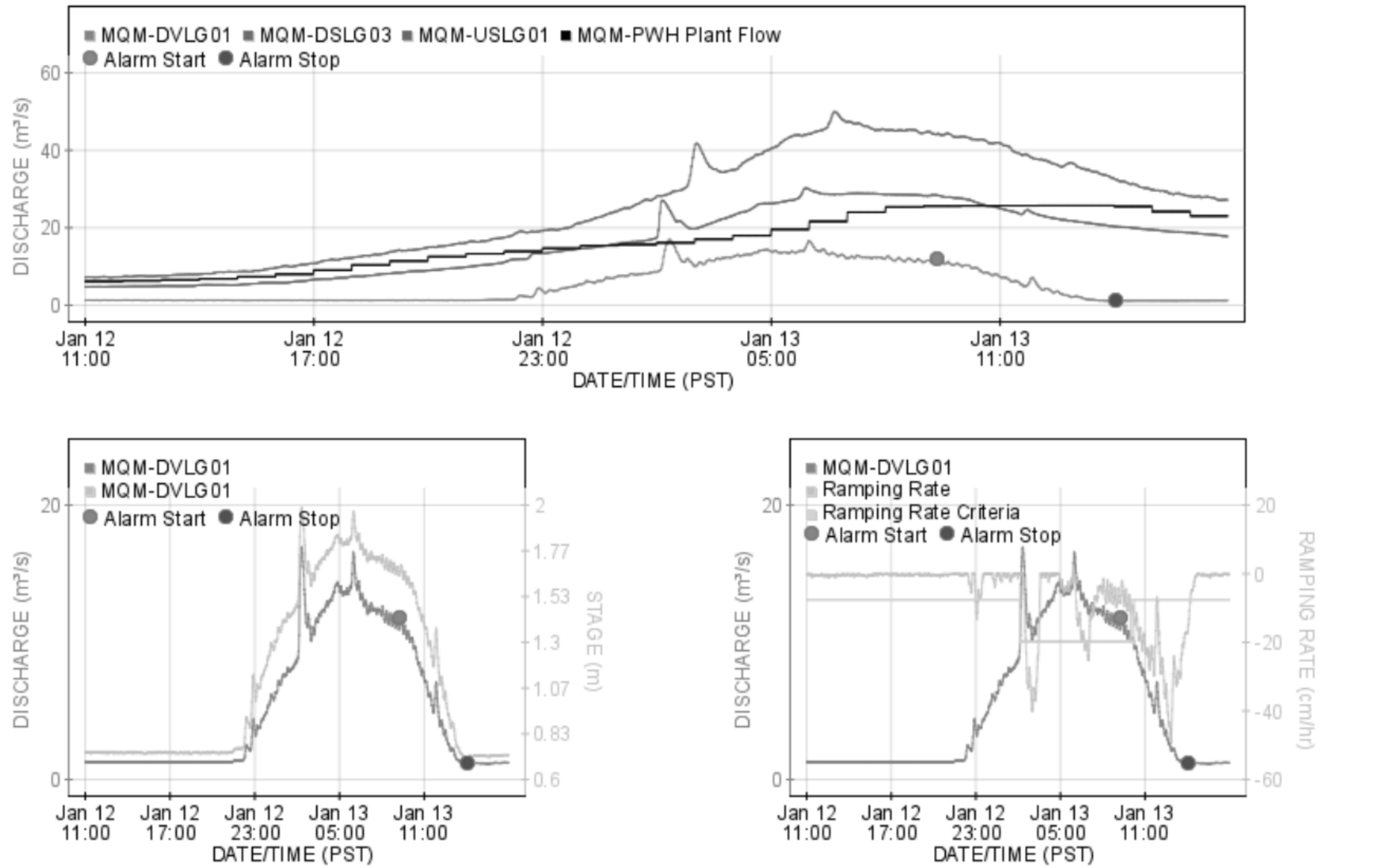





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**Figure 21. Discharges on January 20, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

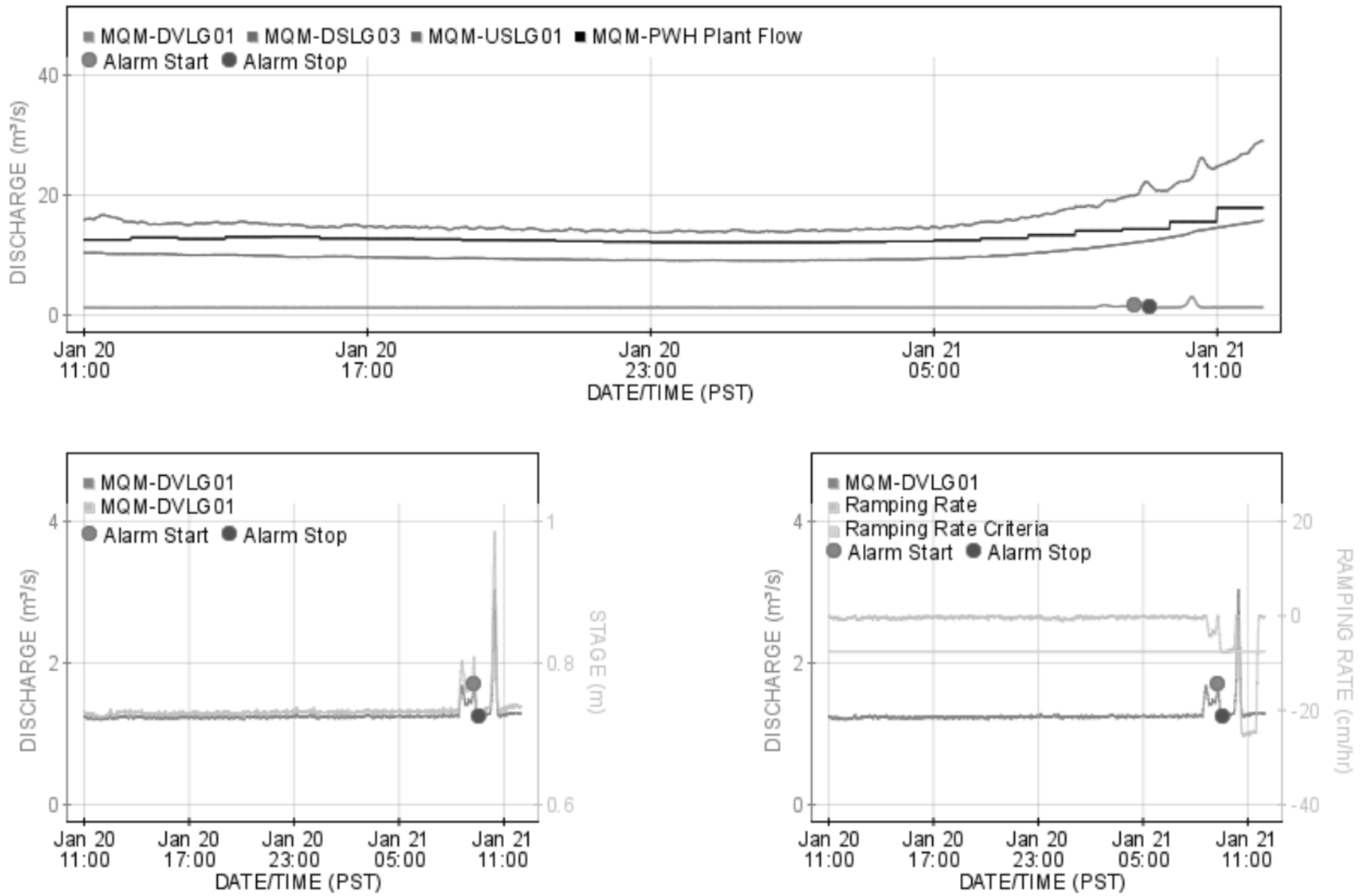


**Figure 22. Discharges on January 20, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

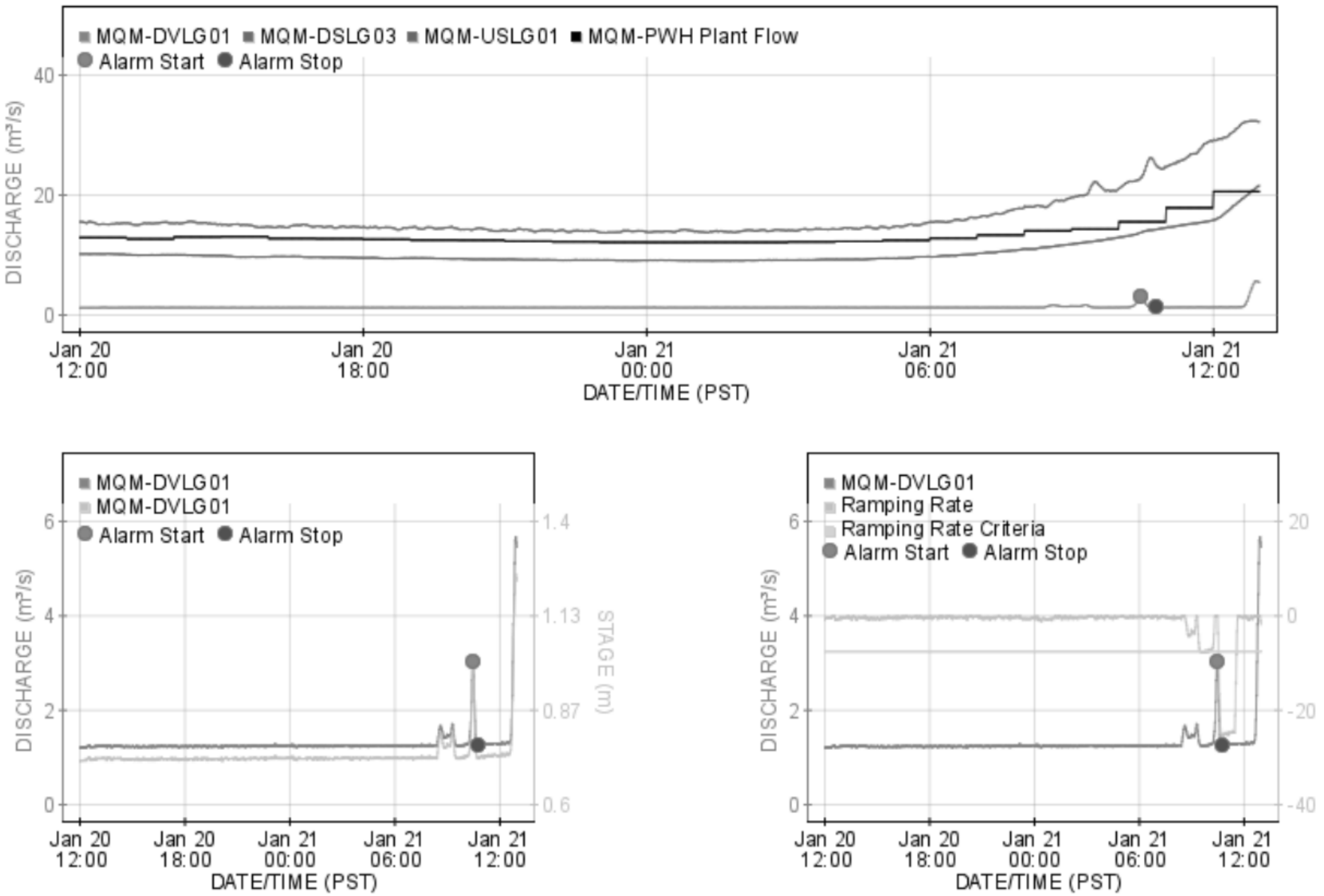


**Figure 23. Discharges on January 22, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

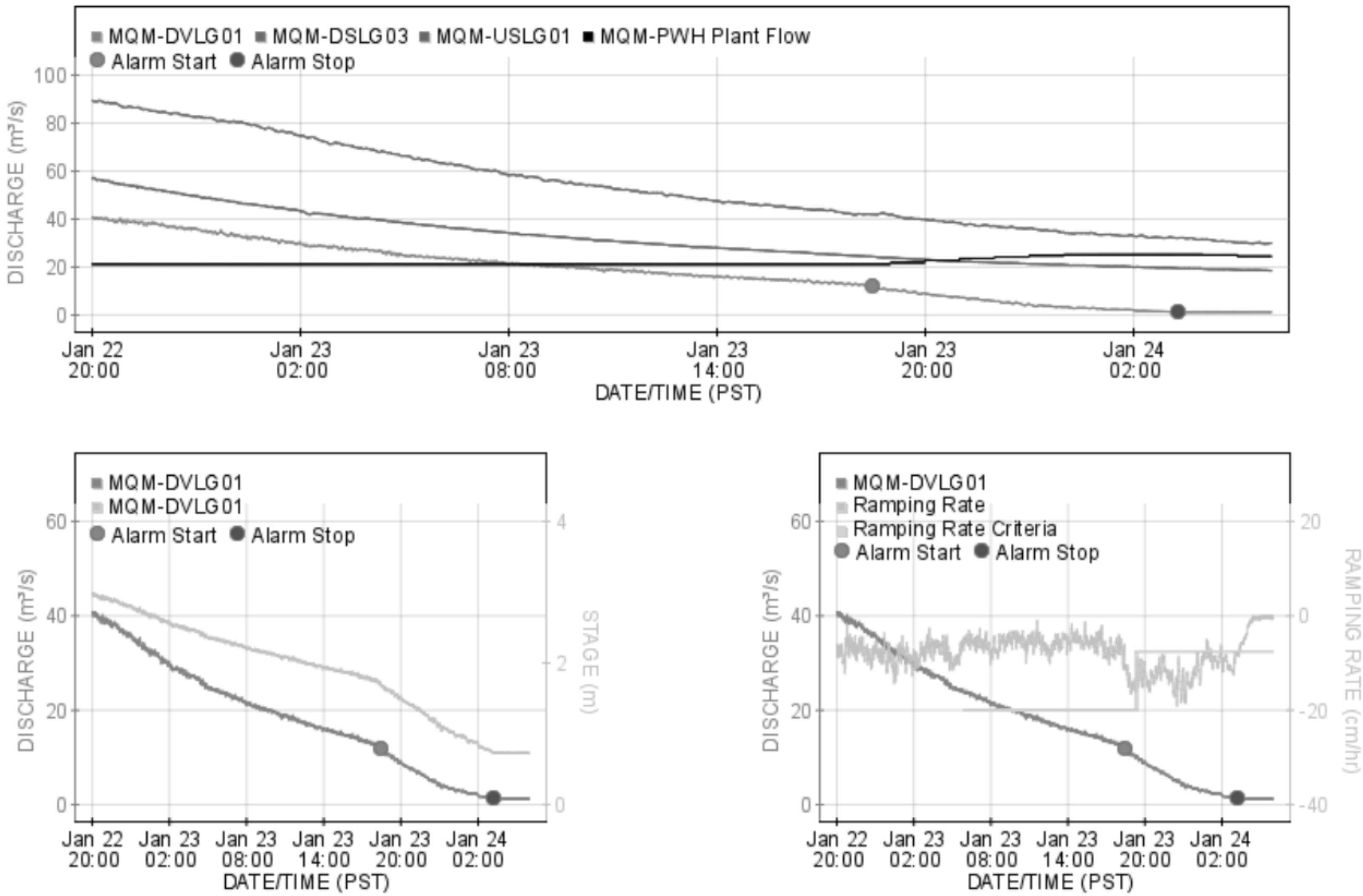


**Figure 24. Discharges on January 28, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

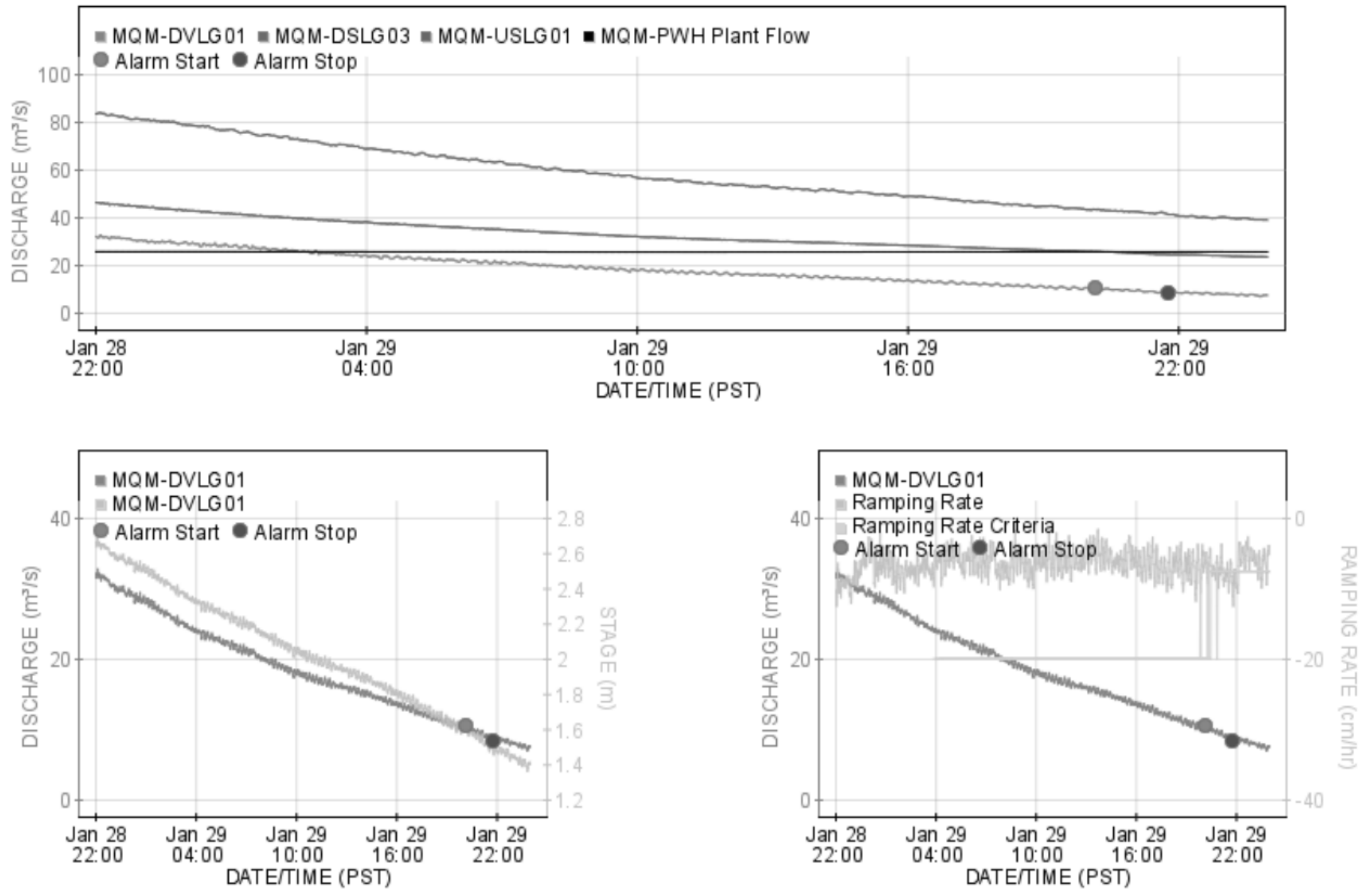


**Figure 25. Discharges on January 29, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

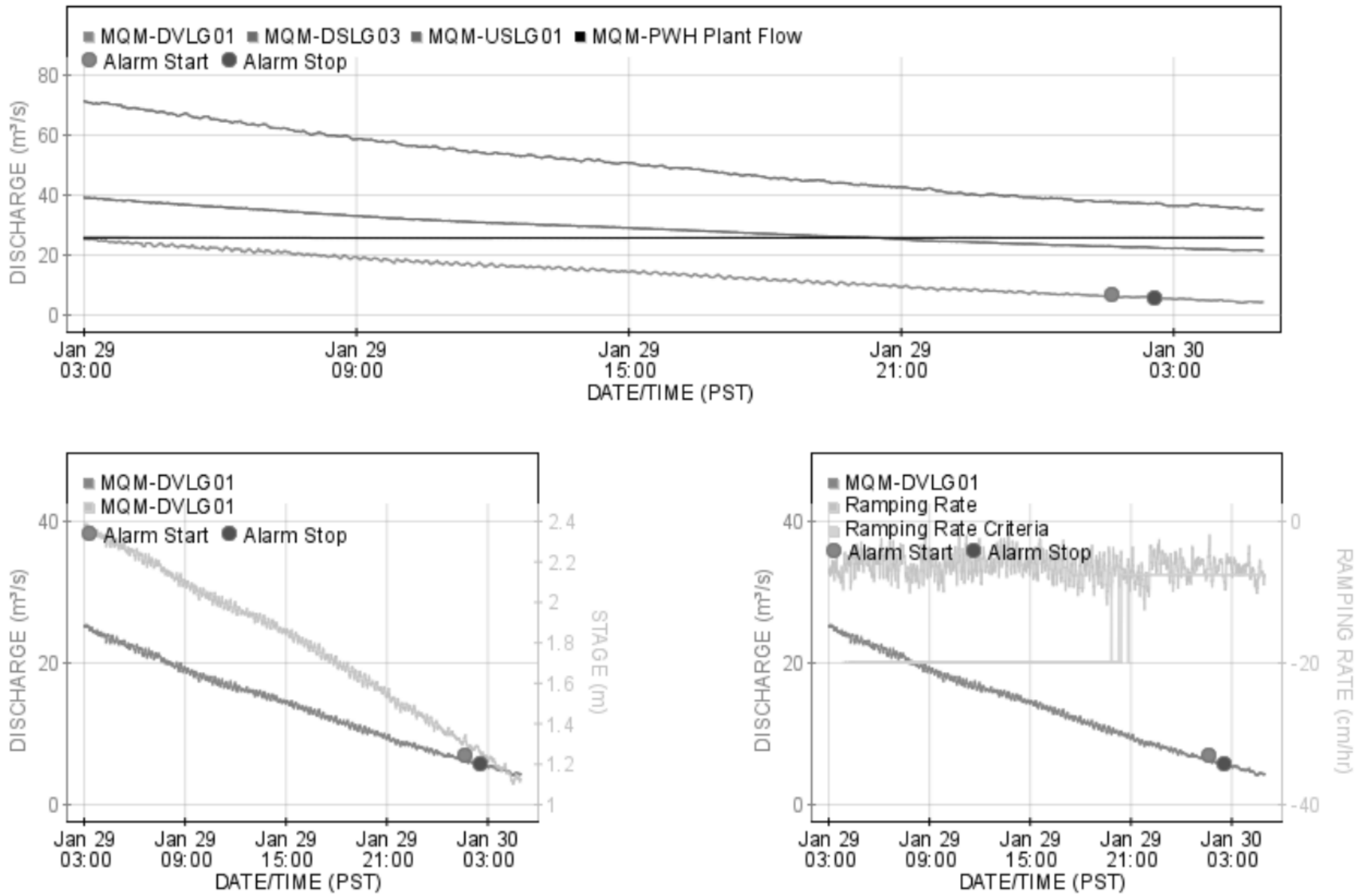


**Figure 26. Discharges on January 29, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

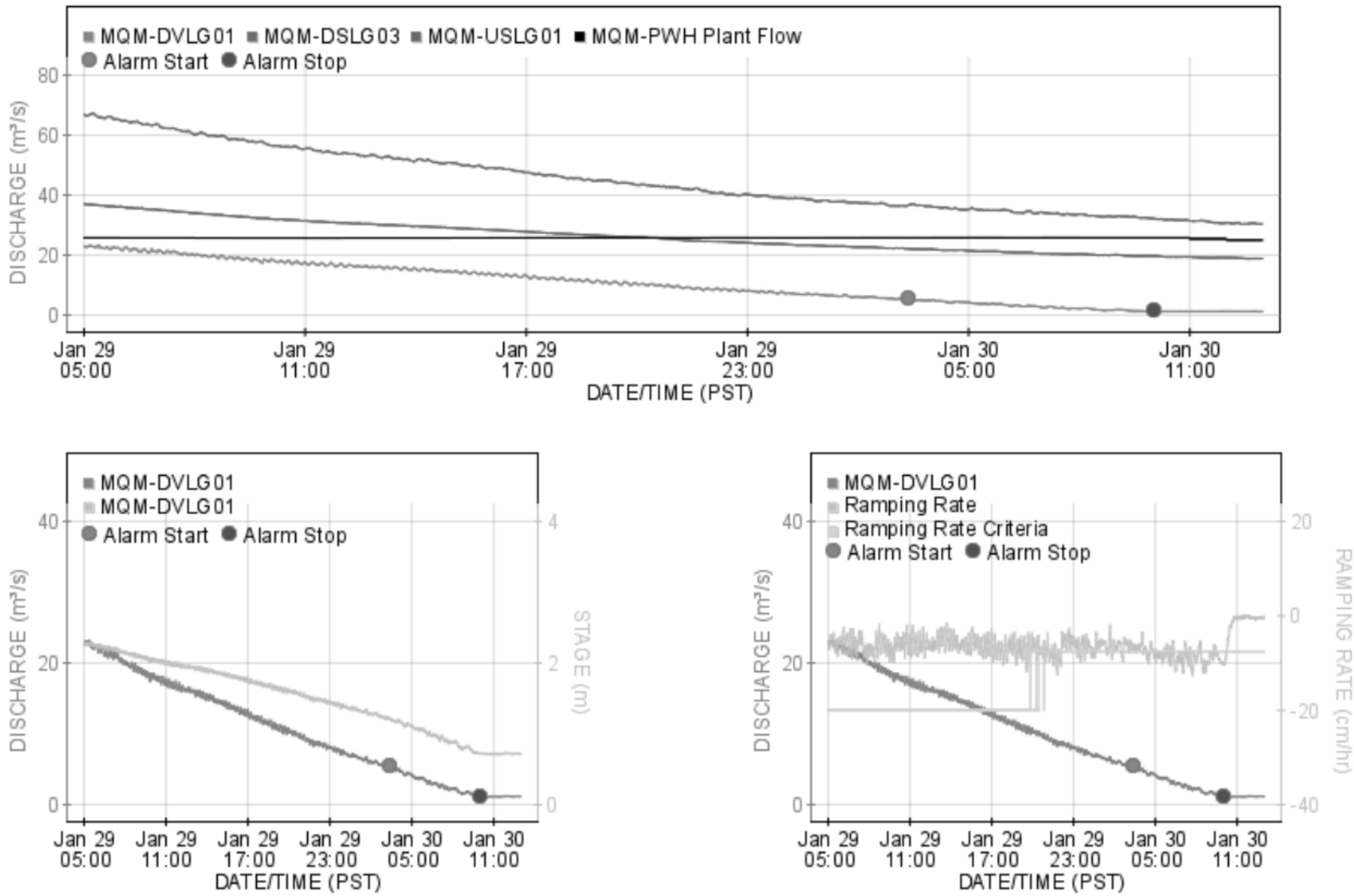
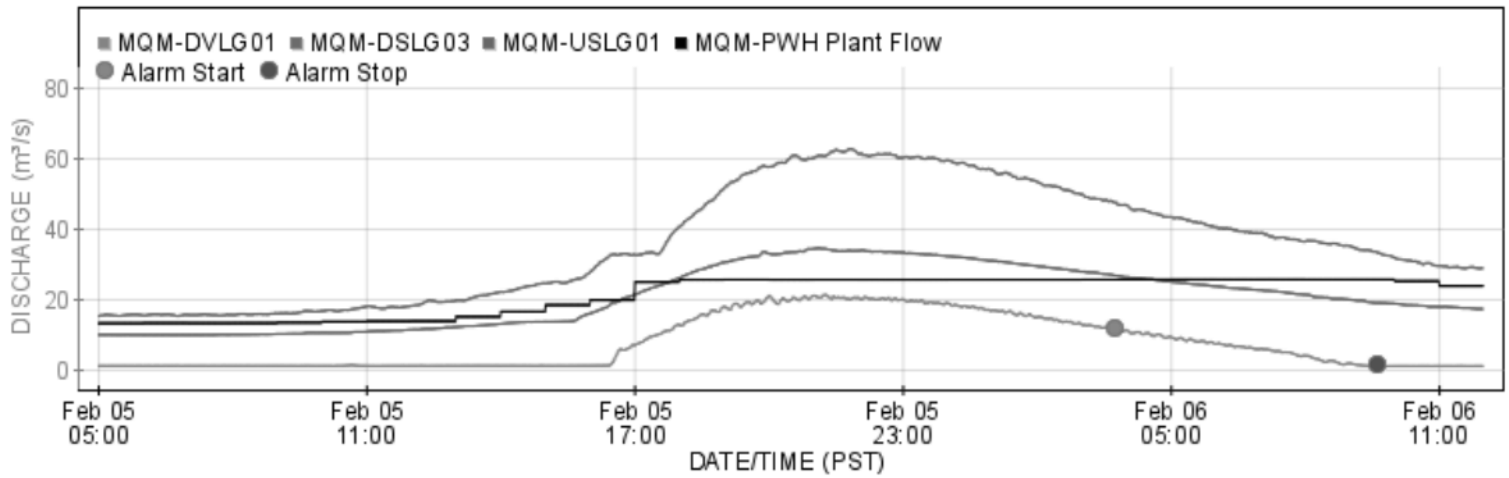
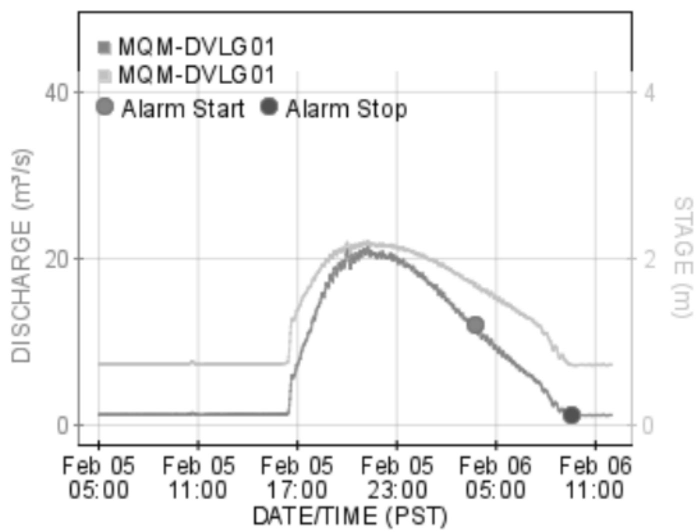


**Figure 27. Discharges on February 5, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**



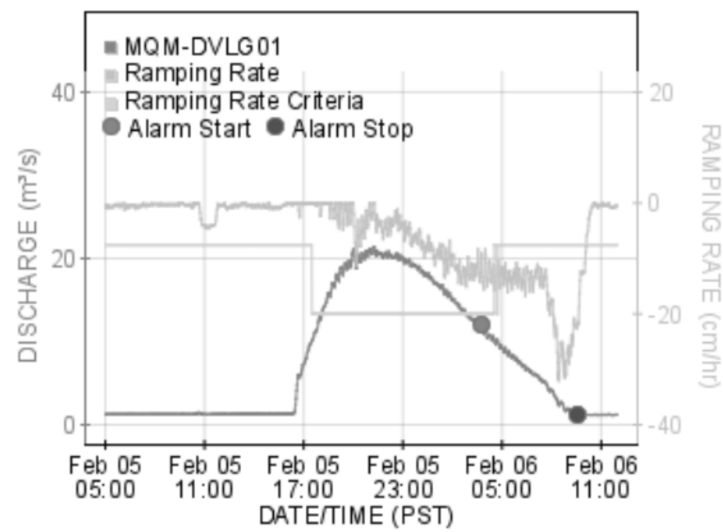



**Figure 28. Discharges on February 10, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

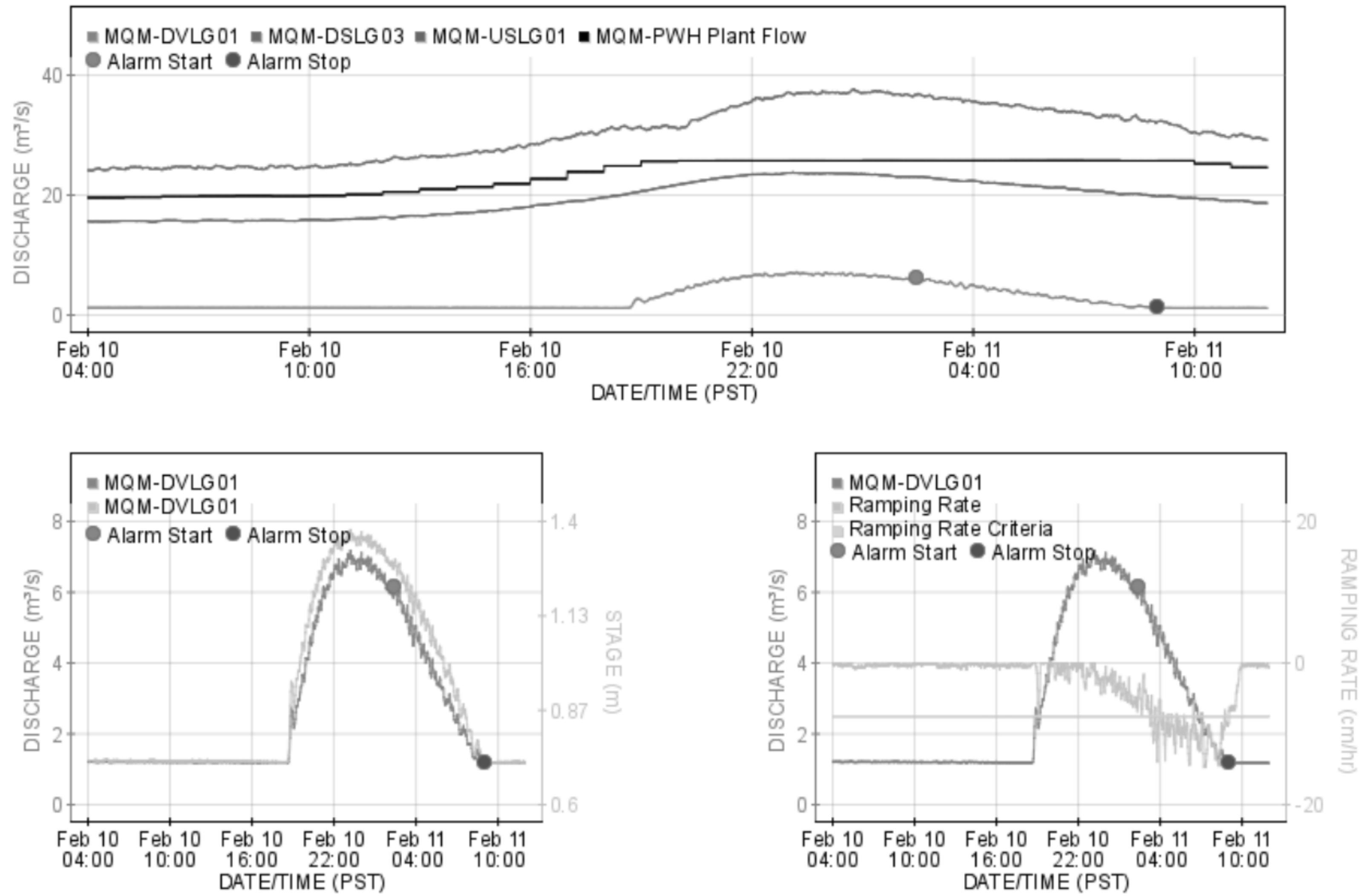


**Figure 29. Discharges on February 13, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

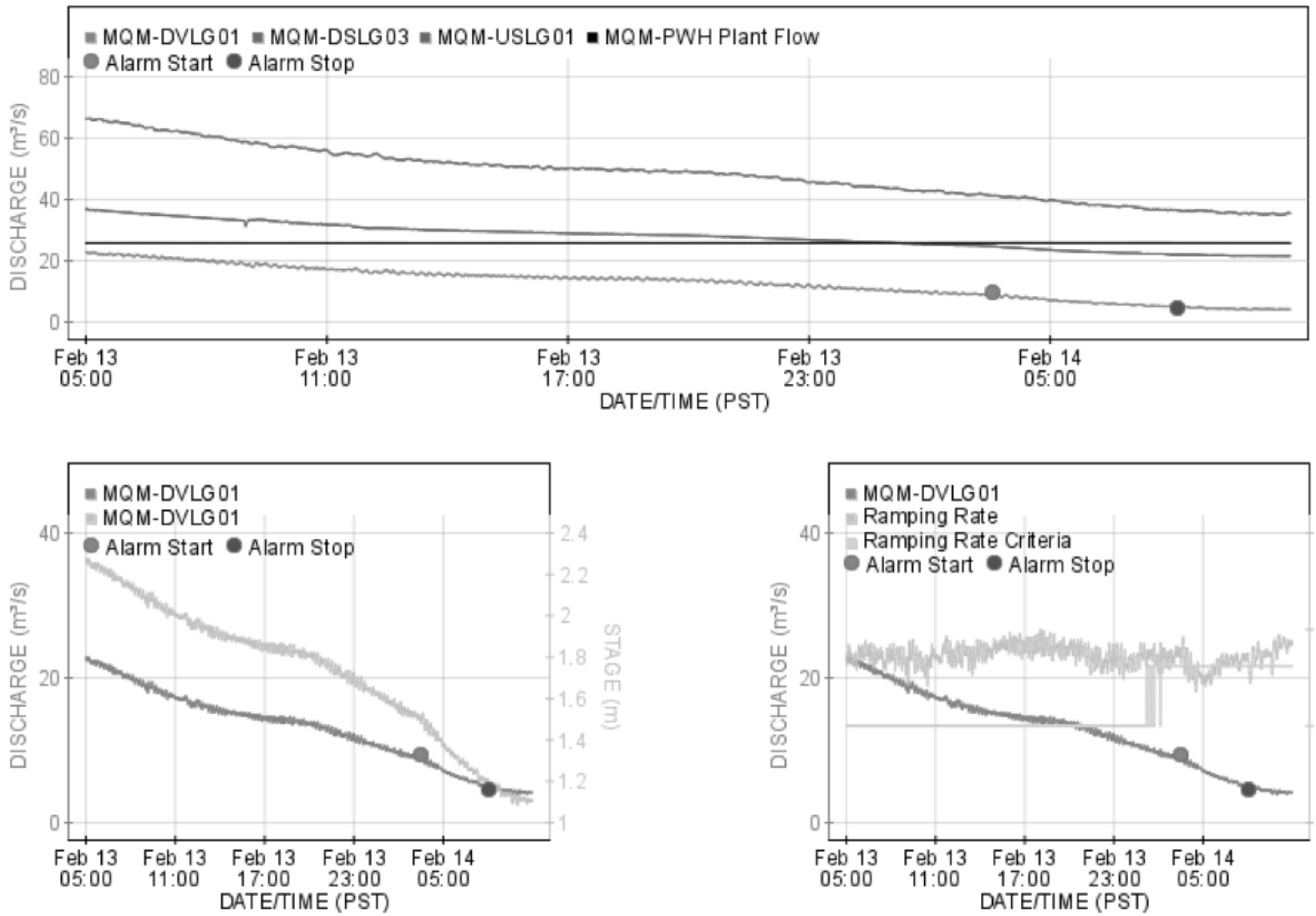
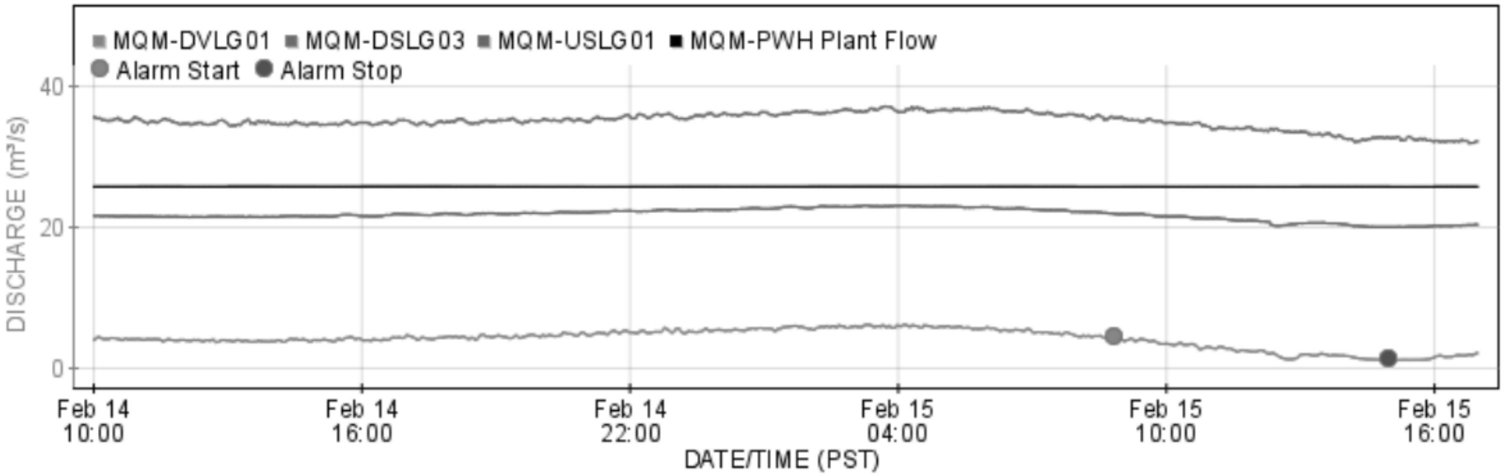
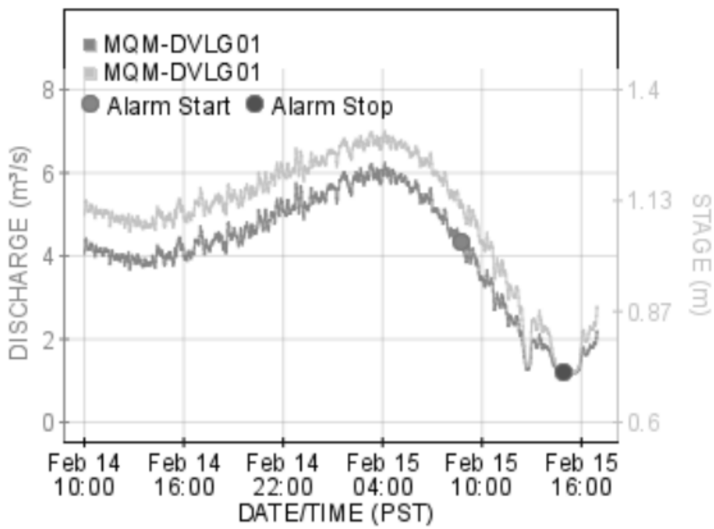


**Figure 30. Discharges on February 14, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**



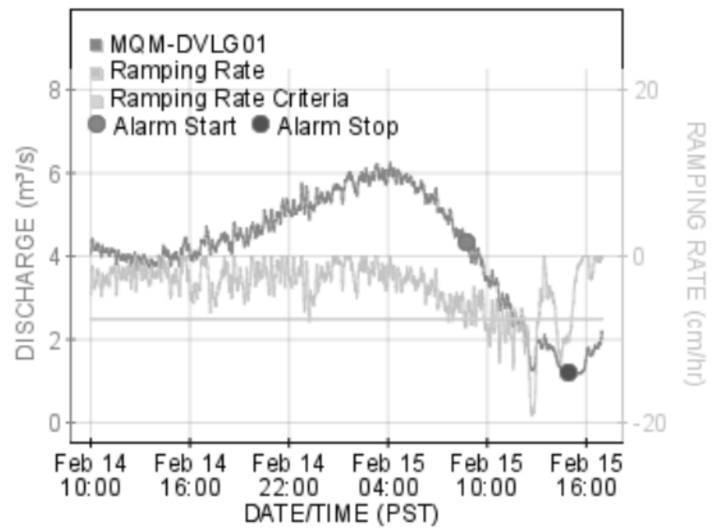
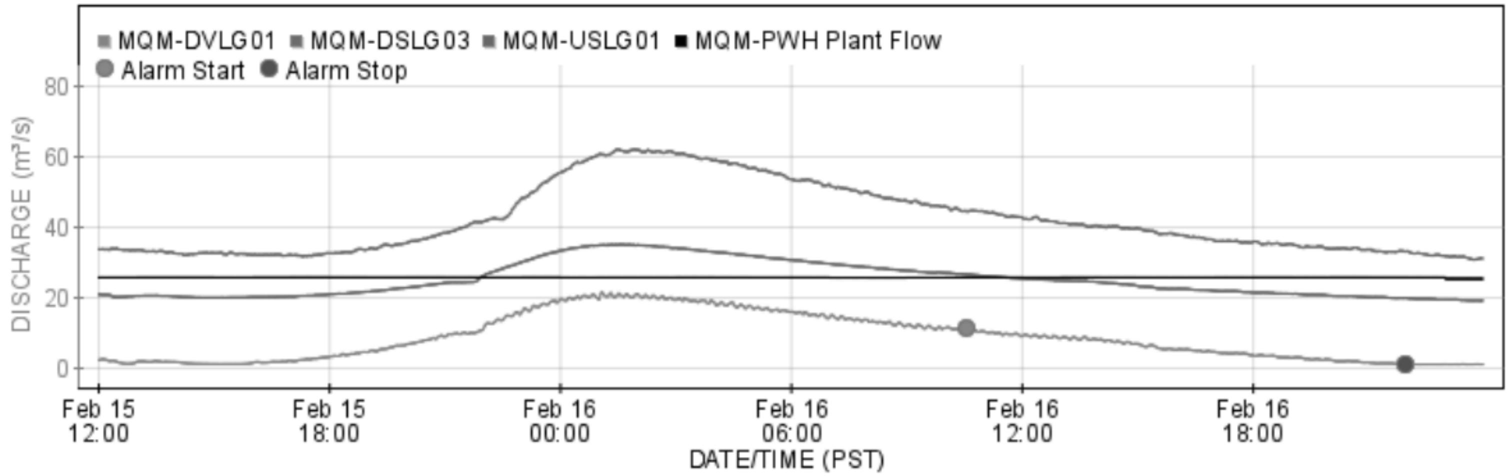
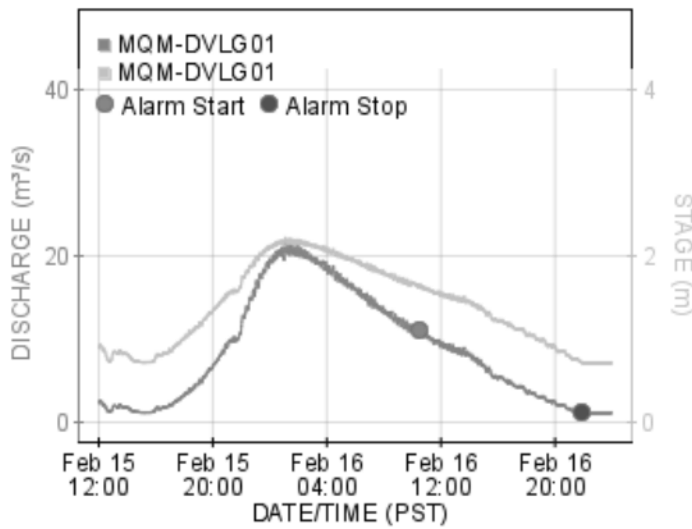



**Figure 31.** **Discharges on February 15, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**



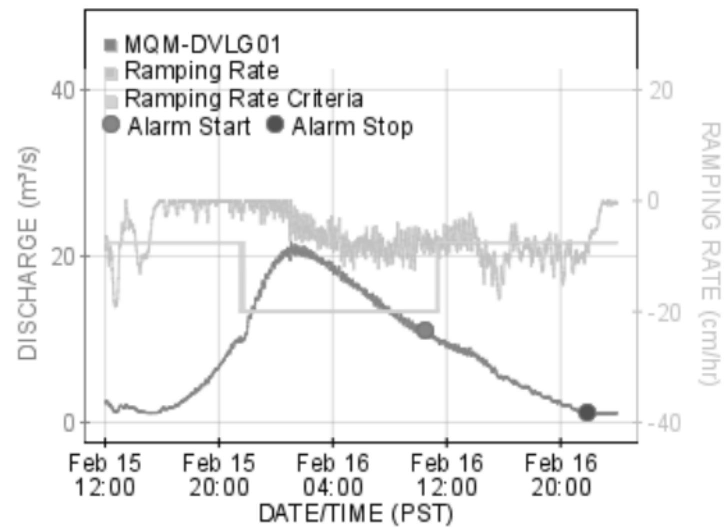



**Figure 32. Discharges on February 18, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

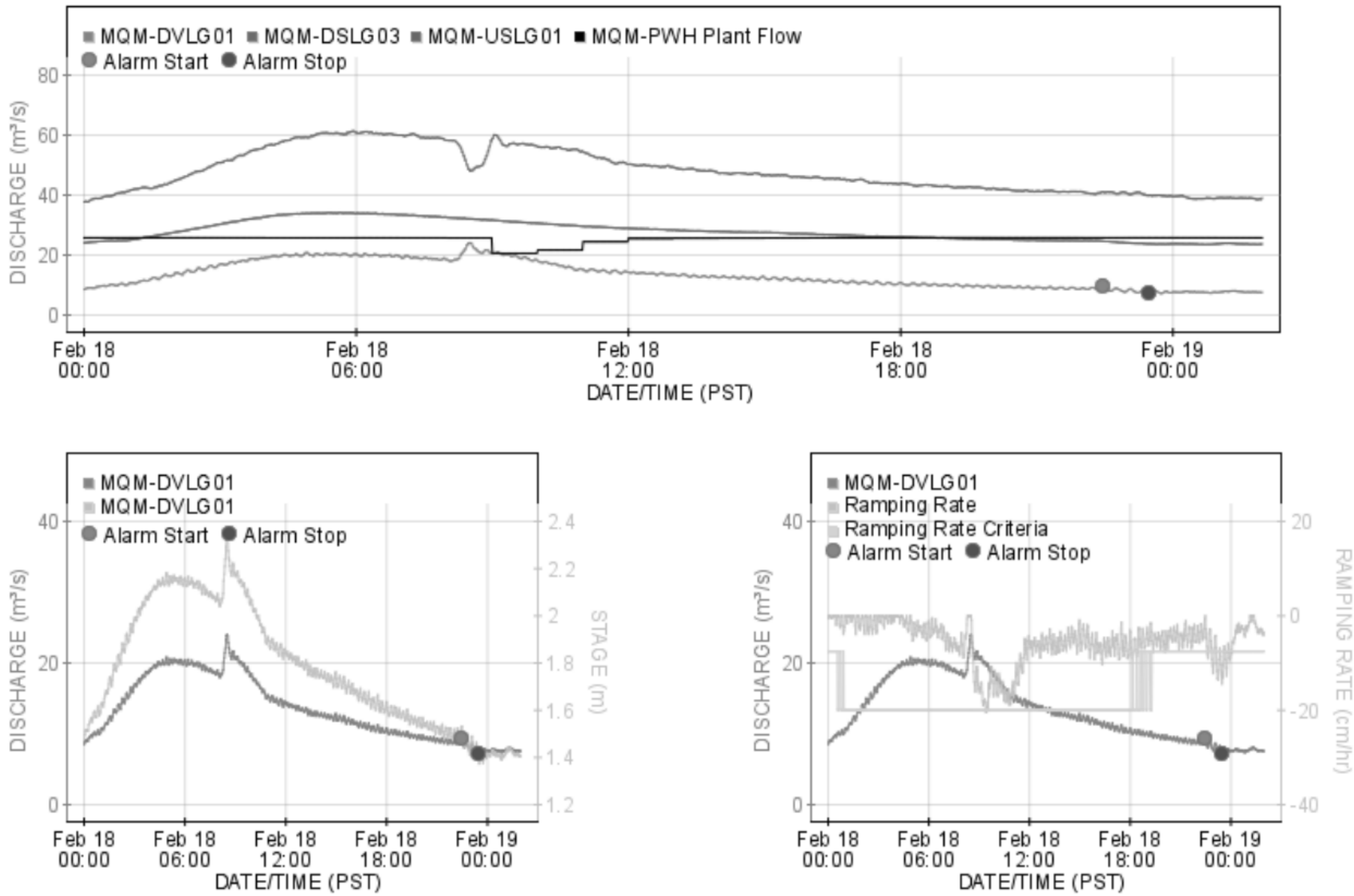





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**Figure 33.** **Discharges on February 18, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

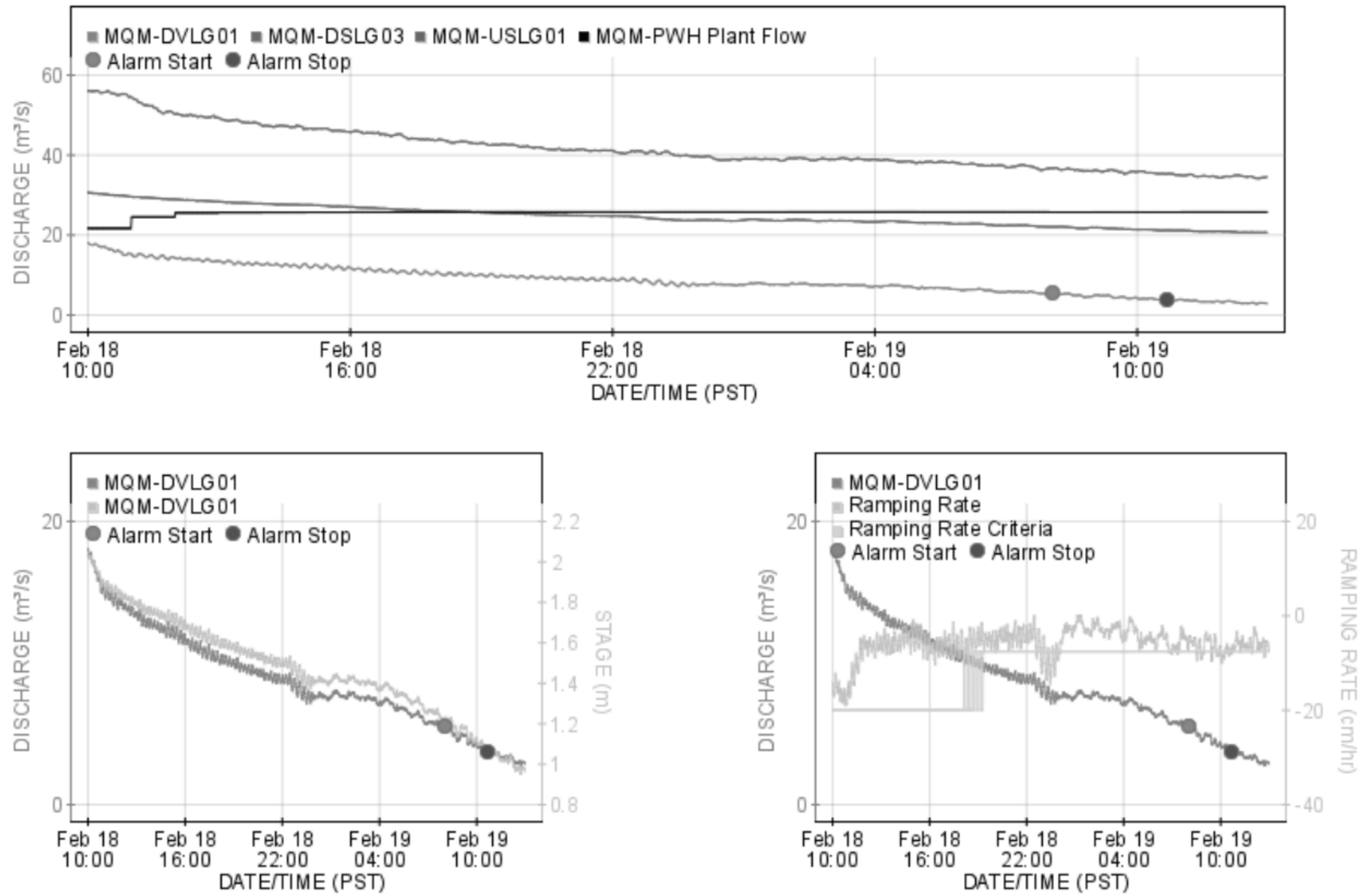

**Figure 34. Discharges on February 18, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

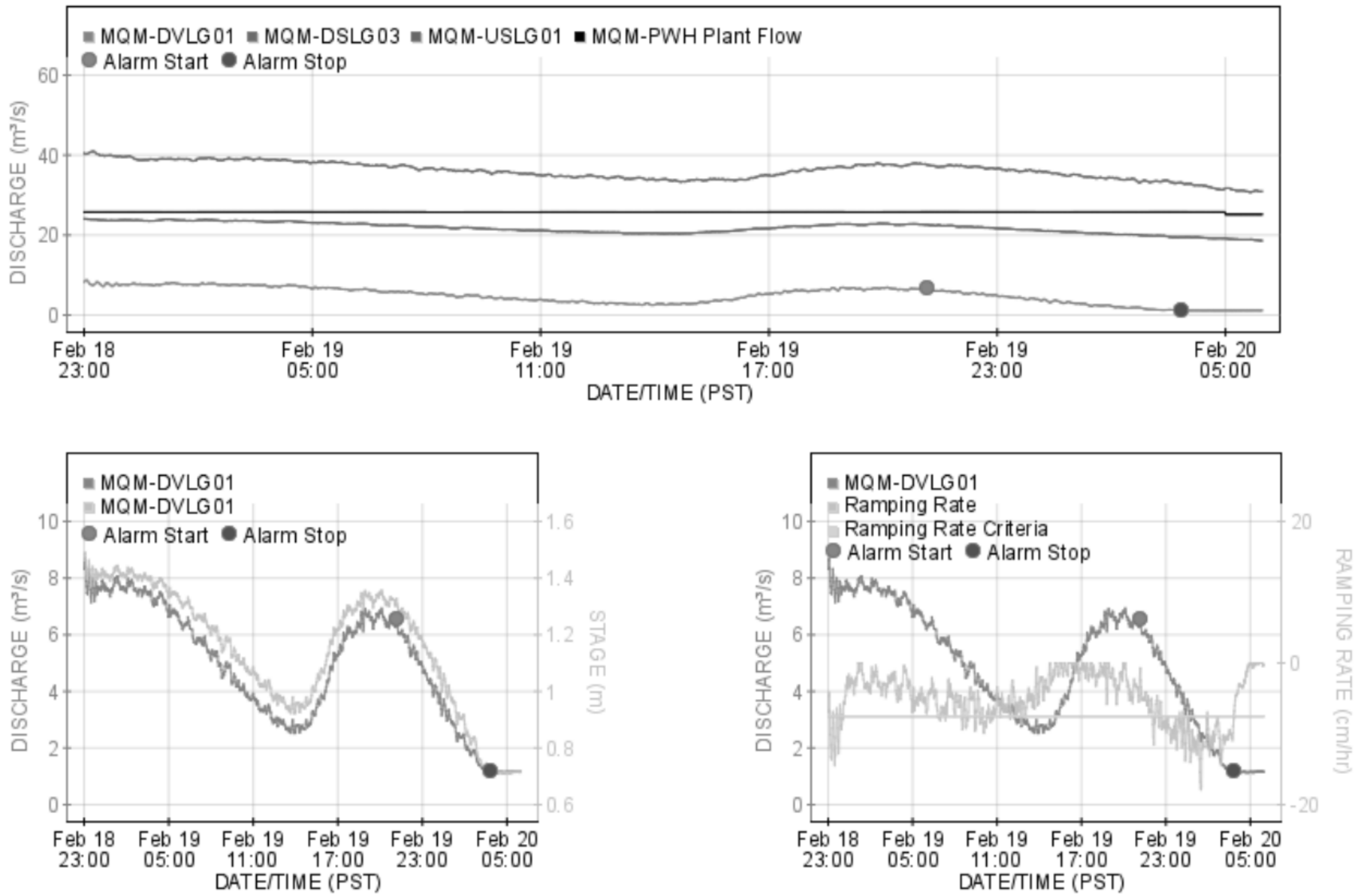




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**Figure 35. Discharges on March 1, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

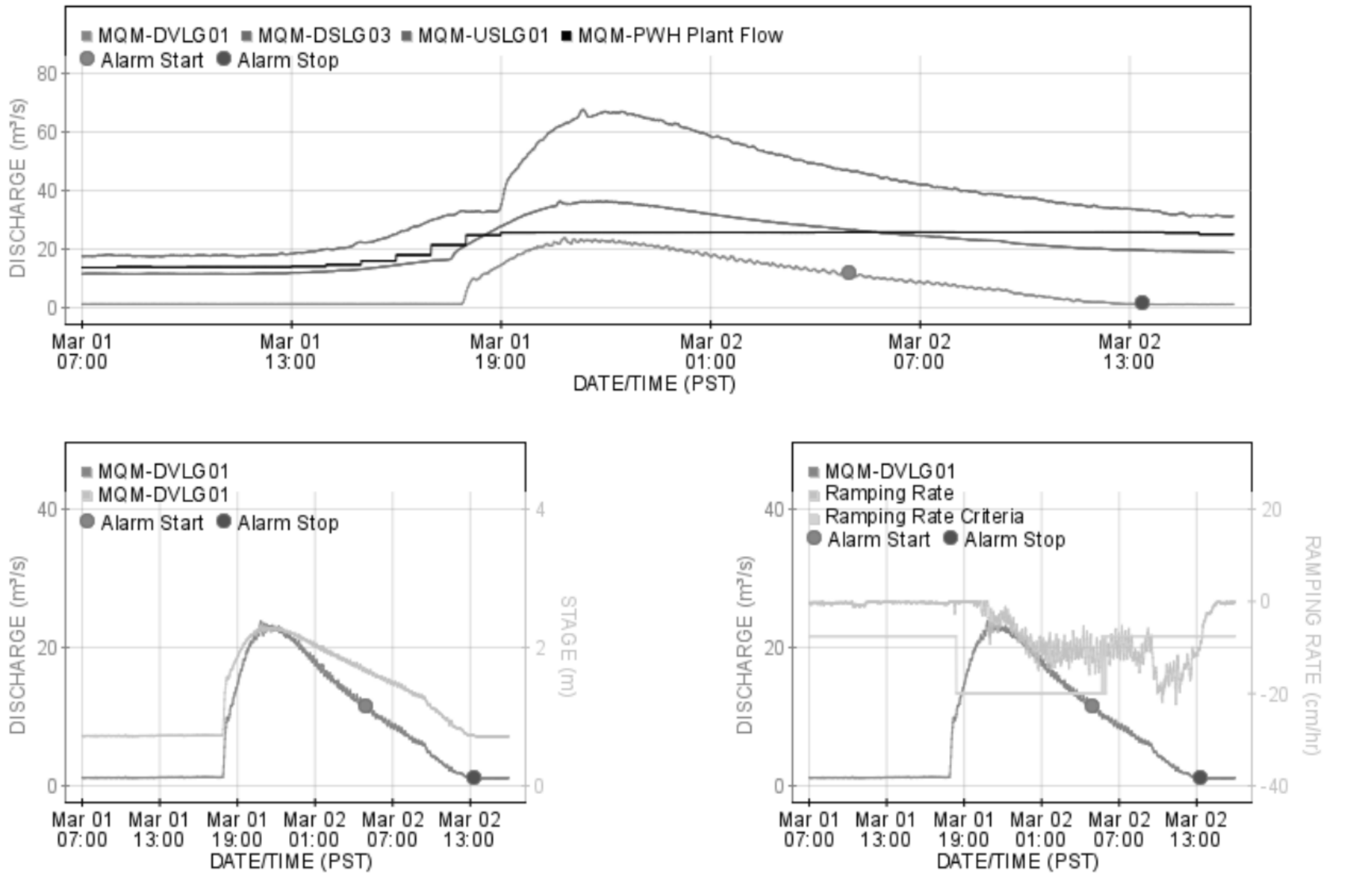


**Figure 36. Discharges on March 3, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

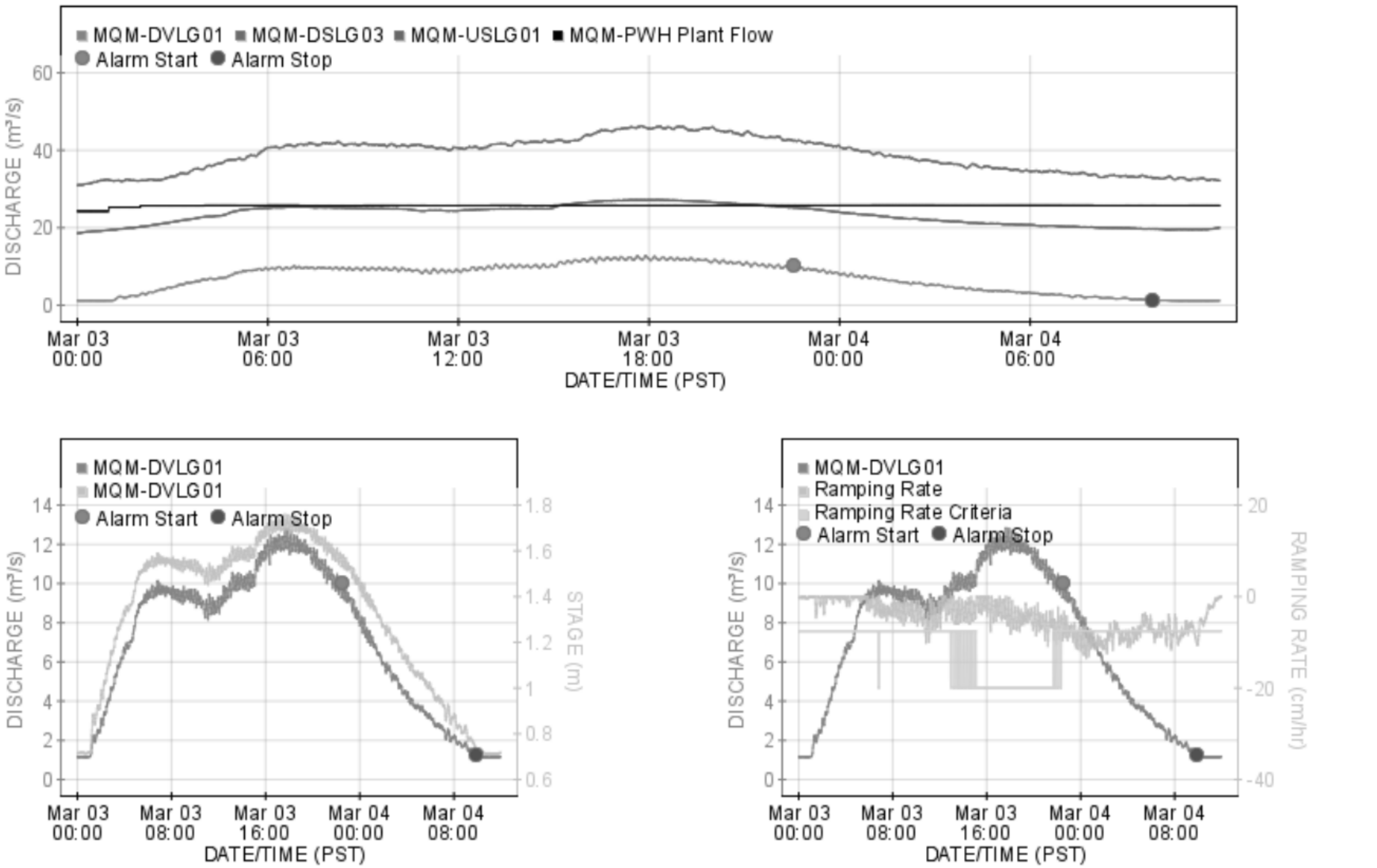


**Figure 37. Discharges on March 6, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

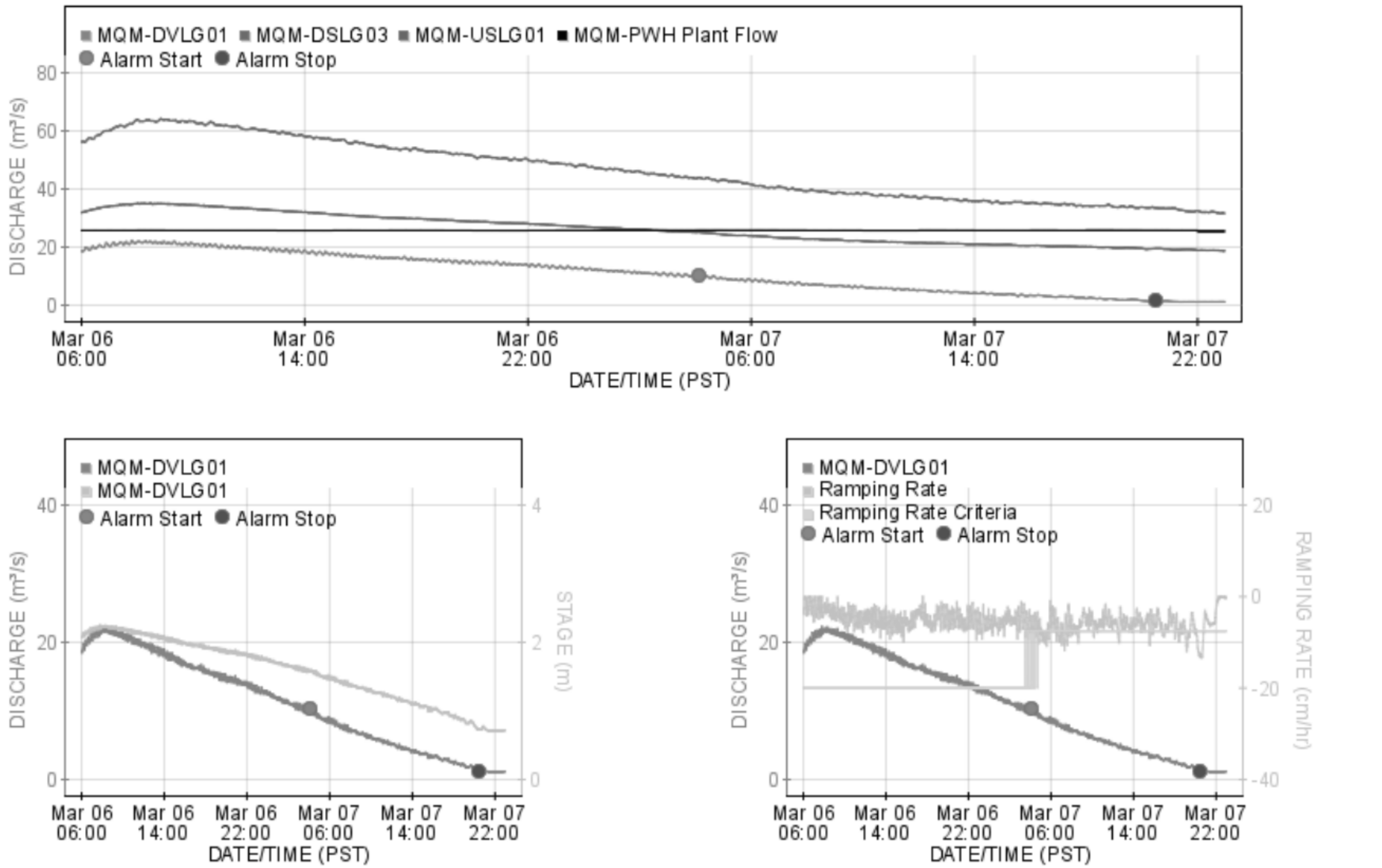


**Figure 38. Discharges on March 10, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

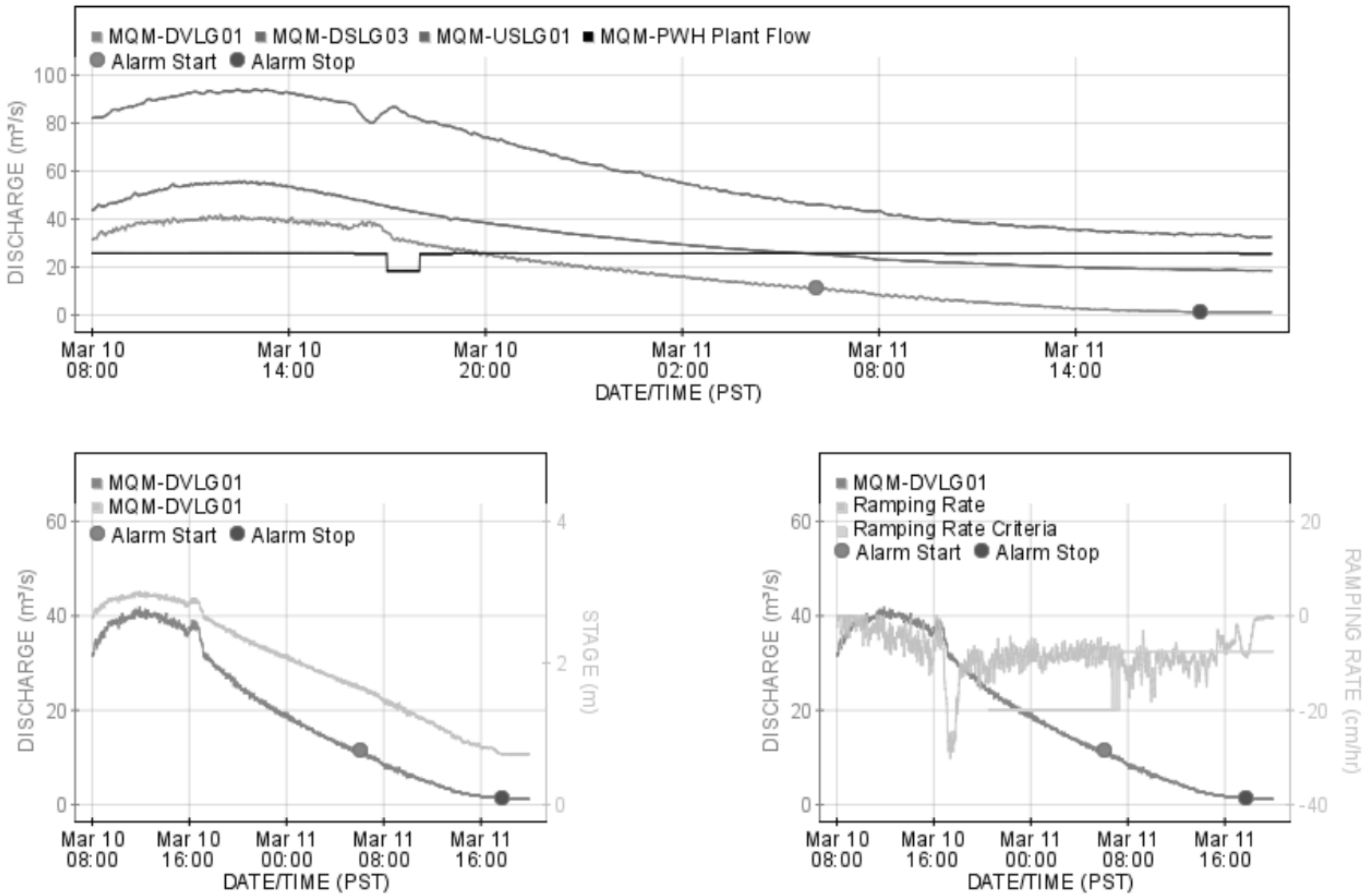


**Figure 39.** **Discharges on March 11, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

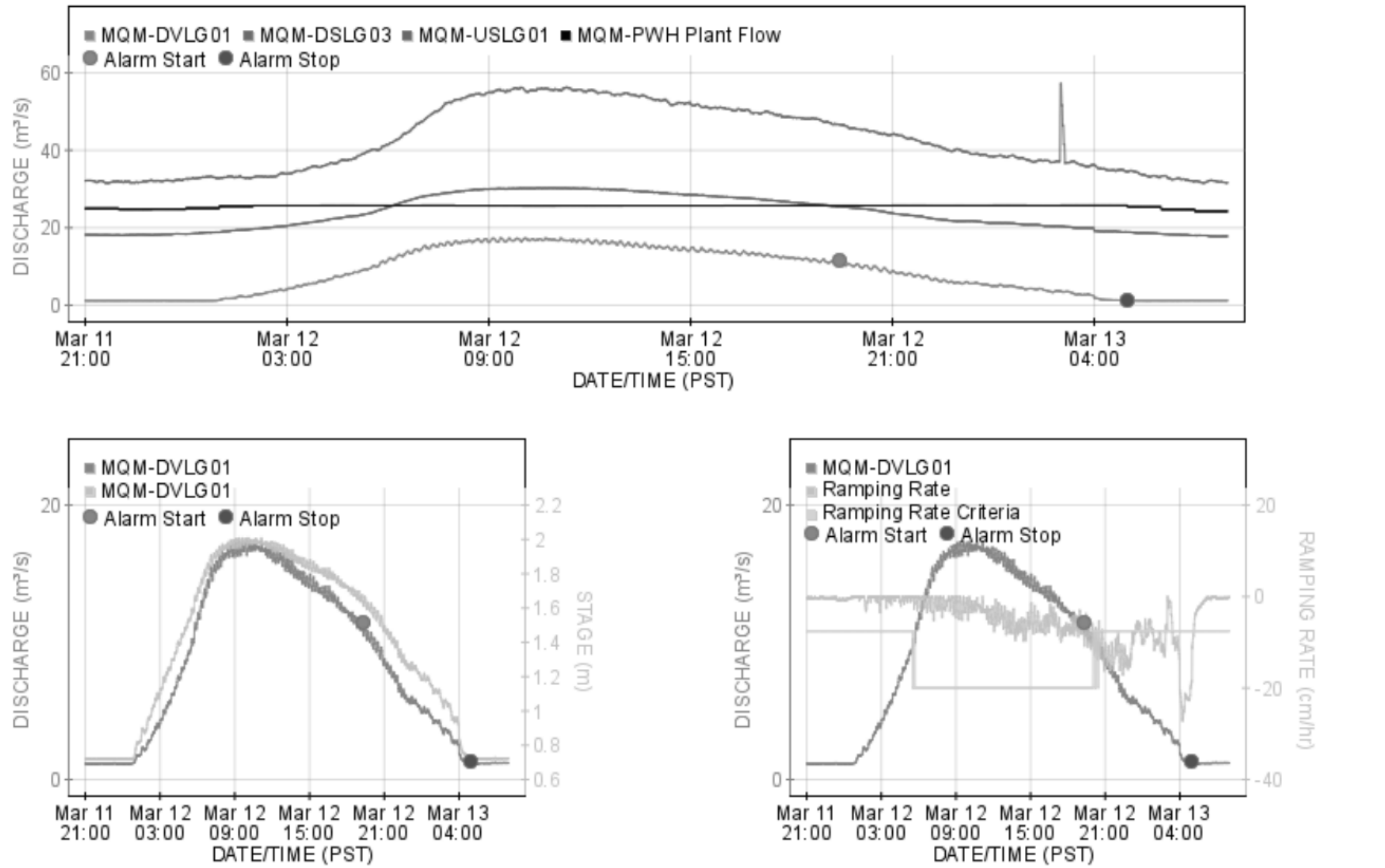
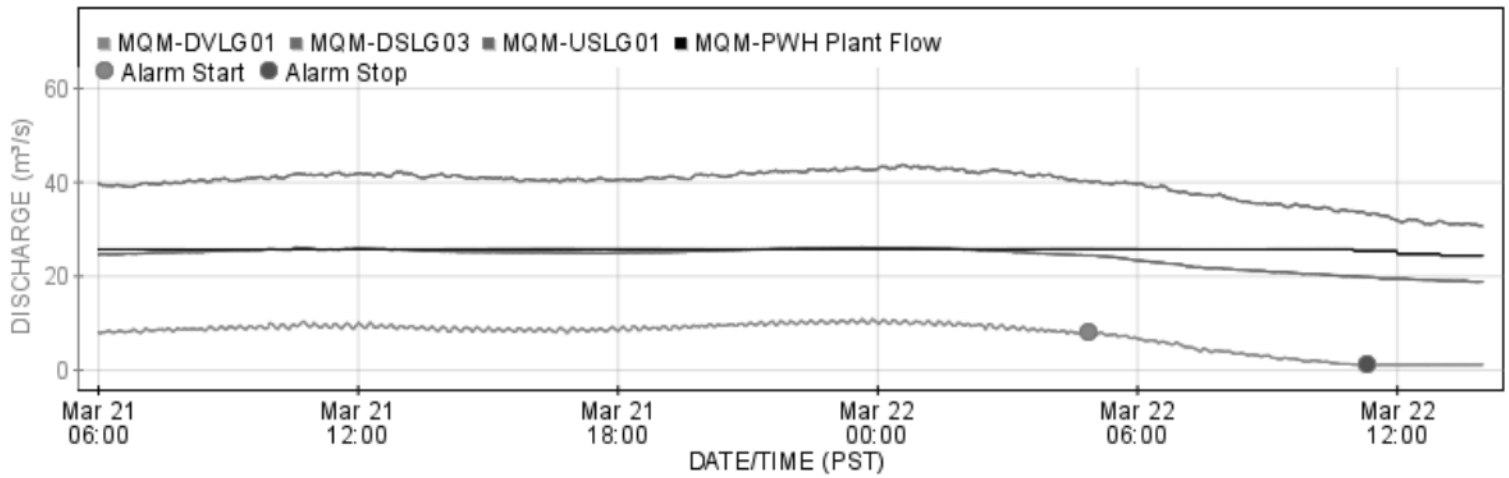
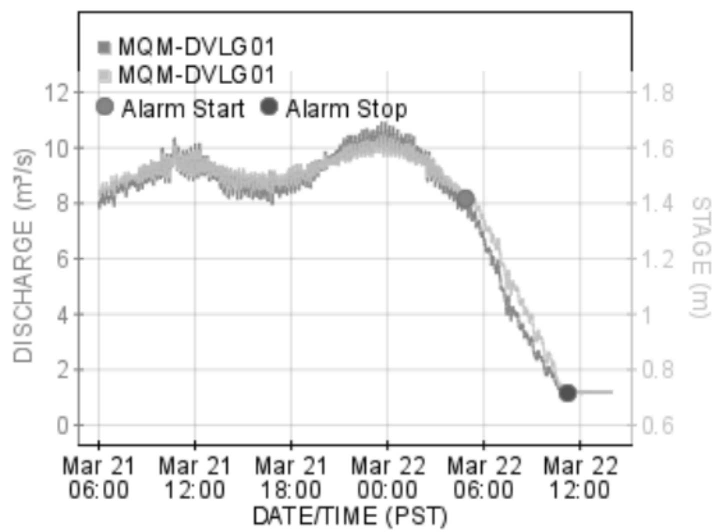


**Figure 40.** **Discharges on March 21, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**



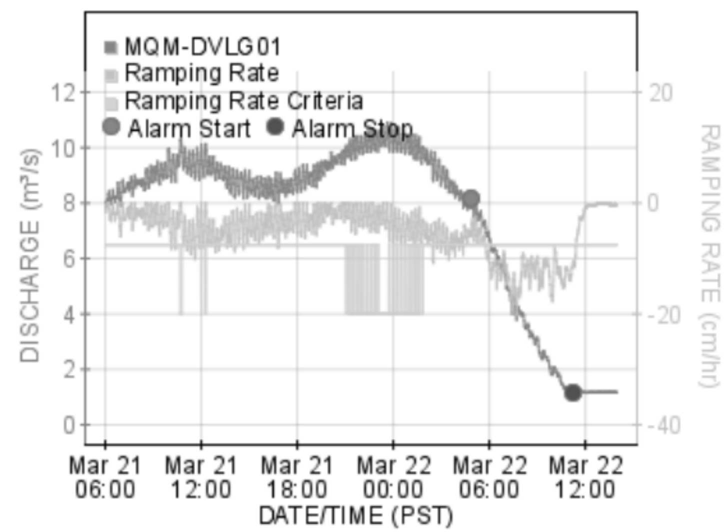



**Figure 41. Discharges on March 23, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

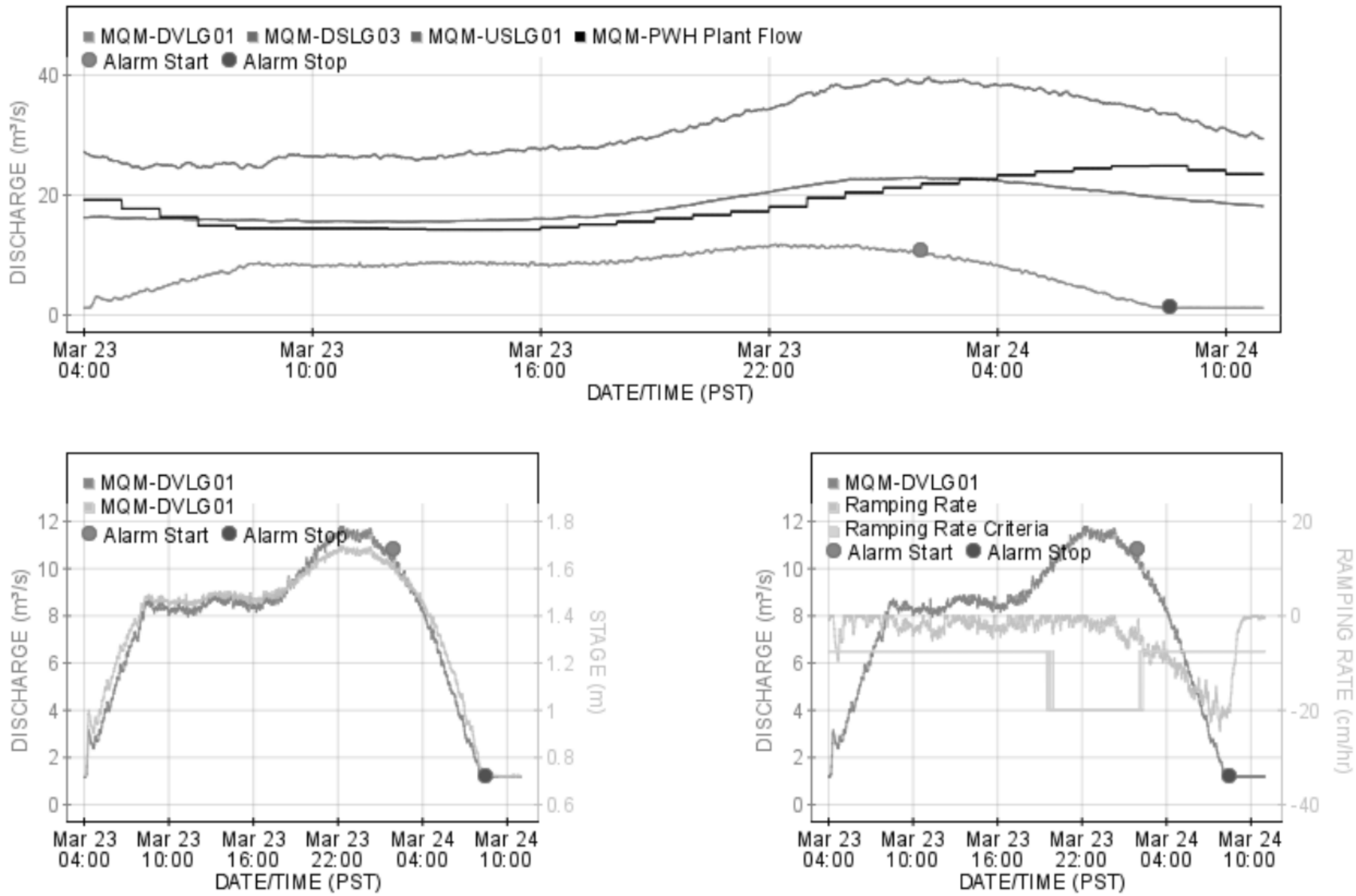


**Figure 42.** **Discharges on March 31, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

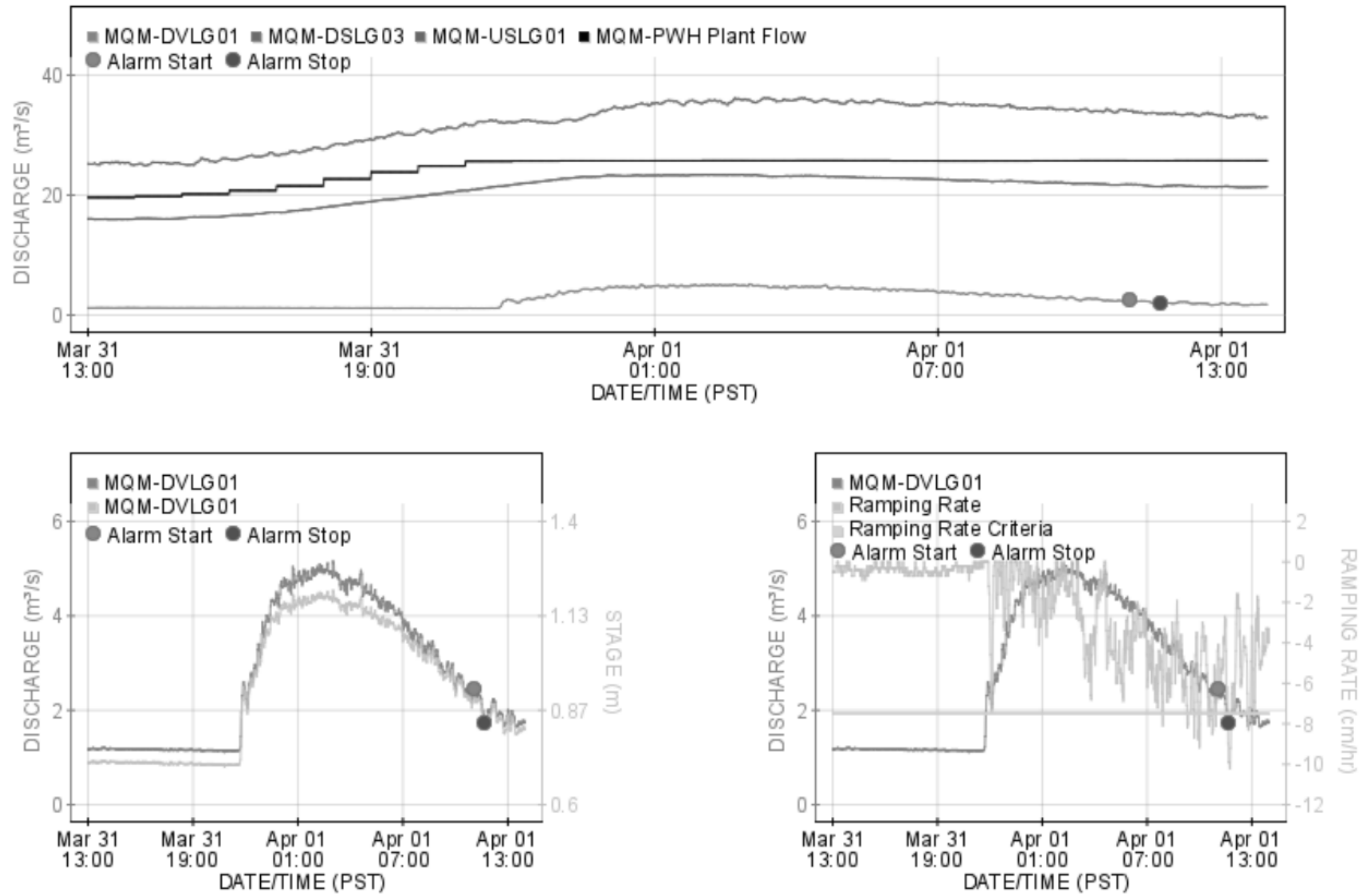
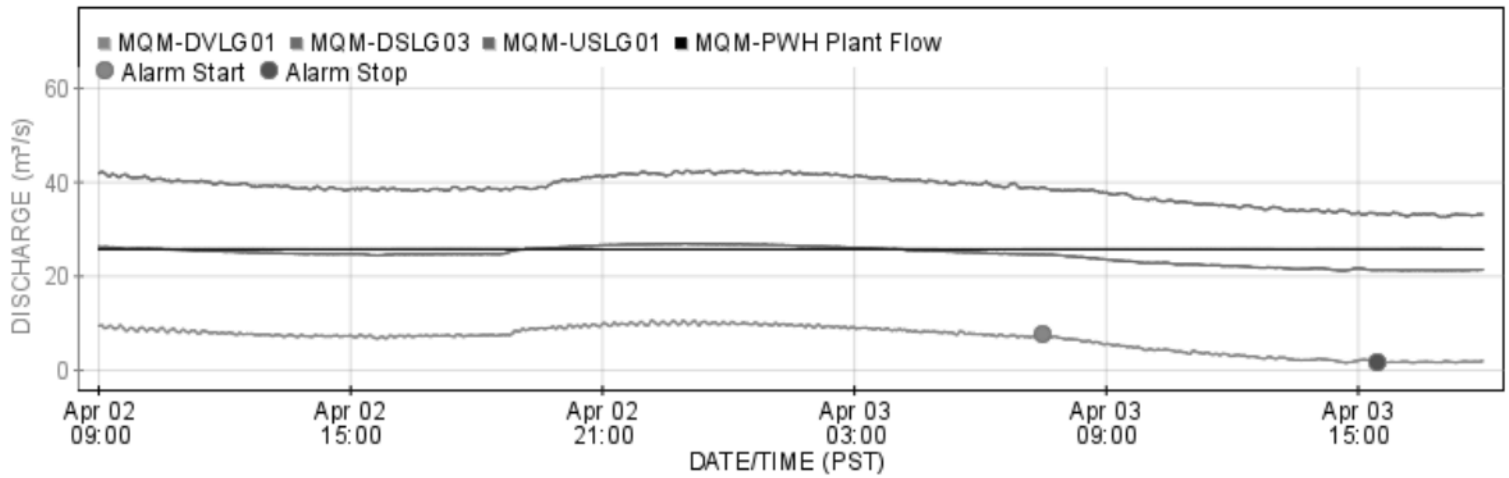
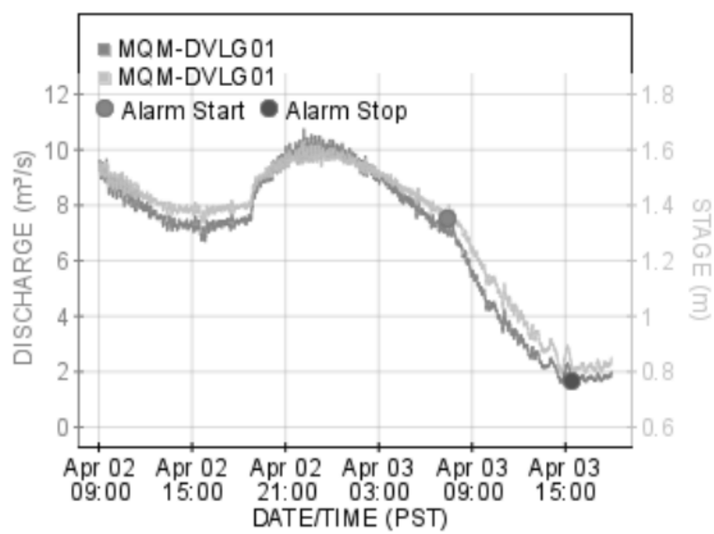


**Figure 43.** **Discharges on April 2, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**



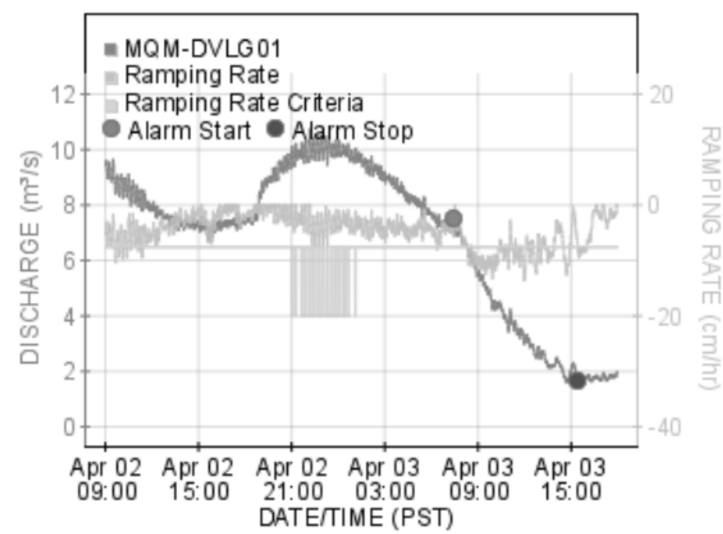
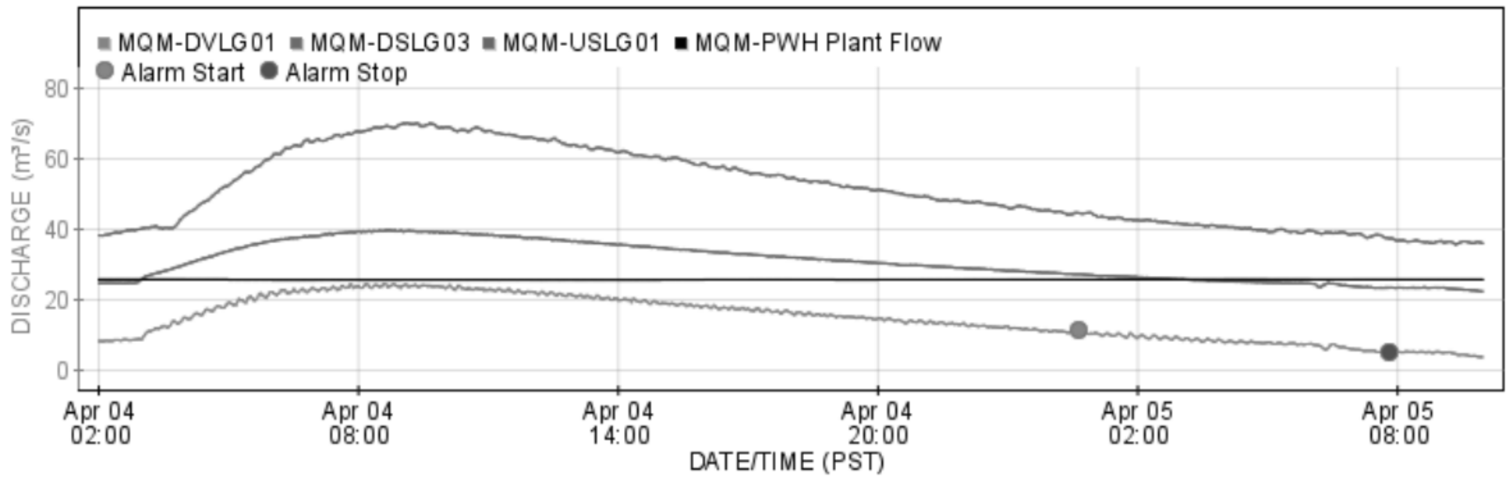
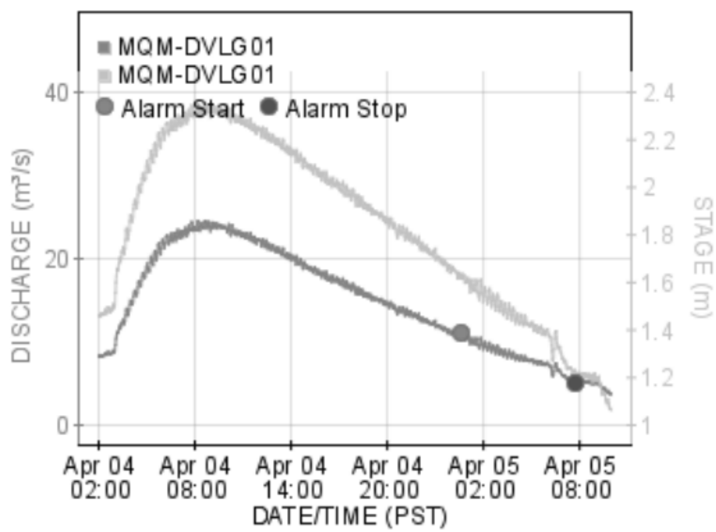



**Figure 44.** **Discharges on April 4, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**



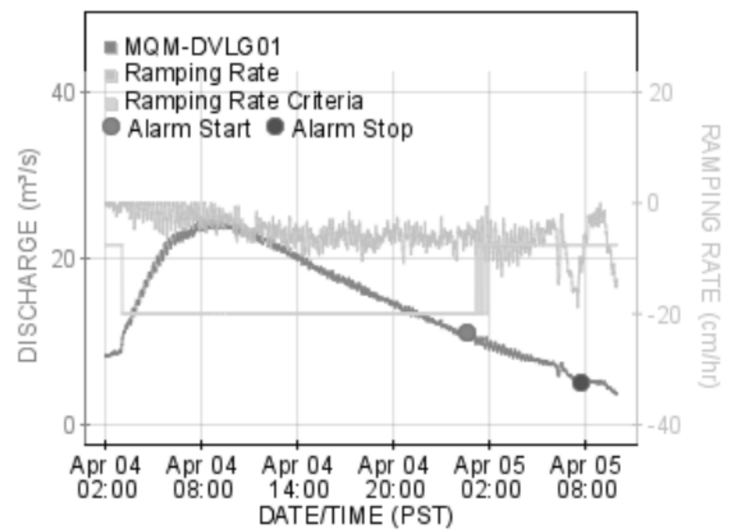



**Figure 45. Discharges on April 4, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

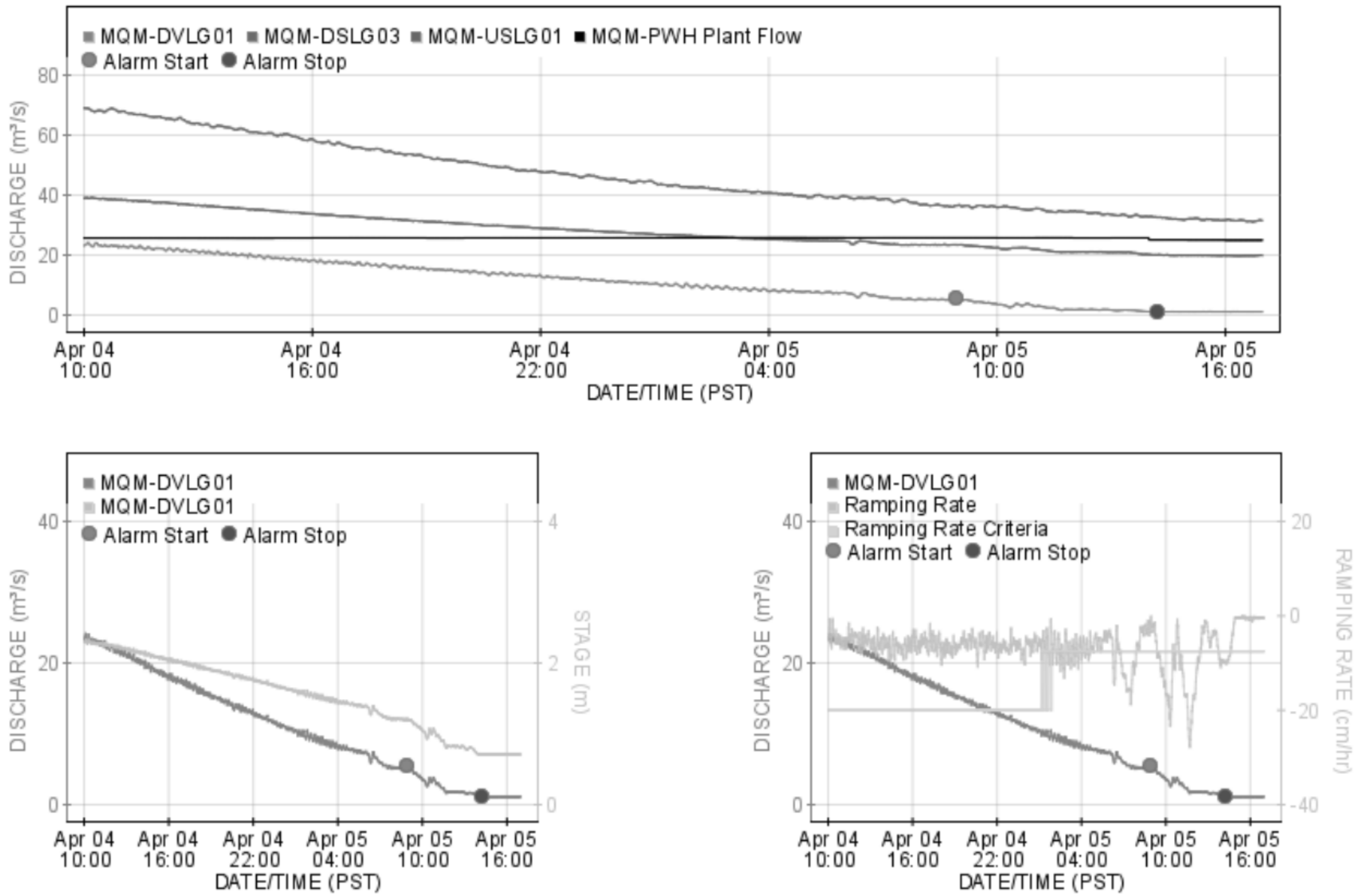


**Figure 46.** **Discharges on April 9, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

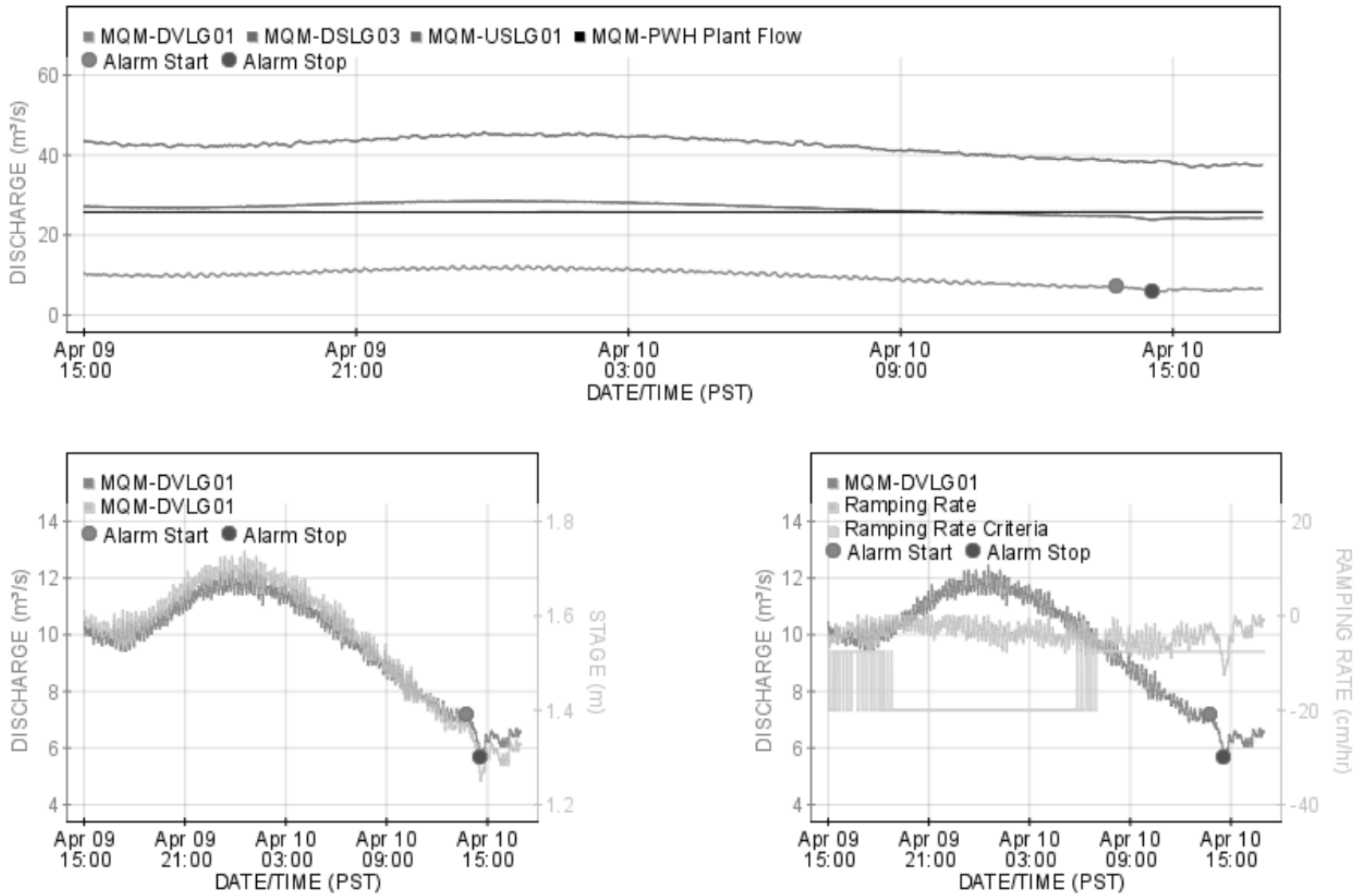


**Figure 47. Discharges on April 10, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

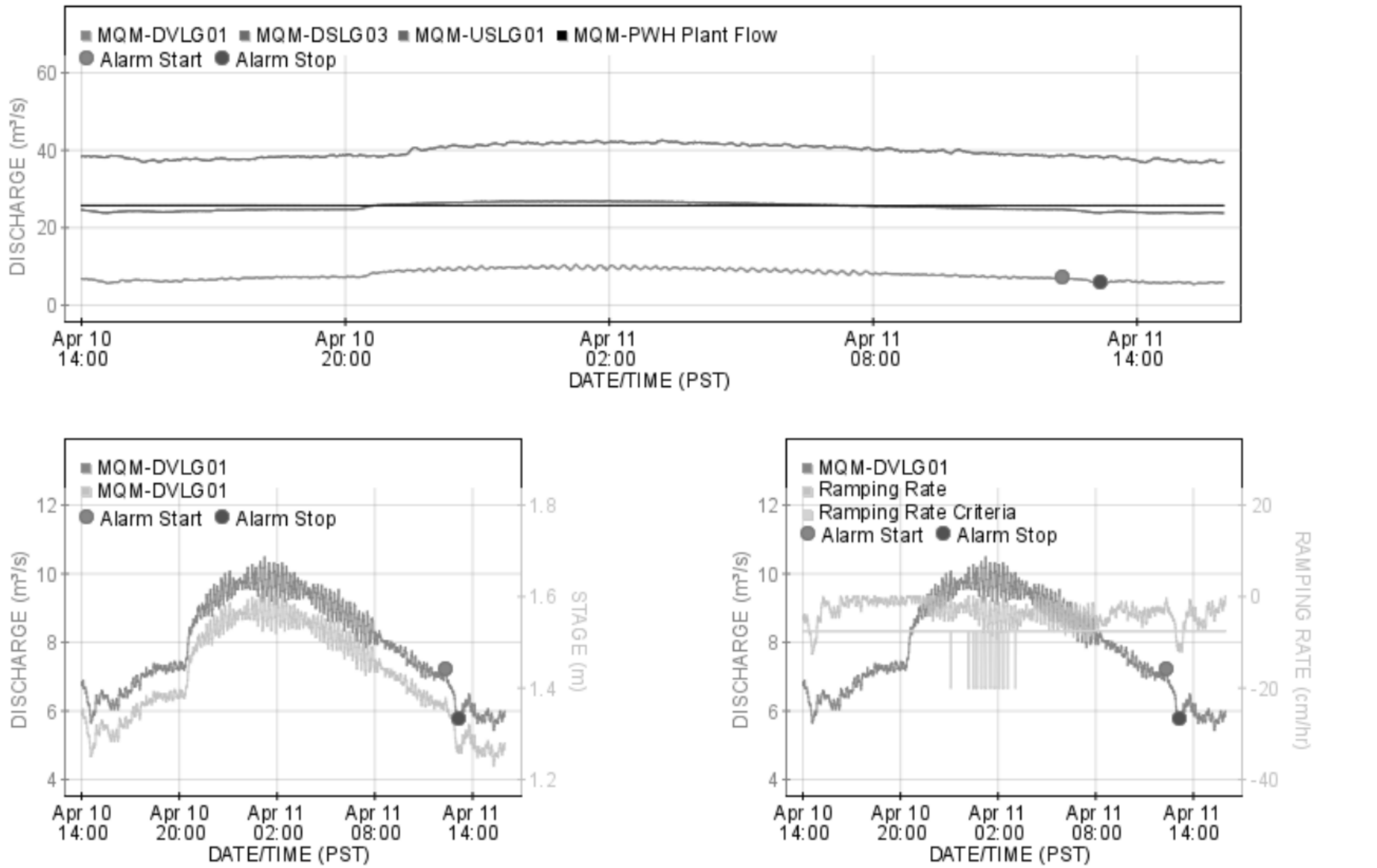


**Figure 48. Discharges on April 12, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

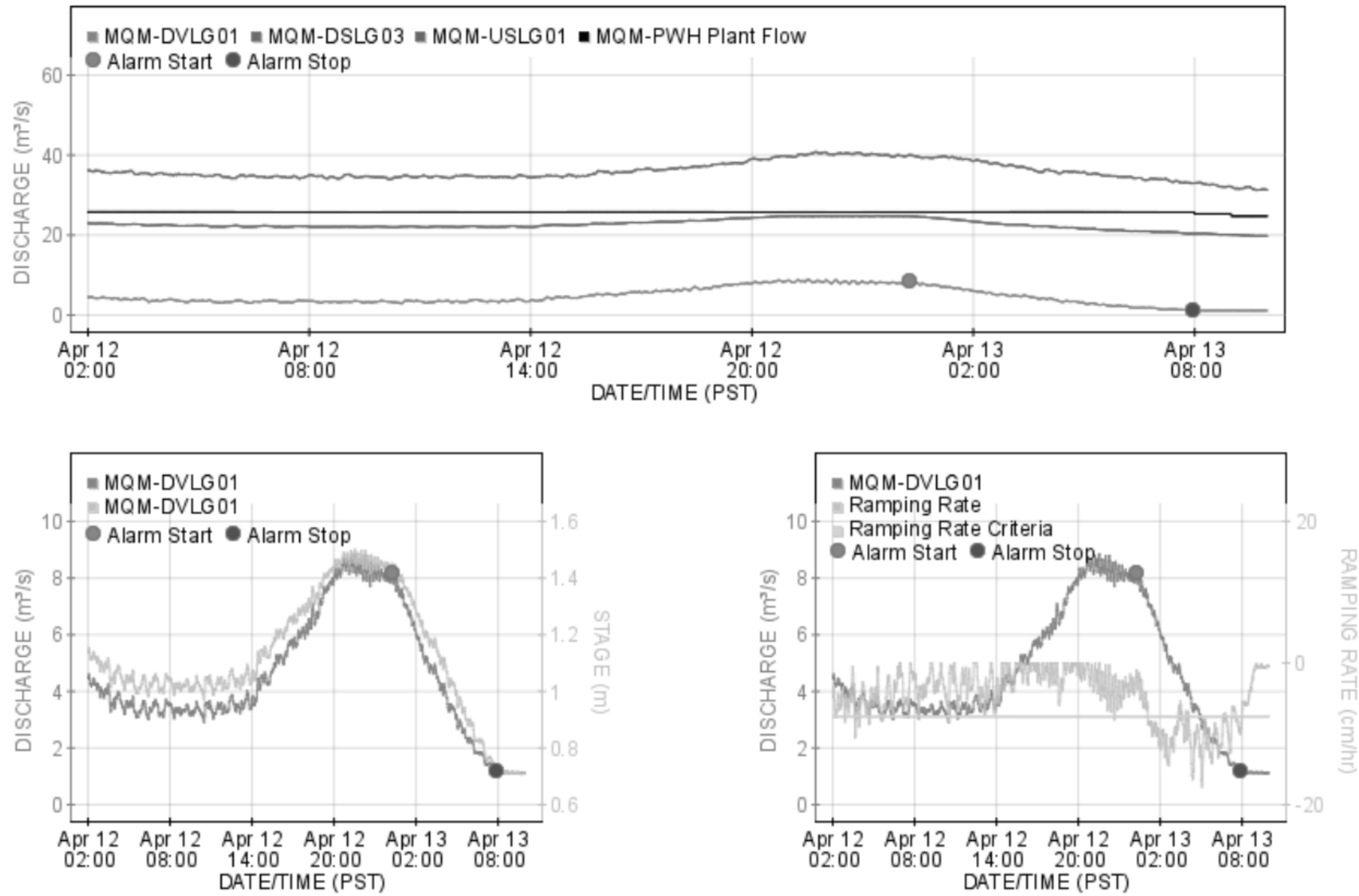


**Figure 49.** **Discharges on April 24, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

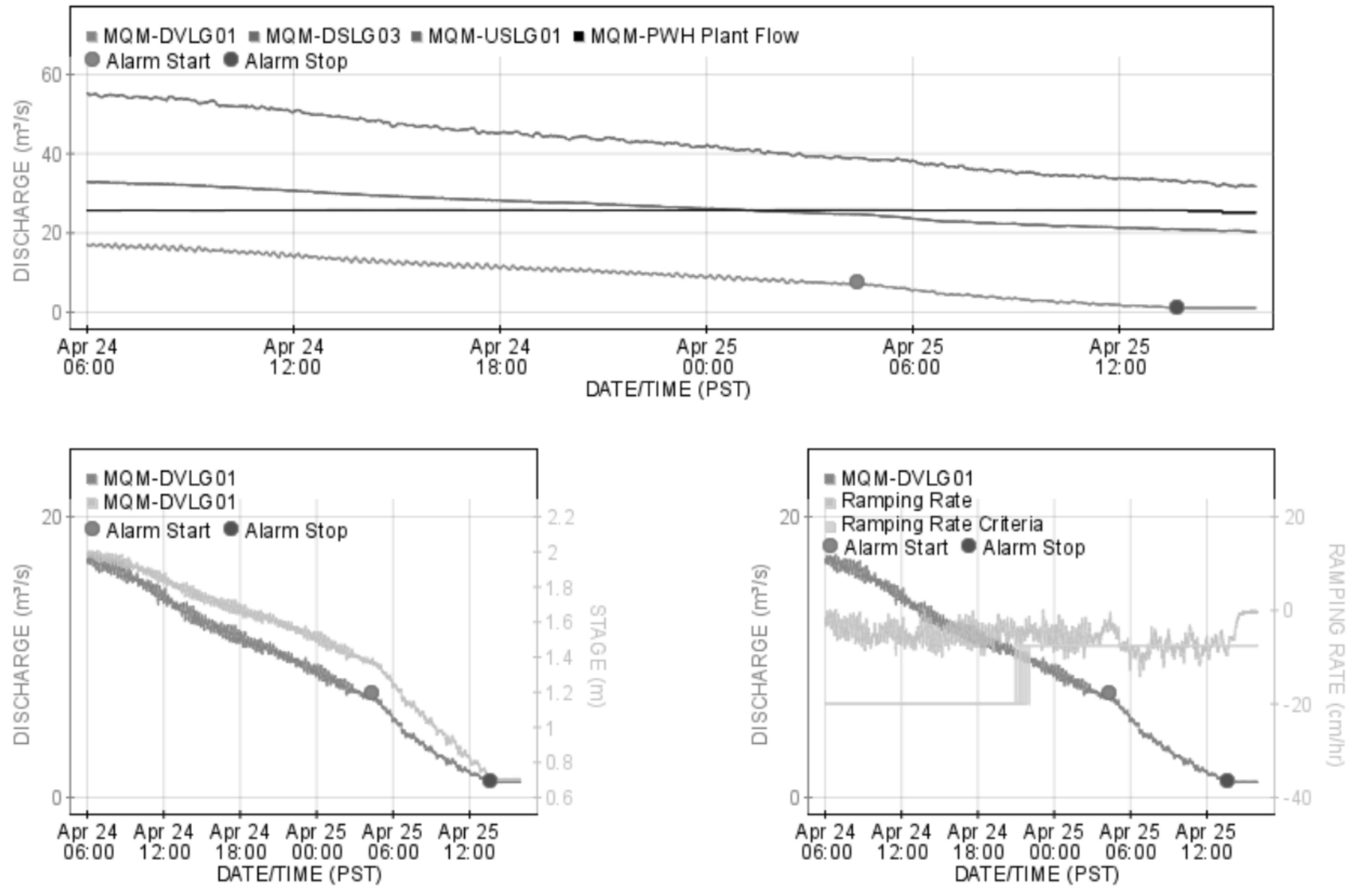


**Figure 50. Discharges on May 1, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

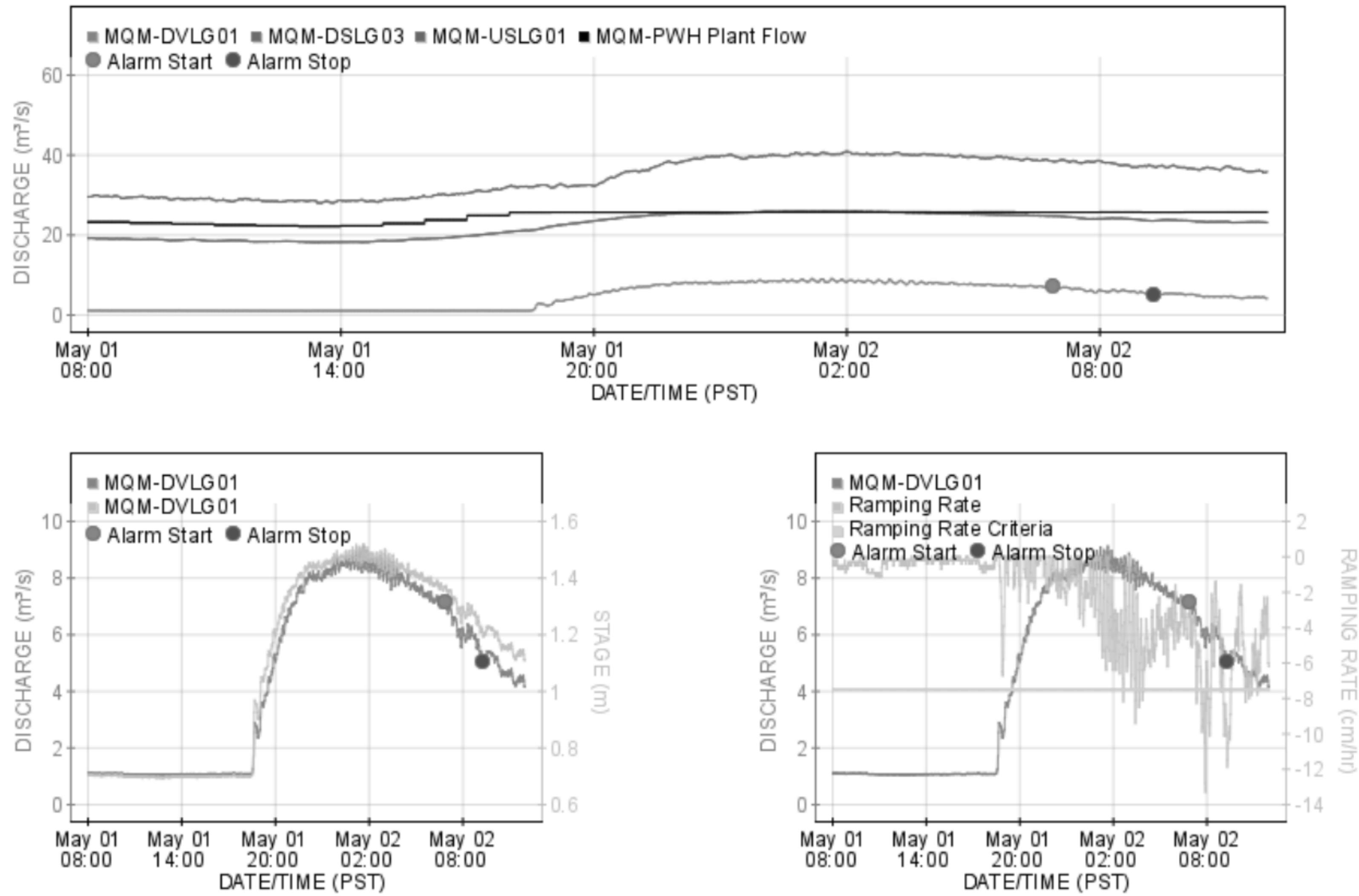


**Figure 51. Discharges on May 4, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

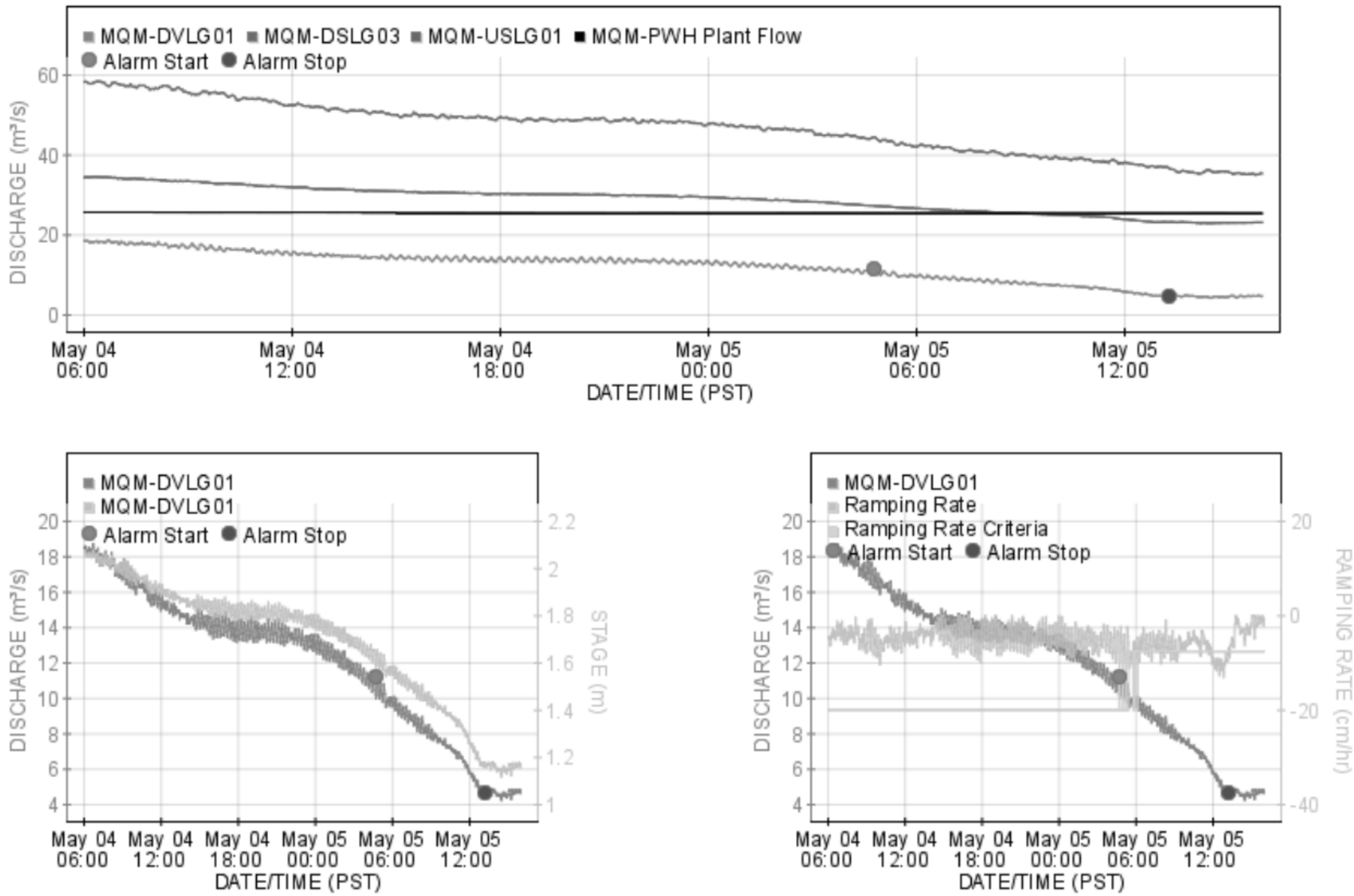
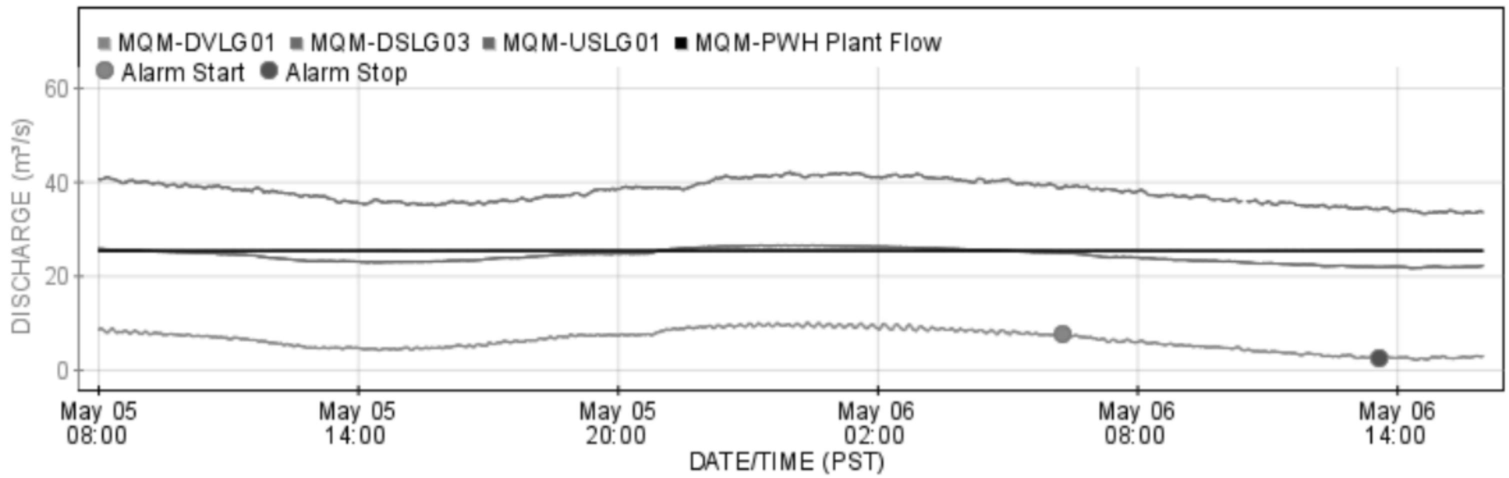
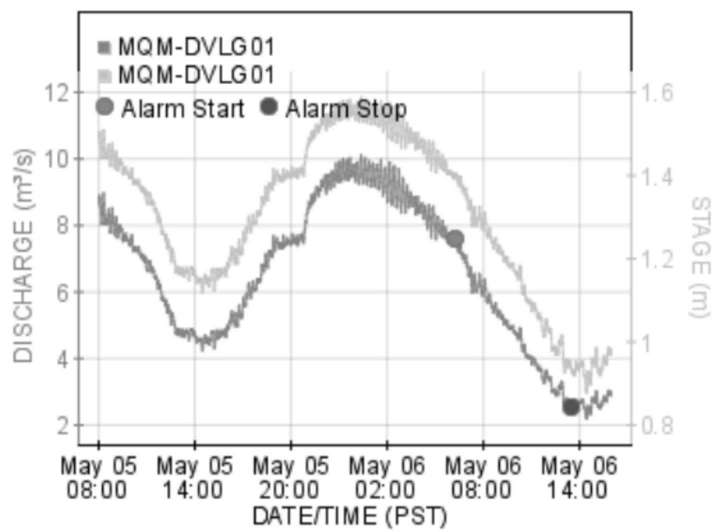


**Figure 52.** **Discharges on May 5, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**



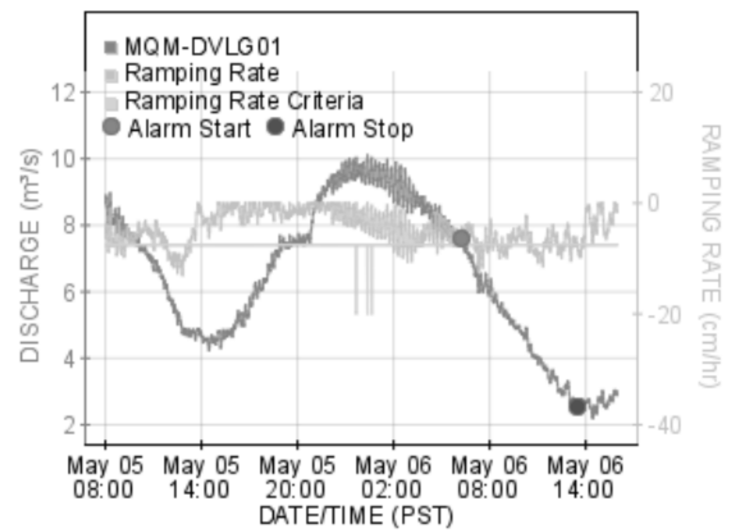



**Figure 53.** **Discharges on May 6, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

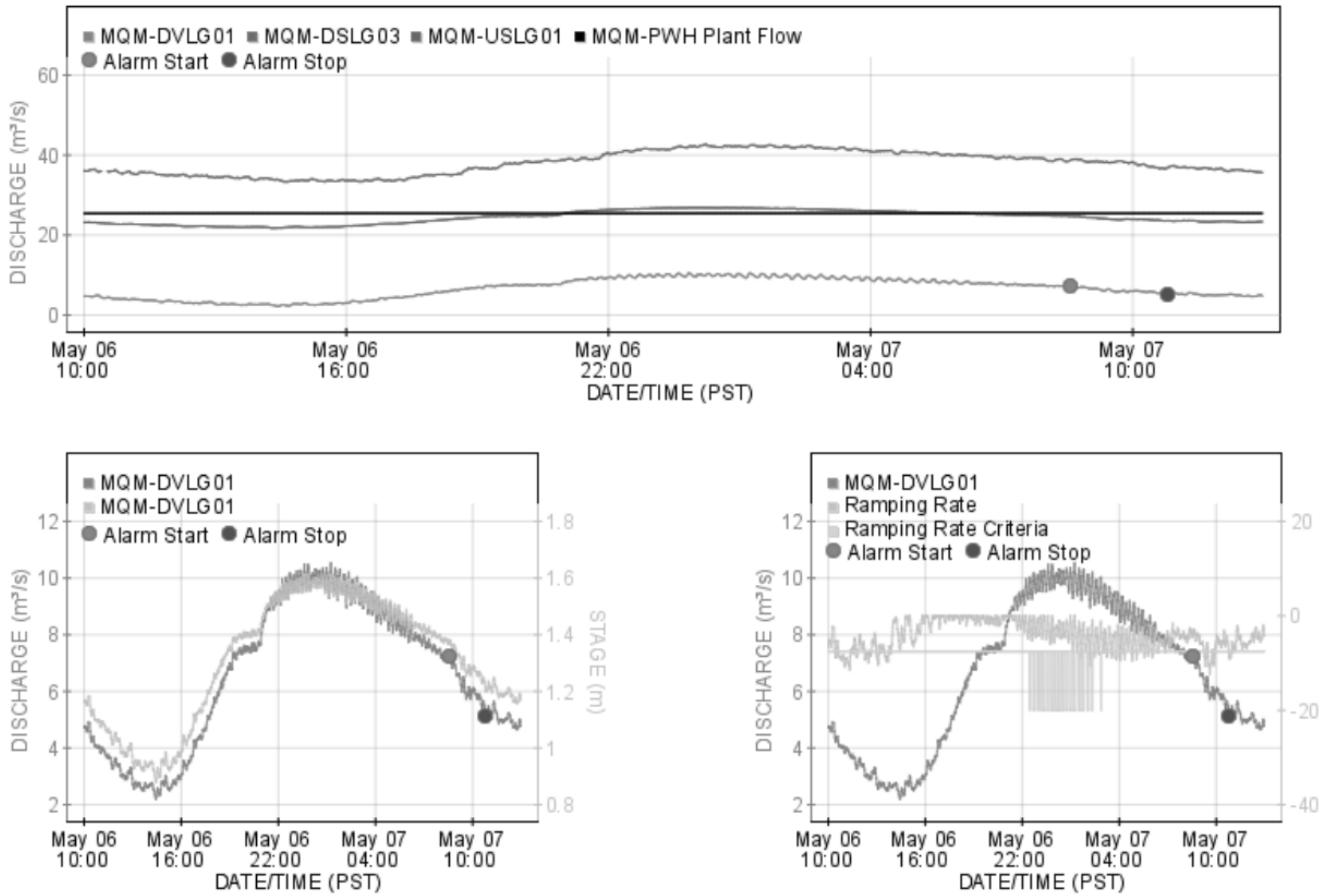





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**Figure 54. Discharges on May 8, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

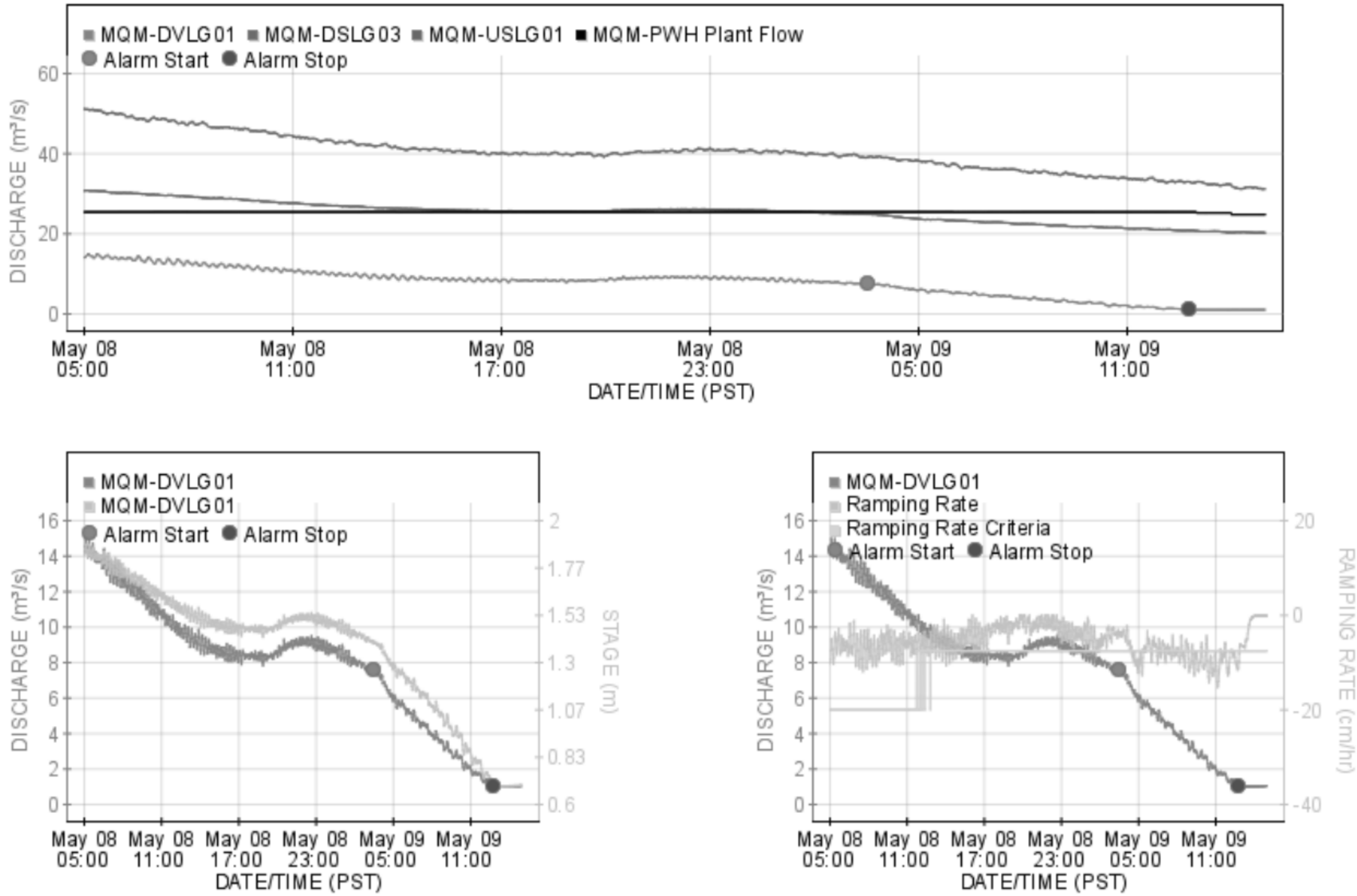


**Figure 55.** **Discharges on May 9, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**

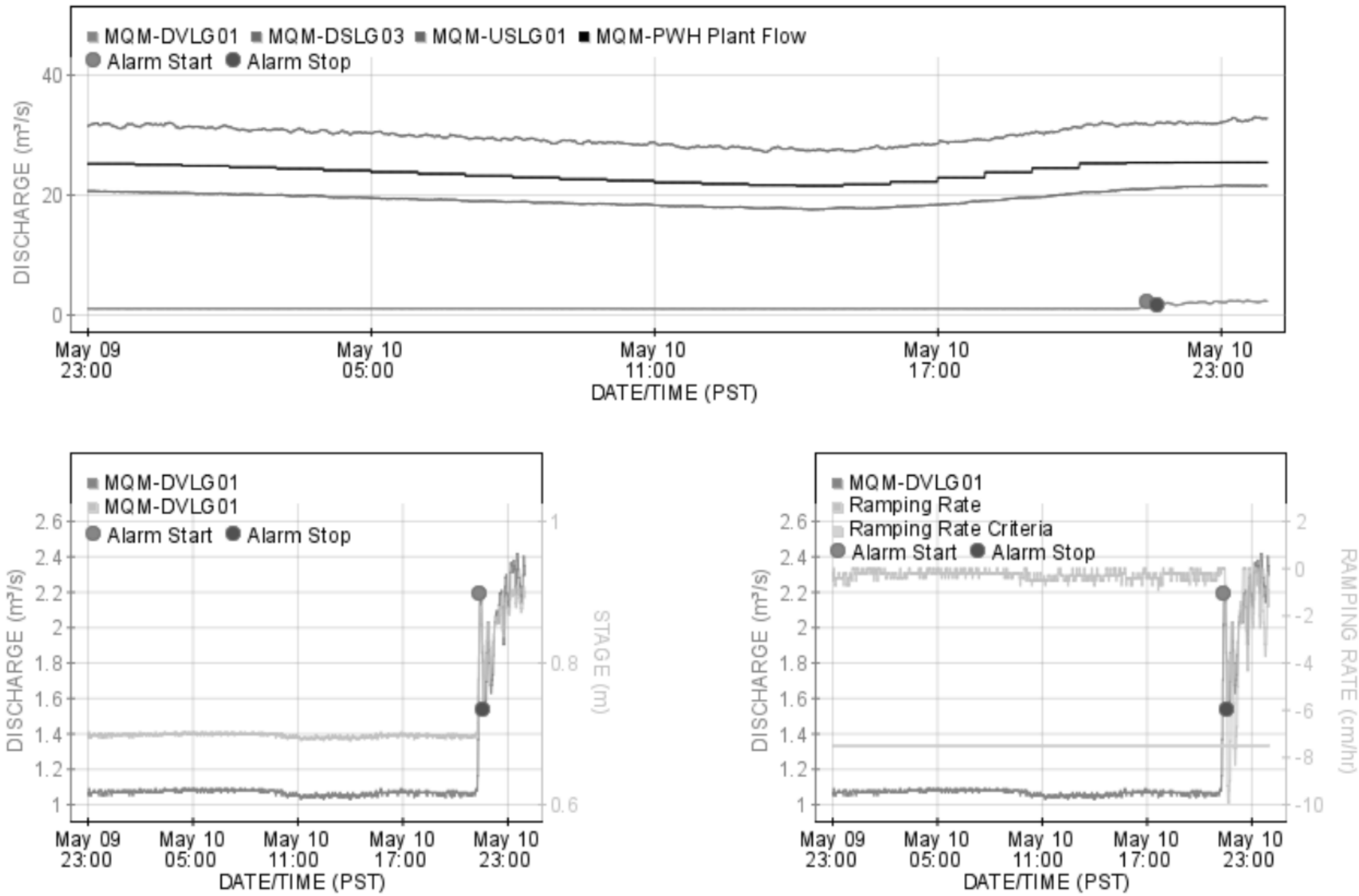
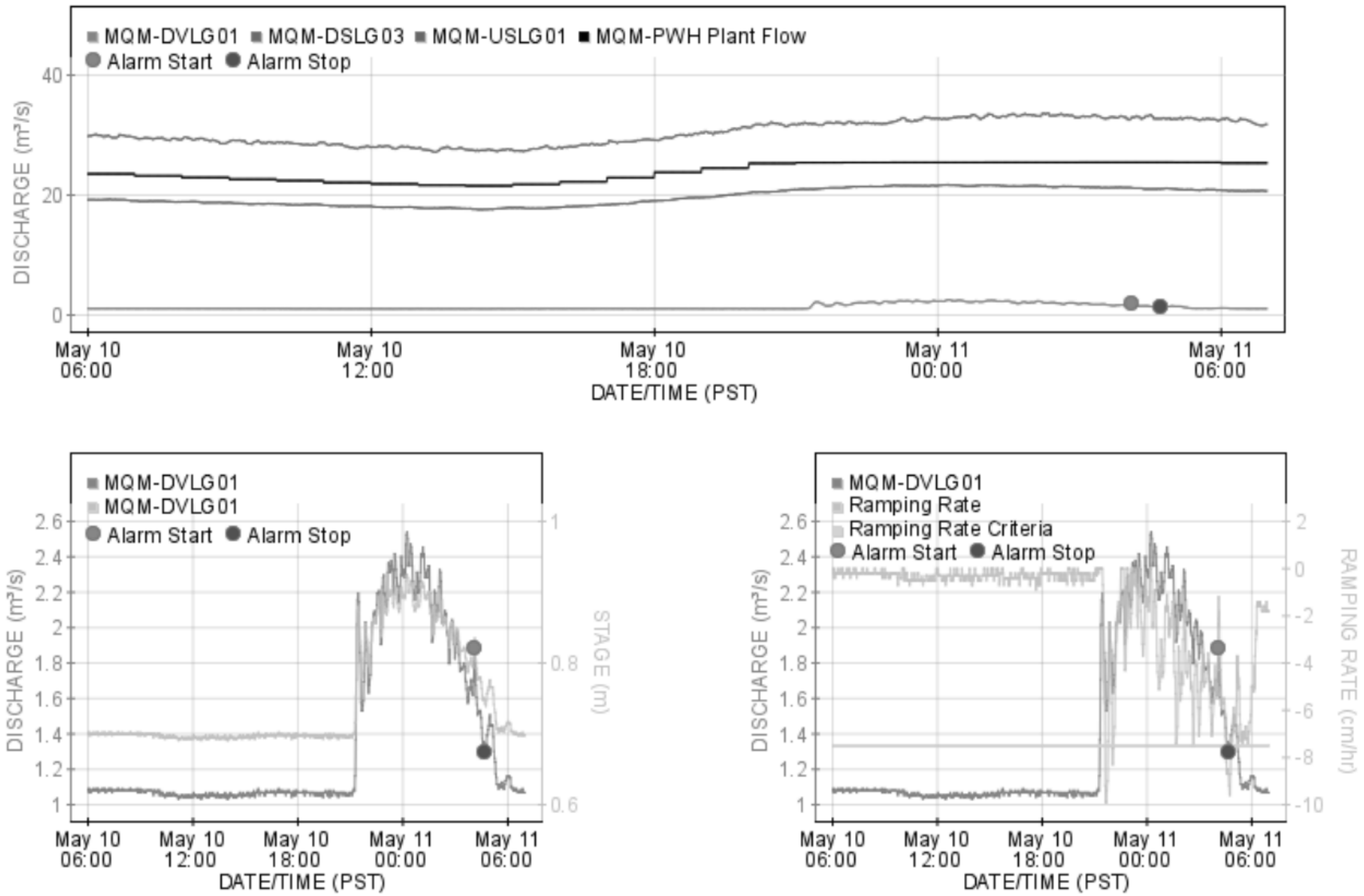


**Figure 56. Discharges on May 10, 2016 ; a) at the downstream permanent gauge (MQM-DVLG01) over time, b) in relation to stage at the MQM-DVLG01, and c) in relation to ramping rates at MQM-DVLG01.**



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Ministry of Forests, Lands and Natural Resource Operations

Water Stewardship Division

# OPERATING PARAMETERS AND PROCEDURES

## Lower Mamquam Hydroelectric Project

**June 14, 2017**

# Atlantic Power Corporation

## Operating Parameters and Procedures Report

### Lower Mamquam Hydropower Project

Version 7

June 14, 2017

**Mamquam River Generating Station**
39241 Powerhouse Springs Road
Squamish, BC V8B 0C2

Prepared by Atlantic Power Corporation

# APPROVAL PAGE

## Approved Operational Parameters and Procedures Report

**Date of OPPR:** November 31, 2016

**Revision of OPPR:** June 14, 2017

## On behalf of the Proponent (Licensee)

**Full Name:** Scott Ronaldson

**Signature:**

**Date:**

## On behalf of the Water Stewardship Division

**Full Name:** Scott Babakaiff

**Signature:**

**Date:**

# Revision Tracking

Versions and revisions of the OPPR and supporting appendices have be described and tracked to provide a revision history and to identify the current version:

**Operational Procedures and Parameters Report**

| Revision Number | Date | Description | Prepared By (Proponent) | Agency Review (WSD) |
|---|---|---|---|---|
| 1 | April 31, 2014 | Revised OPP for Review | MN, TS | |
| 2 | | Revised as per MFLNRO request | MN | |
| 3 | September 19, 2014 | Revised as per MFLNRO request | MN | |
| 4 | December 5, 2014 | Revised as per MFLNRO request | MN | |
| 5 | December 23, 2014 | Revised sections 3.3.3, 3.3.2.2, 4.2.1, as per MFLNRO request | MN | |
| 6 | November 21, 2016 | Revised sections 3.1.1.2, 3.1.2.1, as per MFLNRO request, also 3.3.4 updated with new penstock flow meter, sections 6&7 updated contact list | MN | |
| 7 | June 14, 2017 | Revised Contacts listings to reflect staffing changes at Atlantic Power Corporation. Revised section 2.2.1.4. Deleted multiple references to 297.1 and replaced with 297.0 | SR | |

**OPPR Supporting Appendices**

| Appendix | Revision Number | Date | Description | Prepared By (Proponent) | Agency Review (WSD) |
|---|---|---|---|---|---|
| **Addendum B** | 4 | December 5, 2014 | Added Addendum B | Ecofish | |

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# LIST OF APPENDICES

# Section 1.0 - LIST OF ACRONYMS

| | |
|---|---|
| AMSL | Height above mean sea level |
| BC DSR | BC Dam Safety Regulation 44/2000 |
| DFO | Fisheries and Oceans Canada |
| EPP | Emergency Preparedness Plan |
| IDF | Inflow Design Flood |
| ESD | Emergency Shut Down |
| FLNRO | Ministry of Forests, Lands and Natural Resource Operations |
| FSL | Full Supply Level |
| FSR | Forest Service Road |
| GWh | Giga Watt Hour |
| HMI | Human Machine Interface |
| HP | Horsepower |
| HPU | Hydraulic Power Unit |
| IFR | Instream Flow Requirement |
| LCO | Leave to Commence Operations |
| mA | MilliAmps |
| MCC | Motor Control Centr |
| MFLNRO | Ministry of Forests, Lands and Natural Resource Operations |
| mg/l | Milligrams per litre |
| MRF | Minimum Release Flow at Headworks |
| MW | Megawatt |
| NTU | Nephelometric Turbidity Units |
| OPP | Operating Parameters and Procedures |
| OMS | Operation Maintenance and Surveillance Plan |
| PEP | Provincial Emergency Program |
| PEP-EMBC | Provincial Emergency Program within Emergency Management British Columbia |
| PIR | Project Interconnect Requirements |
| PLC | Programmable Logic Controller |
| POI | Point of Interconnection |
| SDM | Statutory Decision Maker |
| TSV | Turbine Shut-off Valve |
| VAC | Volts, Alternating Current |
| VDC | Volts, Direct Current |
| WSE | Water Surface Elevation |

# Section 2.0 - PROJECT INFRASTRUCTURE

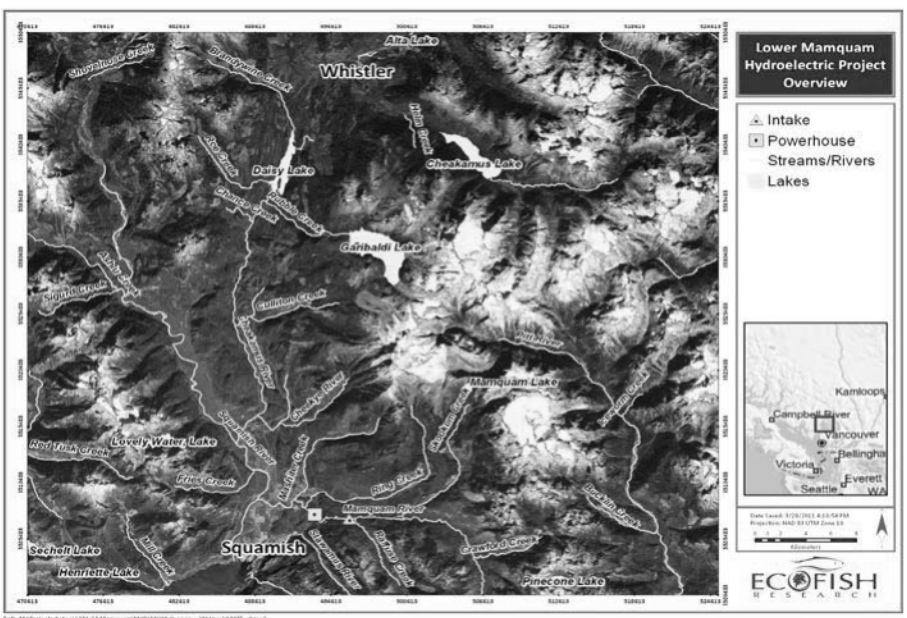
## 2.1 LOCATION, OWNER and PERMITS

### 2.1.1 Project Location and Ownership

The Mamquam River Hydroelectric Project is licensed to Atlantic Power Corporation and the legal owner is Atlantic Power Corporation. The Mamquam River Hydroelectric Project (Project) is located about 4 km east of the town of Squamish in western British Columbia. The project diverts water from the Mamquam River into a tunnel that feeds two turbines for power production. The powerhouse is at the downstream end of a tunnel approximately 3 km from the intake facilities.

The Mamquam River flows northwest from the Coast Mountains and joins the Squamish River near the town of Squamish. It drains 378 km2 of water into a mountainous area just south of Garibaldi Provincial Park. Elevations in the watershed range from near sea level at the mouth to over 2,600 m at Mount Garibaldi. The diversion site is located 8 km from the mouth of the Mamquam River, at the head of Mamquam Falls. The drainage area at the diversion site is 273 km2. Most of the drainage area is made up of steep sided valleys with very dense vegetation ranging from large trees to small shrubs and grasses. There is a small glacier-covered area at the headwaters of Skookum Creek, which drains into the Mamquam River upstream of the diversion.
Mapping location references are:

Latitude and Longitude: North 49 43 296
West 123 05 507



### 2.1.2 Detailed Location & Access

The Project is located off of the Mamquam River Forest Service Road, in Squamish, BC, Canada. The Mamquam River Forest Service Road is located approximately three km north of Shannon Falls Provincial Park and 1.3 km south of downtown Squamish. Proceed east up Forest Service Rd for approximately 3.8 kilometers, and turn left at a 3-way intersection. Follow this road for approximately four km to the gate to the Project Powerhouse, and proceed across the bridge, taking the left branch to the Powerhouse 0.1 km further down the road. .See Appendix A for Site Map of the Project. Detailed security measures are addressed in Section 2.3. Detailed information on access infrastructure is provided in Section 2.2.6.

### 2.1.3 Regulatory Permits & Authorizations

This section identifies regulatory permits and authorizations. The permits and authorizations for this Project are provided in Table 1.

**Table 1 List of Regulatory Permits and Authorizations**

| Permits/Authorizations | Identifier |
|---|---|
| Water file number(s) | 2000966, 2003040 |
| Land tenure number(s) | 241931, 236420, 236422, 236423, 236424 |
| Conditional Water License | 102850 & 123692 |
| Road Use Permit | 9283-13-02 |

The Project Water License is an all-encompassing license issued by the BC Ministry of Environment, Land and Parks which outlines Atlantic Power's water usage rights for Mamquam and includes the requirements of several regulatory bodies. The original conditional license, CWL 102850, was granted in May 1994 and allowed for the diversion of up to 23.45 m3/sec from the Mamquam River. In 2009, Atlantic Power's predecessor company, EPCOR, was granted a conditional water license, CWL 123692 that allowed for the diversion of an additional 6.55 m3/sec. The new license had a number of requirements based on current reporting requirements on new hydroelectric plants as well as historical information requirements for Mamquam.

These requirements include:

1. Submit and implement a plan to monitor in-stream flows.
2. Submit and implement an Operational Environmental Monitoring Plan. The plan will assess the impact of operations on the river fish habitat with a focus on ramping and dam lowering operations.
3. The monitoring plan will be in effect for five years with a final report submitted at the end of the five year period.
4. A water reserve of 1 $m^3$/sec for use of the Crown for the protection of fish.
5. Inspection requirements, specifically dam safety and penstock inspections in accordance with the BC Dam Safety Regulation.

All Mamquam staff and management shall ensure that the Mamquam Generating Station is operated in accordance with the conditional water license for the facility and all requirements for the license are satisfied.

### 2.1.4 Adjacent Water Licenses and Other Users

#### 2.1.4.1 Adjacent Water License Holders

[If Applicable] The Project stream also supports other water license holders. These license holders are listed in Table 2

***Table 2 Other Water License Holders in Watershed***

#### 2.1.4.2 Other Users

| Water License Number | Water License Holder | Location Relative to Project |
|---|---|---|
| *C102839* | *Canadian Hydro Developer* | *1 km upstream* |
| *C129047* | *SCPP Holdings* | *6 km upstream* |

Recreational – Fishing and kayaking

## 2.2 PROJECT INFRASTRUCTURE

This section describes all physical works authorized under the Water License, and any other infrastructure associated with monitoring or confirmation of regulatory/license requirements. The Project's general arrangement drawings are provided in Appendix B.

### Diversion Structures

This section describes in detail the diversion structures of the Project.

#### 2.2.1.1 Diversion Weir Rubber Dams

**General**
The project's two air inflatable rubber dams were supplied by Bridgestone Engineered Products Co. The air blowers, air control valves with actuators, level and pressure transmitters and control system software were also provided by Bridgestone. The Allen Bradley controller and MCC were provided by RSL Systematic.

**Description**
The rubber weirs are designed to operate for extended periods of time at any position from fully inflated to fully deflated with the upstream water level between El. 296.000 and 297.000. In addition, the rubber weirs are capable of operation for extended periods in fully deflated position with the headpond as high as El. 298.000

The rubber weir is fabricated from reinforced sheet rubber that is formed into a tube and it is anchored at the base and piers of the diversion weir foundation. The rubber is clamped using continuous clamp plates retained by a series of anchor bolts embedded in the concrete. The clamps are continued up the sides of the piers.

To avoid material deterioration caused by ozone and ultraviolet, EPDM (Ethylene Propylene Diene Monomer) additive is incorporated in the rubber fabric, Vibration suppression is achieved through the finned rubber body structure which allows aeration under the nappe.

Each rubber dam is provided with an air blower and control system. There is an interconnection which allows either air blower to inflate either rubber dam

The control system is capable of operating the weirs in manual, automatic and remote control modes. The control system monitors and controls the water level upstream of the rubber weirs by controlling the internal pressure of the weirs. On command from the PLC the control system is capable of maintaining the rubber weirs at any specific elevation and adjusting the height of the rubber weir to maintain constant head-pond level, at any level between El. 296.800 and El. 297.200.

An automatic flood control safety device is provided to fully deflate the rubber weirs when head-pond level reaches El. 297.600

### Maintenance

The rubber dam maintenance procedures shall be in accordance with "Bridgestone" instructions contained in the rubber dam maintenance manual. For the air blowers maintenance requirements refer to the "Service and Parts Manual for Blower model DR9" by "Rotron Incorporated."

Should maintenance require the installation of Stoplogs, refer to sections 2.2.1.4 and 4.2.6.

## Sluiceway Logboom

### General

A sluiceway log boom is provided in the head-pond to restrain entry of floating objects into the approach channel.

### Description

The boom is formed from Tuffboom waterway barriers chained together and anchored in four places.

### Maintenance

Inspect and restore the log boom as required.

## Sluiceway Radial Gate

### General

The sluiceway radial gate equipment, including radial gate, embedded parts and guides, gate hoist and hoist support bridge is supplied by Linita Welding. The gate is installed at the end of the sluiceway to allow sediment and debris to be flushed from the approach channel.

### Description

The sluiceway radial gate is a vertical lift gate with an upstream skin plate and a side upstream Teflon seal. It is assembled from two main sections with a splice plate.

The gate is lifted by four falls of galvanized wire rope, type 6 x 19. - 19mm diameter. Reducer, motor and brakes are a single unit assembly manufactured by "FLENDER" It combines a "Flender" Motor helical worm gear speed reducer will a disk brake and a 2hp 1750rpm, 575 VAC/ 3ph NEMA 4 motor.

**Maintenance**
Maintenance of the sluiceway radial gate shall be performed in accordance with manufacturers' instructions

#### 2.2.1.4 Stop-Logs

***General***
Stop logs are a common component in hydroelectric facilities. They are used to provide isolation from surrounding water in order to permit inspection and repairs on the following components of the diversion works:

1. Inflatable weirs
2. Radial gate
3. Tunnel

The generating station was specifically designed to permit continuing commercial operation with stop logs in place. They are intended to remain installed on a temporary basis.

The intake stop-log set sections are of fabricated steel construction with main- horizontal beams connected to end members designed to transfer the hydraulic loads to the embedded guides. The gate seals are Huntington, J-type rubber seals coated with a layer of fluorocarbon bolted to the stop-logs with stainless steel fasteners.

One stop-log section fitted with a 300mm diameter rubber seated butterfly valve which allows re-watering of a de-watered power tunnel. A 9000mm valve operator is provided to allow both opening and closing the valve from the top of the stop-log guides at EL. 299.500, with the valve on the bottom stop-log section.

The stop-log follower consists of a horizontal follower beam with two hooks designed to engage at pickup points on the stop-logs. The follower is guided by the stop-log such that the follower hooks will positively engage a submerged stop-log. The hooks are retracted by a tiller mechanism with a nylon tiller rope attached to it. The stop-log hooks are pivoted on stainless steel pins and have self-lubricating bronze bushings. The follower can be handled with a single point lift using a mobile crane.

**Installation Recommendations**
Under no circumstances are the stop-logs to be installed under flowing water conditions. The units must be shut down with wicket gates and inlet valves closed.

The proper sequence of the tunnel unwatering and refilling is described in the section on the Tunnel, in this manual.
Installation of the intake structure stop-log set is accomplished by the procedure outlined below:

a. Attach the crane hook to the follower beam. Connect tiller rope to the tiller.
b. Using the follower beam, raise the bottom stop log section (the one with a valve)
c. Wet sealing surfaces to minimize abrasion.
d. Guiding the follower by the stop-log guide, carefully lower the section until it rests on the sill beam and crane ropes become slack
e. Using the tiller mechanism, unhook the follower.

f. Using the follower beam, raise next stop-log section.
g. Repeating steps 3 - 6 install the remaining sections.

**Removal Recommendations**
Removal of the draft tube gate is accomplished by the procedure outlined below:

a. Attach the crane hook to the follower beam. Connect tiller rope to the tiller.
b. Guiding the follower by the stop-log guide, engage the follower's hooks at pickup points on the stop-log section. Check that follower's hooks are positively engaged a submerged stop-log at both points.
c. Lift the stop-log section, move it to the storage place and disengage the follower beam.
d. Repeating steps 2 and 3 remove the remaining sections.

Installation recommendations for the diversion structure stop-logs and bulkhead gate

a. Install an intermediate stop-log guide
b. Attach a crane hook to the lifting lugs of the bulkhead gate
c. Wet sealing surfaces to minimize abrasion.
d. Lower the gate until it rests on the sill beam and crane ropes become slack.
e. Install five section intake structure stop-log set as described above.

Removal Recommendations for the diversion structure stop-log

- Removal of the stop-log is accomplished in the opposite order to installation procedures.

**Note:**
If a stop-log section becomes jammed while lowering through guides, i.e., main hoist rope goes slack, attempt to raise the section and re-lower. Should the section jam again, do not attempt to move the section again until the condition has been thoroughly investigated and the jam rectified.

If a crane overload device trips while the stop-log is being raised, the section may have jammed in the guides. Do not bypass the overload device or attempt to raise the section farther. Lower the section, verifying the movement, i.e., the rope does not slack. If the section can be lowered, attempt to raise it again. If the overload device operates again, or if the section will not lower, do not attempt any further movement of the section until the conditions have been thoroughly investigated and the situation rectified.

***Maintenance***
Inspect the stop-log sections prior to and following each use. Note in particular the following items:

- Stop-log section
- Condition of seals
- Condition of the valve and operating mechanism
- Possible structural damage
- Follower beam
- Condition of bumpers
- A hook release mechanism
- Tiller rope

If painting is required, refer to the "Associated Engineering" documents for the protective coating originally supplied. The paint material should be compatible with the system and should be applied in accordance with manufacturer's instructions.

**Intake Trashrack**

***General***

Four intake trashrack sections, complete with lifting slings are provided for installation at the front of the intake to prevent large debris from entering the power tunnel.

***Description***

The trashrack sections were designed by "Associated Engineering" and manufactured by "Lochhead - Huggerty". The sections are fabricated steel construction with vertical rack bars welded to five horizontal support members which transmit loads to the vertical embedded guides.

Two wire rope lifting lugs are attached to the top of each section to allow removal and installation of the sections with a mobile crane. The sling length allows the top to be docked at deck level (EL. 299.500).

Differential pressure across the trashrack is monitored by two sets of three water level transmitters.

***Operation***

The trashrack sections should be installed or removed only when the units are shut down with wicket gates and turbine inlet valves closed.

**Installation Recommendations** - Prior to reinstalling the trashrack sections, the intake area downstream of the trashrack guides should be inspected (by diver) to ensure no debris has fallen into the intake area downstream of the trashracks.

Attach the crane hook to the trashrack sling. Carefully lower the section until it rests on the bottom of the embedded angle.

**Note:** If a trashrack section becomes jammed while lowering through guides, i.e., main hoist rope goes slack; attempt to raise the section and re-lower. Should the section jam again, do not attempt to move the section again until the conditions have been thoroughly investigated and the jam is rectified.

If a crane overload device trips while the trashrack is being raised, the section may have jammed in the guides. Do not bypass the overload device or attempt to raise the section farther. Lower the section, verifying the movement, i.e., the rope does not slack. If the section can be lowered, attempt to raise it again. If the overload device operates again, or if the section will not lower, do not attempt any further movement of the section until the conditions have been thoroughly investigated and the situation rectified.

***Maintenance***

The trashrack should be kept clear of debris and trash to minimize head losses. The frequency of cleaning will be dictated by the operating characteristics of the station and by seasonal changes in water quality

Table 3 provides a summary of the key diversion structures, their dimensions and elevations.

**Table 3 Summary of Diversion Structures**

| Diversion Structures | Height (m) | Width (m) | Elevation (AMSL) (m) |
|---|---|---|---|
| Headpond | 3.25 | 40 | 297.0 |
| Intake Screen | 4 | 11.5 | 293 |
| Top of Weir | 3.25 | 15 | 297.1 |

| | | | |
|---|---|---|---|
| Bottom of Sluicegate | 6.2 | 10 | 291 |

### 2.2.1 Water Conveyance System

This section describes in detail the Project's water conveyance system, which consists of Tunnel and penstock the total volume of the system, when filled with water, is approximately 10000m3. The total gross head from the full headpond level to the tailrace water level is 267 m.

**Tunnel**

***General***

The water passage from the intake to the powerhouse consists of a 420 m long upper tunnel, a 157 m vertical shaft and a 2600 m long lower tunnel. The upper tunnel is a "D" shaped tunnel 3.6 m wide by 3.6 m high driven by drilling and blasting. The shaft is a 3.1 m diameter raise bored vertical shaft connecting the lower tunnel with the upper tunnel. The lower tunnel is 4.1 m diameter driven by a tunnel boring machine (TBM).

***Description***

The upper tunnel, shaft and most of the lower tunnel are not lined. However, the rock is reinforced using rock bolts or protected with shotcrete in sections which require special treatment. In the section of the lower tunnel where the ground cover is not sufficient to withstand the internal water pressure, a 2.1 m diameter steel penstock is installed within the tunnel. This penstock is 435 m long and is surrounded by a concrete plug at the upstream end to form a seal with the rock. At the downstream end, this penstock divides into two 1.3 m diameter penstocks which extend through the powerhouse wall and connect to the turbine inlet valves on the generating units.

There are two rock traps in the tunnel. The first rock trap is located at the downstream end of the upper tunnel, just upstream of the vertical shaft. The second rock trap is located in the lower tunnel just upstream of the 2.1 m diameter penstock.

***Operation***

The procedure for filling the tunnel after it has been unwatered for inspection or maintenance is contained in Unit Dewatering System of this Operations Manual.

The rate at which the tunnel is depressurized (drained) for inspection or maintenance must be carefully controlled. If the tunnel is depressurized too rapidly, high seepage pressures may loosen shotcrete and rock causing local failures. The procedure to be followed in Dewatering the Tunnel is contained in the section on Unit Dewatering System of this manual.

Note: The tunnel outside the steel penstock must be unwatered if the lower tunnel is unwatered. This procedure will limit the stress in the anchor bolts which would occur if the penstock was unwatered and floated in the tunnel. The procedure for unwatering the annulus between the steel penstock and the rock is outlined in the Penstock section of this manual.

***Maintenance***

Pressure changes resulting from unwatering the tunnel are the most likely cause of local rock failures. Therefore, the tunnel should be unwatered carefully and infrequently. However, at least once in the first five years of service, the tunnel should be partially unwatered so that the rock trap in the upper tunnel can be inspected and cleaned out if necessary. The amount and size of the material deposited in the rock trap should be used to judge if the lower tunnel rock trap needs to be cleaned out. This inspection should also be used to judge the frequency of subsequent inspections.

**Penstock**

***General***

The penstock is a steel conduit installed inside the tunnel. The penstock is designed to provide the water passage in the section of the tunnel where the strength of the rock is not sufficient to withstand the hydraulic pressure. The penstock is 2.1 m diameter and 435 m in length. Near the powerhouse, a bifurcation distributes the water into two 1.3 m diameter penstocks. These smaller penstocks pass through the powerhouse upstream wall and are connected to the turbine inlet valves.

The upstream end of the 2.1 m diameter penstock is anchored with a concrete plug poured and grouted to the rock of the tunnel. At the downstream end, the bifurcation is embedded in a concrete anchor block.

Between these two concrete anchors, the penstock is supported on saddles and ring girders. It is held in place by the ring girders and hold-down straps at the saddle supports. The annulus between the outside of the penstock and the rock of the 4.1 m diameter rock tunnel is normally filled with water but can be unwatered to make inspection of the penstock and tunnel possible.

***Operation***

Ground water will seep into the annulus in the tunnel outside the penstock. This annulus will fill with water but cannot rise above elevation 43. This level will be constant because a drain is installed in the wall of the manhole.

This annulus can be unwatered to permit access to the annulus for inspection of the tunnel or penstock. To unwater this area, follow the procedure outlined below:

1. Open the checker plate manhole cover.

2. Lower the Flygt Model 2201 or equal submersible pump down to the bottom of the shaft, with sufficient flexible discharge piping and sufficient power cord attached.

3. Route the discharge pipe to tailrace either through the drain pipe at elevation 43 or on the yard at elevation 50.

4. Close the appropriate breakers to supply power to the pump and start the dewatering pump.

5. The water level in the shaft will be lowered. Leave the pump running to handle seepage water after the water level has reached the bottom of the penstock.

6. Air to ventilate the annulus during inspection can be provided by powering the existing blower and operating it for at least one hour prior to annulus entry. Always check air quality readings prior to entering annulus.

7. At the end of inspection, stop the pump and blower, disconnect the power supply, and raise the pump out of the shaft.

8. Replace the checker plate manhole cover and ensure it is properly attached and sealed.

***Maintenance***

The annulus outside the penstock must be unwatered if the lower tunnel is unwatered. This will limit the stress in the anchor bolts which would occur if the penstock was unwatered and floated in the tunnel.

Table 4 summarizes the attributes of the Project's water conveyance system.

**Table 4 Summary of Water Conveyance Systems**

| Water Conveyance Structures | Length (m) | Elevation (AMSL) (m at entry) | Diameter (m) | Number of Stream Crossings |
|---|---|---|---|---|
| Upper Tunnel | 420 | 293 | 3.6 | N/A |
| Vertical Tunnel | 157 | 254.5 | 3.1 | N/A |
| Lower Tunnel | 2600 | 97 | 4.1 | N/A |
| Penstock | 435 | Est. 45 | 2.1 | N/A |

### 2.2.2 Powerhouse Power Generation Equipment

**TURBINES**
***General***
The two Francis turbines are each rated at 25,000 kW at a net head of 243.5 m. The units were supplied by DEC and manufactured in the DE 1W factory in Deyang, China.

The turbine is directly connected to the vertical shaft synchronous generator. The turbine spiral case is connected to the turbine inlet valve through a removable pipe section which incorporates a dismantling coupling at the inlet valve.

Hatches are provided for personnel access to the spiral case and draft tube. A hinged inspection port is also provided in the spiral case at the small end of the spiral case. The design allows runner removal from below the spiral case.

The turbine wicket gate is controlled by two servomotors with oil supplied by the hydraulic power unit (HPU).

***Operation and Maintenance***
The pressure relief valve, hydraulic cylinders, HPU, displacement transducers and limit switches should be maintained as outlined in their respective operating and maintenance manuals provided by Bailey, Parker and Hydra-Power Systems.

The need for minor overhauls of the equipment can be expected on a routine basis. The inspections listed in the manufacturers' instruction manuals provide a good indication of when these repairs are necessary.

**TURBINE INLET VALVES**
***General***
A spherical type turbine inlet valve is provided at the entrance to each turbine spiral case. The purpose of the valve is the following:

- To permit unwatering of the turbine passages for turbine inspection and maintenance

- To close when the turbine is shut down to prevent leakage through the turbine wicket gate
- To close in an emergency under flowing water conditions, in the event of loss of control of the turbine

***Description***
The turbine inlet valve (TIV) is a 1300 mm diameter spherical valve. There is one valve for each of the two generating units. Both valves were manufactured in Deyang China.

The TIV has one hydraulic cylinder operator and a counterweight for closing the valve. A rigid flange connection is provided between the valve and the penstock upstream. The connection to the pipe section between the valve and the turbine spiral case is through a dismantling coupling.

The valve has both service (downstream) and maintenance (upstream) seals. The seals are operated by water pressure. The maintenance seal has a positive mechanical locking device. Oil for the hydraulic cylinder operator will be supplied from the hydraulic power unit (HPU).

***Operation***
The valve disc must be fully open during normal operation of the turbine. It is not allowed to stay at any other position to regulate the flow rate, or to be locked by the full-open-position manual lock of the servomotor. Otherwise, the valve cannot serve the purpose of emergency protection. When the valve is to be shut down for TIV maintenance, or to examine the turbine, the following procedure is followed:

a. Service seal water is diverted to the drainage system by the four way solenoid valve.
b. Close the spherical valve using the hydraulic cylinder. Secure the locking device on the servomotor to guarantee the safety of maintenance personnel.
c. The manual four way valve is opened to allow seal water to pressurize the upstream maintenance seal.
d. Using procedures outlined in the unwatering section of this manual, unwater the TIV and turbine.

***Maintenance***
The turbine inlet valves, cylinders, and seal water valves should be maintained as outlined in their respective operating and maintenance manuals provided by Dongfang Electrical Machinery Company.

A maintenance schedule should be adjusted by the operating personnel as experience is gained with the system.

The need for minor overhauls of the equipment can be expected on a routine basis. The inspections listed in the manufacturers' instruction manuals provide a good indication of when these repairs are necessary.

**HYDRAULIC POWER UNIT (HPU)**
***General***
The Hydraulic Power Unit (HPU) develops a hydraulic control signal of sufficient magnitude to operate

Servomotors which position turbine wicket gates, Turbine Inlet Valve (TIV) and Pressure Relief Valve (PRV).

HPU has been designed and supplied by "Hydra Power Systems" (HPS). There is one HPU for each of the two generating units. Each HPU system is independent of the other.

In addition to the HPU's, HPS supplied the operating cylinders for the TIV's and the servomotor cylinders for the turbine.

***Operation***

The HPU system is located on the turbine floor of the powerhouse and it is PLC controlled. The HPU is setup to be fail safe with the loss of control power or PLC causing the unit to unload. The HPU consists of a lead/lag pumping system that loads according to system pressure. The lead pump comes on at 1270 psi and the lag pump comes at 1240 psi. At a pressure of 1210 psi the system will shut down. The lead/lag pump unload pressure is 1440 psi. The lead pump is started when the pressure reaches 1270 psi. A two second timer elapses before the pump is loaded and the accumulators charged. When the pump reaches the unload pressure, valve DV1 de-energizes causing the pump to run unloaded. A ten minute timer will keep the pump running and then a pump will run loaded for an additional 3 minutes until the pressure reaches 1500 psi and then the pump will stop. If during the 10 minute timer the pressure drops below 1270psi, the pump will again be loaded.

The HPU accumulator has total volume of 160 gallons and is available to absorb sudden changes in system pressure. The default condition for the turbine when the system is de-energized is for the wicket gates and TIV to be closed and the PRV to be open. The operation of the HPU is controlled by four pilot valves that receive commands from the PLC system. The four solenoids have the following operation:

| Relay | Function |
|---|---|
| SD1 Wicket Gates | SD1 controls the valve which transmits system pressure to SV1. SV1 controls the position of wicket gates. When SD1 is de-energized SV1 is closed and the wicket gates will close as well. |
| SD2 PRV | SD2 is associated with the operation the Pressure Relief Valve (PRV). While SD2 is energized the PRV is controlled by SV2. On a startup, the PRV is closed by energizing SD2 which gets SV2 to operate until the PRV is closed. A normal shutdown de-energizes SD2 resulting in the operation of the PRV being a slave to the wicket gates operation. A slave circuit will open the PRV when the wicket gate is closing, this is accomplished by venting the oil from the slave servomotors that operate the wicket gates through the rod side of the PRV servomotors. |
| SD3 TIV | SD3 is used to open or close the Turbine Inlet Valve through the operation of SV3. When SD3 is energized the TIV is opened and will remain open as long as SD3 is energized. De-energizing SD3 has the effect of closing the TIV. |
| SD4 PRV Failure Relay | SD4 is used for shutting down the unit when the PRV fails to open. SD4 is de-energized resulting in the wicket gates closing in 30 seconds and the inlet valve closing in 90 seconds. |

When the PLC generates a startup condition, SD2 is energized applying system pressure to SV2 and then closing the PRV. Next, SD3 is energized in order to open the TIV. The SV3 valve is given system pressure and then opens the TIV. When the inlet is being opened the HPU pumps are run so that the accumulator is not discharged during this operation. The turbine is now ready for the start sequence.

The PLC energizes all four SD pilot valves during a turbine start. With the system armed, the PLC opens the wicket gates through SV1 to the set point. When the wicket gates are at the set point, SV1 will remain in the neutral servo position. During normal operation the slave circuit that operates the PRV is isolated from the movement of the wicket gates and the slave servomotors.

A normal system shutdown is initiated by the plant operator. Initially SD1 and SD2 are de-energized which does two things: the wicket gates begin to close using 10 second timing and the slave circuit to the PRV is active meaning that he PRV will open as the Wicket Gates close. A low pressure shutdown is the same as a normal shutdown with the exception that the shutdown signal comes from the HPU pressure transducer and not the operator.

If the PRV does not open during the shutdown sequence, a feedback signal will tell the PLC that the PRV has failed. The PLC will then de-energize SD4 and SD3 and the result will be that the Inlet Valve will close in 90 seconds and the wicket gates will close a bit slower (30 seconds) without the pressure relief valve available to vent pressure. Otherwise the pressure would rise to unacceptable levels in the tunnel.

Total loss of power will de-energize all four SD pilot valves and the hydraulic system will close the wicket gates in 10 seconds while opening the PRV using the slave circuit. The Inlet valve will also close in 90 seconds.

The HPU system is programmed to automatically recovery from any shutdown 1 hour after the event occurred.

***Automatic Control and Alarms***
HPU has the following control actions:

| ACTION | RESULT |
|---|---|
| System Pressure < 1210 psi | Shutdown – Normal |
| Wicket Gate Failure | HMI Alarm |
| PRV Failure | Shutdown – PRV |
| Inlet Valve Failure | HMI Alarm |
| 600 V Power Lost | De-energize SD1which will bring the unit to No load. |
| Accumulator Proximity Switch activates and gas pressure is below 1400 psi. | HMI Alarm – HPU gas leak. |

***Relay Protection***
An HPU low/low pressure signal, wired in series with the turbine speed switch, trips locking-out relay 86M if accumulator pressure drops to 175 kPa (1210 psi) and turbine is rotating.

***Maintenance***
HPU maintenance should be done in accordance with HPS instructions.

Relay protection should be checked as part of the scheduled maintenance of the generating unit relay protection equipment.

**GENERATORS**

***General***

Two vertical shaft synchronous generators rated 31.25MVAl25N1W, 13.SkV, 60Hz 720rpm were design and supplied by "Dongran Electrical Machinery Works" (DFEN1) Sichuan, China.

***Description***

For a detailed description of the generator units see DFEM document No F574 "Instruction of Vertical Shaft SF25-10/3250 Hydro Generator" and document No F575 "Operation and Maintenance Manual of SF25- I 0/3250 Hydro Generator"

***Operation***

The generators are capable of continuous operation at the rated parameters. Continuous overload capabilities depend on ambient air and water temperatures and conditions of the turbine-generator unit. In no case manufacturer's stated parameters shall be exceeded. For detailed operation instruction refer to DFEN1 document No F575 "Operation and Maintenance Manual of SF25- 10/3250 Hydro Generator"

Under normal automatic mode of operation, the generator controls and the Static Excitation System (SES) will maintain the operation within the specified limits.

Although a number of alarm and indicating devices, permissive devices, interlocks, and protective devices have been provided for the generator, an operator performing a manual operation must always be deliberate, i.e., characterized by awareness of the consequences.

#### *2.2.3.1* ***Generating Equipment***

This section describes details on the numerous components comprising the generating equipment.

**TURBINES**

Turbine details are provided below:

| | |
|---|---|
| Turbine Type: | Francis |
| Number of Units: | Two |
| Unit Capacity: | 26MW |
| Shaft Orientation: | Vertical |
| Synchronous Speed: | 720RPM |
| Over speed Rating: | 1270 RPM |

**GENERATORS**

Generator details are provided below:

| | |
|---|---|
| Manufacturer: | Dong Fang |
| Type: | Vertical |
| Rate Terminal Voltage: | 13.8KV |
| Rated Power Factor: | 0.80 |
| Frequency: | 60HZ |
| Enclosure: | Metal |
| Service Factor: | Continuous Duty |
| Synchronous Speed: | 720 rpm |
| Maximum Overspeed: | 1270 rpm |
| Stator Winding Connection: | Star |
| Insulation Rating: | Type F |
| Operating Temperature Rise: | 50 Degrees C |
| Rotation: | Clockwise form above |

**[COMPONENT NAME]**

[Please add additional headings as required for your project, examples provided below.]

- Turbine shut off valves;
- By-pass Valve;
- Bearings;
- Hydraulic power unit;
- Switch gear;
- Cooling water; and
- Filtered water

### *2.2.3.2 Energy Dissipation System*

**PRESSURE RELIEF VALVE**

***General***

The pressure relief valves are connected to each turbine spiral case to reduce transient pressures in the power tunnel resulting from rapid closure of the turbine wicket gates, and to maintain river flow downstream of the facility when a rapid reduction in turbine discharge occurs.

### 2.2.3.3

***Description***

The pressure relief valve (PRV) is a 42" Bailey Model 810 Inline Polyjet valve. There is one pressure relief valve for each of the two generating units. Each of the 42 inch Bailey Polyjet valves is operated by two hydraulic cylinders. The hydraulic cylinders have a 13 inch stroke.

**2.2.3.4** The hydraulic system is designed so that the relief valve operates as a synchronous bypass, and opens automatically on wicket gate closure. Valve closure is controlled by the station PLC. The hydraulic system also has provision for manual operation of the pressure relief valve, independent of wicket gate movement.
The system is failsafe so that the turbine wicket gate closure rate will be physically restricted if the relief valve fails to open on turbine shutdown. This ensures that the maximum transient pressure does not exceed design values.

The valve has flanged and bolted inspection ports to allow for inspection of the valve for debris.

The flow of each PRV can be varied from 0 to 12 (m3/s)

***Operation and Maintenance***
The pressure relief valve, hydraulic cylinders, HPU, displacement transducers, and limit switches should be maintained as outlined in their respective operating and maintenance manuals provided by Bailey, Parker, and Hydra-Power Systems.

The need for minor overhauls of the equipment can be expected on a routine basis. The inspections listed in the manufacturers' instruction manuals provide a good indication of when these repairs are necessary.

### 2.2.3 Tailrace

The tailrace is located on the downstream portion of the powerhouse and feeds directly into the Mamquam River. River levels determine the level of the tailrace, although the tailrace is 10+ meters deep. The tailrace has isolation gates for the draft tubes and bypass valves for both units.

### 2.2.4 Switchyard and Interconnection

This section describes details on the switchyard and interconnection.

**SWITCHYARD AND TRANSMISSION LINE**
***General***
The switchyard consists of an incoming line structure with a 3-phase line disconnect, three lightning arresters, set of instrument current transformers, set of instrument potential transformers, two unit step-up transformers with a set of bushing current transformers, two unit breakers and disconnects.

The unit step-up transformer is covered separately in a different section. This section covers the balance of the equipment.

***Description***
The 69kV switchyard contains the high voltage equipment necessary for linking Mamquam Power station to the BC hydro power distribution system via a 4.8km 69kV transmission line. It is located in fenced area adjacent to the east wall of the control building. The equipment is mounted on a concrete foundation and has concrete retaining walls around the transformers' area to contain oil spills. The switchyard has a drainage pit with the provisions for oil separation.

The switchyard grounding system, connected to the powerhouse grounding system, reduces touch and step voltages to the safe values. Under the normal operating conditions the generated power is supplied to BC

Hydro through step-up transformers, transformers' breakers 52T1 and 52T2, transformers' disconnects DT1 and DT2 linked by a 69kV bus, which is connected to the transmission line by the line disconnect switch DL1.

A set of potential and current transformers supply voltage and current values to the metering and transmission line relay protection systems.

Station class surge arresters located on the dead end tower protect station electrical system from incoming voltage surges.

Although normally each of the generators is connected to the common 69kV bus independently, in the case of one of the transformers outages both generators can work with a single step-up transformer, provided that the transformer's rating is not exceeded.

Automatic Controls, Protection and Alarms

The transmission line electrical protection is based on the two similarly and separately wired line protection relays "ABB," type REL511 to form redundant relay protection system.

The relay trip coil "A" is tripped by the breaker failure signal. The breaker failure signal is activated if current continues to flow or if either of the transformers' breakers is not tripped after a predetermined time. It causes an immediate trip of the generator breakers 52G1, 52G2, transformers' breakers 52T1, 52T2, tie breaker 52B and unit(s) shutdown.

The relay trip coil "B" is tripped by the following signals: 21 - Distance Protection, Zone I & Zone 2
50/51 - Overcurrent
27/59 - Under/Over Voltage
81 - Over/Under Frequency
59G - Ground Fault 60FL - PT Fuse Loss BC Hydro Trip
Coil "B" trips transformers' breakers 52T1, 52T2. Unit(s) unloaded to "no load" mode and stopped with an hour time delay.
For the particulars pertaining to the RELS 11 refer also to the "ABB" "User's Guide REL511, Line Distance Protection Terminal. No INIDU06030-EN Version 1.1"

***Operation and Maintenance***
Operations and maintenance shall be in accordance with manufacturers' recommendations.

BCH interconnection equipment shall be maintained in accordance with the requirements of the Electricity Purchase agreement between CBC and BC Hydro and Power Authority. In particular, maintenance of protection equipment shall include but not limited to calibration testing all protective relays and trip testing to circuit breaker at intervals of not more than three years.

### 2.2.5 Access

#### 2.2.6.1 <u>Infrastructure</u>

Access to the intake is via the Mamquam forestry service road. Access to the powerhouse is via the forestry service road and then Powerhouse Springs Road

### 2.2.6 Permits/Agreements

Road use permit 9283-13-02

## 2.3 SECURITY

### 2.3.1 General

Site security and measures are required for the following reasons:

- *Proximity to Mamquam river access*
- *Proximity to area trails*
- *Road access via Powerhouse Springs Road for the powerhouse*
- Road access via Mamquam Forestry Road

The security for this Project is provided by the following systems and processes:

- *Fencing, Gates, and Doors;*
- *Alarm Systems*
- *Video Surveillance.*
- Auto callout for Alarms

### 2.3.2 Fencing, Gates, and Doors

The powerhouse and intake each have 2 sequential access gates that are locked during non- business hours. The intake building and powerhouse have full perimeter fencing, and the switchyard has additional perimeter fencing. Both the intake building and the powerhouse have lockable doors with a security system.

### 2.3.3 Communication

In this section communication links between project infrastructure and to the outside are described, including land lines, cellular, and satellite communication. Communication links include:

- *A fiber optic line with both telephone and internet communications to the outside as well as between intake and powerhouse*
- *Cell phone communications to outside*
- *Radio communication to intake and outside*
- *PA system within powerhouse*

### 2.3.4 Alarm System

The plant HMI's record all alarm data including security, fire, and unit alarms and sounds an audible alarm within the plant and intake buildings. After hours alarm events are sent to the operators by auto-dialer to the on call operator's cellphone.

The fire alarm is a separate system with its own audible alarm within the plant and intake. It is triggered by smoke detectors and temperature gauges which are located throughout the powerhouse and intake buildings.

In the event of a plant trip there is a fog horn system to alert river users that river level changes may occur.

### 2.3.5 Video Surveillance

There are 3 cameras for security and surveillance; One at the intake and two at the powerhouse. Each camera can be remotely controlled for viewing different parts of their coverage area. The video is recorded onto a 1 terabyte hard drive with approx. 1 month recording ability before being overwritten.

# Section 3.0 - OPERATING PARAMETERS

## 3.1 DESIGN PARAMETERS

### 3.1.1 Instream Flow Requirement ("IFR")

#### 3.1.1.1 IFR Schedule

In this section the instream flow requirements (IFR) under the water license are described.

The minimum IFR flow is one (1) cubic meter per second through-out the year and does not change seasonally. The IFR is provided via a manually adjusted slide gate that discharges into a one meter diameter IFR discharge pipe which bypasses the intake structures. The gate is located downstream of the intake screen to avoid plugging from debris.

#### 3.1.1.2 IFR Gauging

Accurate real-time instantaneous flow data will be collected to monitor instream flows over the life of the project to ensure compliance with the water license and to provide measures of environmental conditions that will assist in the interpretation of changes in biological components of the environmental monitoring program. For the purposes of verifying compliance with the IFR and flow ramping specifications, stage will be sampled at a frequency of 15 seconds, with a 2 minute average for storage in the data logger.

Flow measurements will be measured at all compliance points with a hydrometric gauge.

*Compliance Point*

Three (3) river level gauges are located immediately (within 100 meters) downstream of the intake structures in a protected pool. A visual staff gauge is not possible in this location.

These gauges are linked into the intake PLC for plant control, as well as a satellite link for remote monitoring. The gauges are now mounted in a protected location out of potential debris flow. The river profile should not change due to the channel being cut into solid bedrock. Stream channel discharges and post-project rating-curves will be verified annually.

The reach location, gauge type, installed equipment, date of installation, are documented in Table 5

**Table 5: Hydrometric gauges: reach, location and number, type & install date**

| Reach Location | Location | Type | Installation Date |
|---|---|---|---|
| Upstream of Intake | 500M upstream of intake (USLG01) | Transducer (1) | 2010 |
| Diversion | 60M downstream of intake (DVLG01) | Transducer (3) | 7- May- 2012 (re-installed after flood event damaged previous gauge |
| Lower Diversion | 50M upstream of tailrace (DVLG02) | Transducer (1) | 2010 |
| Downstream of Powerhouse | 500M downstream of powerhouse (DSLG01) | Transducer (3) | 2010 |

Similar to the downstream of intake gauges, all other gauge flow curves used for regulatory compliance will be verified following the Land and Water BC (LWBC) Hydrometric Guidelines (LWBC, 2005) and RISC (2009) standards. Rating curve verification is required no less than on an annual basis, and may be required more frequently if bed mobilizing stream flow events occur that may alter the accuracy of the rating curve.

Details of the access to and the location of the gauges are provided in the attached 1:20,000 scale map (Appendix B).

### 3.1.2 Ramping Rate Requirements

#### 3.1.2.1 Ramping Rate Schedule

In this section the ramping rate requirements under the water license are described The ramping schedule is provided in Table 6 by river flow rates, including compliance points and ramping schedules. The ramping rates have been developed by Ecofish Research following provincial and federal guidelines.

This section also describes the equipment installed to meet ramping rate requirements. Ramping rates will be achieved on this Project because the following equipment has been installed: The Francis style turbines have been modified and programmed via the PLC to ramp within the ramping guidelines described in table 6. In the event of a plant trip, the pressure reducing bypass valves (PRV's) are designed to transfer the water flow from the turbines through the full operational range and bypass the water through the power plant to maintain uninterrupted river flows. Only in the event of a critical trip will flow through the plant be interrupted. A critical trip is defined as a condition where human safety is in peril or major equipment damage can occur.

Since river ramping is compounded by other factors out of control of the Lower Mamquam plant including natural ramping and ramping from upstream plants, only ramping incidents caused by the lower Mamquam plant will be reported.

If the lower Mamquam plant measures natural ramping or ramping from upstream events that exceeds the specified ramp rates, these events will be recorded, but will not be considered ramping events caused by the lower Mamquam plant.

**Table 6 Ramping rates by compliance point, showing the flow range specific ramping rates by season**

| Compliance Point | Flow Range | Maximum Operational Flow Rate | Ramping Rate at Compliance Point (cm/hr) |
|---|---|---|---|
| **Compliance Point 1 (DVLG01 - 60 meter downstream of intake gauge in diversion reach)** | | | |
| Year round | 0 -10 m3/s | 30 $m^3/s$ | 7.5 cm/hr |
| Year round | 10 - 24 $m^3/s$ | 30 $m^3/s$ | 19.9 cm/hr |
| Year round | >24 $m^3/s$ | 30 $m^3/s$ | unrestricted |
| **Compliance Point 2 (DSLG01 - 500 meter downstream of powerhouse gauge)** | | | |
| Year round | *0 - 30 m3/s* | *30 $m^3/s$* | *3.6 cm/hr* |
| Year round | *30 – 50 m3/s* | *30 $m^3/s$* | *9.9 cm/hr* |
| Year Round | *>50 m3/s* | *30 $m^3/s$* | *unrestricted* |

#### 3.1.2.2 Ramping Rate Gauges

Accurate real-time instantaneous flow data will be collected to monitor ramping rates and ensure compliance with the specified rates over the life of the project. Flow ramping measurements will be measured at all compliance points identified. Hydrometric gauges have been established to allow independent verification of flow conditions at any time.

### 3.1.3 Sediment Transport

Sediment transport of sands and silts occurs throughout the year as river flows increase to the point where these particles are mobilized. However the headpond does trap large gravels and boulders due to the reduction in flow velocity in the headpond, and the damming action of the weirs.

To mobilize these larger aggregates, and to prevent head pond infilling, sluicing and headpond flushing occurs annually, coinciding with very high river flows (above 80 m3/s). This normally occurs during the fall season in October and November when the river is extremely turbid and little noticeable or measureable effect on water quality occurs.

A turbidity gauge has been installed downstream of the intake which will capture changes in river turbidity throughout the year, including times when sluicing occurs. Duration of headpond sluicing and turbidity levels prior to and during will be included in the annual compliance report. This gauge will be calibrated every two years.

**Commented [IWM1]:** Ok?

## 3.2 CONTROLLING AND MAINTAINING PARAMETERS

### 3.2.1 General

This section describes how the project will be monitored and controlled. Table 7 provides a summary of flows continuously monitored by the control system.

**Table 7 Methods for Control**

| System Point | Method |
|---|---|
| Upstream of Intake (USLG01) | 1 Calibrated water level gauge |
| Downstream of intake(DVLG01) | 3 calibrated water level gauges below weir |
| Upstream of Power Plant (DVLG02) | 1 calibrated water level gauge |
| Downstream of Power Plant (DSLG01) | 3 calibrated water level gauge |
| Penstock Flow Meter | Dual flow gauges (to be installed Q3 2014) |

All water level gauges measure changes in water level in 1mm increments, scan for stage readings every 15 seconds, and log average readings every 2 minutes. These instruments have calculated flow curves where changes in water level are converted into cubic meters per second water flows.

The upstream of intake gauge (USLG01) measures water inflow from upstream sources. It does not include Raffuse Creek which flows into the Mamquam River downstream of this gauge.

The downstream of intake gauge (DVLG01) measures the instream flow release (IFR) as well as spill over the weirs and through the sluice gate. IFR is assessed from mean hourly flows. Ramping compliance is assessed by mean hourly flows, and is value calculated as the difference in stage between a particular point and the maximum stage during the previous hour (Addendum B). There are 3 gauges connected to the intake PLC.

**Commented [IWM2]:** Marc – please review, but this should have everything they need in it. It is located at the very end.

The upstream of power plant gauge (DVLG02) measures flows slightly upstream of the plant. This gauge was installed to measure spill transit times from the intake to power plant for PLC programming.

The downstream of plant gauges (DSLG01) measure total river flow approx. 1/2 kilometer downstream of the power plant. Ramping compliance is assessed by mean hourly flows, and is value calculated as the difference in stage between a particular point and the maximum stage during the previous hour (Addendum B).. There are 3 gauges connected to the auxiliary PLC in the power plant.

**Commented [IWM3]:** Note that this may change based on where we install the new gauges.

The penstock flow meter measures flow through the turbines via the penstock. This gauge has been purchased and will be installed in Q3 2014. This gauge will help to program plant PLC's to accurately control ramping and river level changes downstream of the power plant.

#### 3.2.2 Protection Relays

Mamquam upgraded its protective relay system in 2013 using the latest ABB multifunction relays. Each generating unit has its own multifunction relay, and there are two line protection relays for any power line issues

#### 3.2.3 Human Machine Interface ("HMI")

Mamquam upgraded its plant PLC architecture in 2012/2013 using the latest Allan Bradley PLC's. The intake, each generating unit, and the power plant auxiliary have its own PLC. These are displayed on HMI's in the plant and at the intake for operator interaction. The plant is normally fully automated, however when operator intervention is required, processes can be put into manual condition where the operator has control.

#### 3.2.4 Historian

The Allen Bradley PLC has its own historian system to record events. In addition, there is an eDNA historian that records plant operating parameters in Atlantic Power's main servers.

#### 3.2.5 Web Based Digital Video System

There is 1 camera at the plant intake, and two at the plant powerhouse. These record video onto 1 terabyte hard drives which have approximately 2 months data before being overwritten

### 3.3 MONITORING PARAMETERS

#### 3.3.1 IFR Monitoring

3.3.1.1 Monitoring Commitments

Instream flow data collected from the compliance points described in Section 3.1.1.2 will be recorded continually for the life of the project. The gauges will be monitored in real time and linked to automated alarms to provide timely notification of ramping events. This data will be stored and submitted to the regulatory agencies if requested. Instantaneous water level and flow data will be made available upon request. Any non-compliance with the 1 m3/s IFR specified in Section 3.1.1 will be reported to Fisheries and Oceans Canada (DFO) and BC MFLNRO within 24 hours, and measures taken to ameliorate the risk of downstream impacts. Non-compliance reports describing the conditions of non-compliance, the contributing factors, and measures taken to minimize immediate and future impacts will be submitted to DFO and BC MFLNRO within a week of the incident. For the IFR and Ramping compliance gauges, stream channel discharges and post-Project rating-curves will be collected and developed based on the Land and Water BC (LWBC) Hydrometric Guidelines (LWBC, 2005) and RISC (2009) standards. Instantaneous water level and flow data will be made available upon request to regulatory agencies and in annual monitoring reports on instream flow compliance over the life of the Project. Download Schedule: Data will be downloaded & reviewed continuously and submitted annually to agencies.

**Commented [IWM4]:** I didn't see a reference section, but these are the references:

LWBC. 2005. Hydrological Guidelines for Waterpower Projects. Completed by the Surrey Regional Office, Land and Water Management Division (p. 20). Retrieved from http://www.env.gov.bc.ca/lower-mainland/electronic_documents/LWBC Hydro guidelines (July 2005).pdf.

RISC. 2009. Manual of British Columbia hydrometric standards (Version 1.0). Prepared by the Ministry of Environment, Science and Information Branch, for the Resources Information Standards Committee. March 12, 2009. Retrieved from http://ilmbwww.gov.bc.ca/risc/pubs/aquatic/hydrometric/man_BC_hydrometric_stand_V1.0.pdf.

### 3.3.2 Ramping Monitoring

3.3.2.1 Monitoring Commitments

Compliance with the prescribed ramping rates established by Ecofish Research as per DFO and FLNRO ramping guidelines will be followed for the life of the project

**Commented [IWM5]:** Ok?

Non-compliance with the downstream of powerhouse ramping rates caused by the Lower Mamquam hydroelectric power plant, based on calculations in the ramping rate guidelines, will be reported to DFO and MFLNRO within 24 hours of the event.

Non-compliance reports describing the conditions of non-compliance, the contributing factors, and measures taken to minimize the chances of recurrence will be submitted to DFO and MFLNRO within a week of the incident. Instantaneous water level and flow data will be made available upon request to regulatory agencies and in annual monitoring reports on instream flow compliance over the life of the Project.

**Commented [IWM6]:** This commits to it, but does not specify the format – is this ok?

3.3.2.2 Flow Non-Compliance Resulting from Flow Changes Upstream

Ramping rate exceedances caused by rapid flow changes originating upstream of the Lower Mamquam Plant whether natural or other are outside the operational control of the Lower Plant. Any non-compliance resulting from flow changes that originate upstream of the Lower Mamquam Plant will not be reported by the Lower Mamquam Hydro-Electric Project. Reporting of flow changes from upstream plants resulting in flow non-compliance are the responsibility of the plant responsible.

### 3.3.3 Fish Stranding Monitoring

Following any violation of downstream of powerhouse ramp rates caused by the lower Mamquam plant, fish stranding potential will be monitored. A decision to perform a fish stranding survey will be based upon the environmental monitor's conclusion on the ramping violation's potential to strand fish.

In the event of a stranding survey being performed, the results of the stranding survey will be included in the non-compliance report issued within one week of the incident.

### 3.3.4 Diversion Flow Monitoring

Diversion flow monitoring was originally calculated based upon precise flow measurements taken by

Hydro Quebec when the plant was commissioned. Hydro Quebec created a flow chart with correlations between unit output and flow in cubic meters/second.

A penstock flow meter has now been installed, with instantaneous real time measurements. Maximum diversion flows are 30 CMS. If diversion flows exceed 30CMS this will be reported to MFLNRO within 24 hours

### 3.4 NON-COMPLIANCE REPORTING

3.4.1. Downstream Ramping Non-Compliance Incidents

Instances of non-compliance will be initially reported within 24 hours to the Engineer or Regional Water Manager (MFLNRO-WSD) and DFO with a report to be submitted within a week of the incident (see Section 6.1.2 Notification and/or Section 7.4 Contact). All reporting will be in digital format.

1. Ramping will be monitored by a third party environmental consultant.
2. In the event of a non-compliance event downstream of the powerhouse, an automated alarm email will be distributed to plant staff and to the environmental monitor.
3. The environmental monitor will contact plant staff to determine the cause of the incident.
4. An initial report will be delivered via email to MFLNRO and DFO within 24 hours if the incident was caused by the Lower Mamquam plant
5. If it is determined the Lower Mamquam plant caused the ramping incident, and if the environmental monitor recommends a fish stranding search, a fish stranding search will be conducted in the stranding hot spots downstream of the plant (located at the high way bridge).
6. If fish are stranded, a report with fish stranding results, conditions of non-compliance, contributing factors, and measures taken to minimize immediate and future impacts will be delivered to MFLNRO and DFO within one week

# Section 4.0 - OPERATING PROCEDURES

### 4.1 PLANT OPERATIONS

#### 4.1.1 Operating Modes

Head Pond Level Control

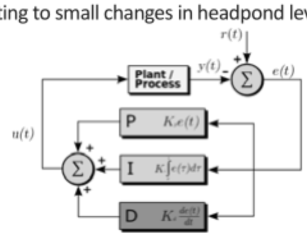
Two rubber weirs maintain the head pond at a constant level of 297.0 m with the provision to operate up to 298 m when the flows are high. The level is maintained by diverting river flow into the tunnel for power generation, spilling the water over the top of the rubber weirs by adjusting their pressure and in high flow conditions, releasing water through the sluice gate. The headpond level is measured in three different locations with the controller selecting the average of the two closest in value. In controlling head pond level the additional variable of rate of change must also be taken into consideration. With the large size of the head pond it takes time for the changes to alter the level. The control is done via a finely tuned PID loop that help compensate for over/undershoot.

The net effect is that the controller will maintain the level through ramping the units or changing the dam pressure at different rates depending on how far the level is from the set point and the rate at which the level is changing. For example, after a large rainstorm, the level would rise on the head pond quickly and the controller would respond by quickly raising generation and/or lower the dam pressure to spill more water. At other times if the head pond level is low but the level is rising quickly the controller may take no action. If it took action based solely on the low level, the pond level would overshoot to a higher level.

With two units at the plant that can operate in a couple of different modes, there are a number of different scenarios in which level will be controlled. In some cases both units will be available to be automatically ramped by the level controller. Other times one of the units will be held at a certain level or be offline making it

Unavailable for ramping but the other unit will still be available. The final case is when both units are unavailable for ramping and the only remaining means to control the pond level is through the pressure of the weirs.

In general the controller can be explained in that it is a response to error. The larger the headpond level is from the set point of 297.0 m the quicker it will respond. This allows us to react quickly to fast changes such as a flood or disturbance from the upstream plant while also eliminating constant fluctuations from over-reacting to small changes in headpond level.




An example of the control loop is shown above. In this example the Plant process output would the signal to raise/lower generation or inflate/deflate the weirs.

Unit Modes of Operation
The two units are able to operate in three modes of operation: Automatic, Power and Manual.

Automatic is the most common mode of operation. In this mode, the unit output is controlled by the level controller to compensate for changes in head pond level. It will raise generation at allowable ramps rates as long as there is available spill. The unit will automatically start in this mode and sync to the grid if there is sufficient spill.

In Power Mode, the unit is held at a user inputted MW set point. The set point can be changed in 0.1 MW increments. The ramp rate is limited to an accepted river stage rate but can be overridden if necessary. The unit can be started and synchronized to the grid using this mode.

Manual Mode allows to the operator to control the actual wicketgate position which relates back to the MW output. The unit cannot be started in this mode.

Ramping

The ramping of the units must be done within an accepted river stage rate. This accepted river stage rate depends upon the total river flow at the current time and must be slow enough to not strand fish. Currently, the limit is dynamically calculated dependent on current river level. The rate is converted to a change in flow or cumecs per hour and then used in ramping the setpoint. Ramping is done in auto and power mode.

The ramp rates are in place during auto mode and power mode. They are ignored during the following situations:

- Manual Mode
- Ramp Rate Override Enabled
- Low Low Forebay Level
- Low Tunnel Level

HMI indication for each unit

- Current Mode
- Total Power Produced (MW) – the total power – should be close to the Ramped Power Setpoint above. It always trends toward the Ramped Power Setpoint.

HMI control for each unit

- Mode Selection: Auto, Power and Manual
- Power Mode Start – end the current ramp
- Power Mode Setpoint
- Stop Pushbutton

Rough Zone Avoidance

The rough zone is the speed at which the angular velocity of the water entering the turbine excites the natural frequency of the runners. When the speed reaches the runner's natural frequency, the turbine begins to resonate and the increased vibration puts large stress on the turbine. This has been improved by automatic air injection into the runners. Operation in the rough zone is to be avoided regardless during two unit operation.

- If both units are below rough zone with rising head pond level resulting in more generation being required, the primary unit will cross the rough zone and the secondary unit will drop a matching amount in load.
- If one unit is below the rough zone and the other unit is above the rough zone with rising head pond level resulting in more generation being required, the unit crosses the rough zone while the other unit drops and equal amount.
- If both units are above the rough zone with the head pond level dropping resulting in less generation being required then the secondary unit will cross the rough zone while the primary unit will increase load by an equal amount.
- If one unit above the rough zone and the other unit is below the rough zone and the forebay level is dropping resulting in less generation being required then the primary unit will drop below the

rough zone and the other unit will increase load by an equal amount.

Wicket Gate Control
The wicket gates are used to control the flow of water to the turbine runners. The Francis type turbines at Mamquam have a total of 20 wicket gates per machine.

When the unit is offline the position of the wicket gates is used to vary the speed of the turbine. When the unit is online the wicket gate position will control the loading or output of the turbine. In Auto Mode the wicket gates are positioned by the PLC to match the demand from the head pond level. In Power Mode the position of the wicket gates is modulated according the desired output of the unit. The Wicket Gates control can also be placed into Manual and fixed at a percent open value entered by the operator in the HMI

Low Tunnel Level
The tunnel is designed to be supported by the water in the tunnel and should the level drop too low too quickly the tunnel could collapse. Low tunnel level is detected by three methods:

- Forebay Level
- Tunnel differential pressure compensated for head loss and converted to a level.
- Scroll case differential pressure for the running unit compensated for head loss and converted to level.

All three have low alarms: the forebay level below 296.5 m and the tunnel levels below 294 m.

At low-low level there is a 2 out of 3 ramp down with the forebay below 295 m and the tunnel levels below 291 m. Two of them will initiate a ramp down of the running units (in Power or Auto Modes) at 10 cumecs per hour.

At low-low-low level there is a 2 out of 3 low-low-low unit trip with the forebay below 295 m and the tunnel levels below 265 m. Two of them will initiate a unit trip.

In the case of loss of communications to the Intake PLC, the tunnel pressures will still be active for a 2 out of 2 ramp down and trip.

It is critical to repair a failed tunnel pressure or scroll case pressure transducer as soon as possible, as it will be one out of 3 in the failed state.

### 4.1.2 Daily Operating Procedures

***This section describes the daily operating procedures.***

DAILY CHECKS

The Daily Checks Form provides a list of items that the operator should check during the daily general site walk through. Any deviations from normal operating conditions should be documented and addressed as required. The following check sheet should be filled out and filed on site for future reference.

**Daily Plant Inspection for the week of ____________________ to ________________ 2014**

**Table 8 Daily Plant Inspection Chart**

| Inspection Location / Item | Mon | Tue | Wed | Thu | Fri | Sat | Sun |
|---|---|---|---|---|---|---|---|
| **Control Room** | | | | | | | |
| **Record in logs** | | | | | | | |
| • U1 & U2 output | | | | | | | |
| • Temperature & vibration | | | | | | | |
| • Seal flows-seal differential | | | | | | | |
| • Meter reading | | | | | | | |
| • Intake trashrack differential | | | | | | | |

| Inspection Location / Item | Mon | Tue | Wed | Thu | Fri | Sat | Sun |
|---|---|---|---|---|---|---|---|
| **Control Room** | | | | | | | |
| **Record in logs** | | | | | | | |
| • Strainer differential & flushing time | | | | | | | |
| • Adjust strainer cycles according to river comp. | | | | | | | |
| • River level | | | | | | | |
| • Tailrace level | | | | | | | |
| • Seal water filter pressure differential | | | | | | | |
| • Oil levels U1 & U2 | | | | | | | |
| *Comments* | | | | | | | |
| **Generator Floor** | | | | | | | |
| •Inspect U1 & U2 brushgear for sparking & brushwear | | | | | | | |
| • Compressors 1 & 2 - filters & oil level | | | | | | | |
| • Thrust bearing oil recirculation | | | | | | | |
| ▪ Oil extraction drain valve-drain daily | | | | | | | |
| • Portable oil filtration cart | | | | | | | |
| *Comments* | | | | | | | |
| **Stator Floor** | | | | | | | |
| • Inspect stator rooms 1 & 2 | | | | | | | |
| • City water pressure (120 *psi*) | | | | | | | |
| • Auxiliary water strainers 3 & 4 - (no shaft seal leaks) adjust accordingly | | | | | | | |
| • Check Stator Rooms 1 & 2 for oil and water accumulations | | | | | | | |
| *Comments* | | | | | | | |
| **Turbine Floor** | | | | | | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| • HPU U1 & U2 | | | | | | | |
| Oil level | | | | | | | |
| Temperature | | | | | | | |
| Nitrogen Pressure | | | | | | | |
| Breather Desiccant | | | | | | | |
| • Oil mist extractor collection cans | | | | | | | |
| • Drain valves (open at all times) | | | | | | | |
| • Strainer Pit (no debris etc.) | | | | | | | |
| • Ensure blower on for strainer pit if accessing | | | | | | | |
| • Manually backflush strainer U1 & U2 | | | | | | | |
| • Flush fire pump inlet elbow | | | | | | | |
| • Ensure "Y" strainer at 80 *psi* | | | | | | | |
| • Cooling water pump seal flow | | | | | | | |
| • Cooling water pump bearing temperature | | | | | | | |
| **Inspection Location / Item** | **Mon** | **Tue** | **Wed** | **Thu** | **Fri** | **Sat** | **Sun** |
| **Control Room** | | | | | | | |
| **Record in logs** | | | | | | | |
| **Turbine Floor** continued | | | | | | | |
| • Check strainers for excess water leakage & adjust seals | | | | | | | |
| • Check turbine pit for oil leaks | | | | | | | |
| • Check shear pin air pressure | | | | | | | |
| *Comments* | | | | | | | |
| **TIV Floor** | | | | | | | |
| • Air pressure on airbags U1 & U2 seals (20 *psi)* | | | | | | | |
| • Seal water flow (80 *psi*) | | | | | | | |
| • Sump pump | | | | | | | |
| • Flush water seals | | | | | | | |
| • Primary oil skimmer (lower float daily to skim) | | | | | | | |
| • Secondary oil skimmer (belt not slipping or stopped) | | | | | | | |
| *Comments* | | | | | | | |

The Project shall operate as a run of river facility. This means part of the available river flow is diverted into the tunnel/penstock at the headwork's, through the plant for energy production, and then returned to the river at the powerhouse.

The minimum instream flow is released by a slide gate located downstream of the intake screen

The plant is staffed Monday to Friday during normal business hours. 1 operator is on call for all other times (evenings/weekends) via an auto-dialer system which calls the operator's cell phone. Normally the operator can be at site within ½ hour. The operator also has the ability to operate the plant from his home computer shortening reaction times

Notify BCTC at 604 455 1710 prior to starts after outages, and for special operating conditions (Guarantee of no re-closure, guarantee of isolation, etc.). This is a requirement for electrical power generation into the grid. As flow in the river is maintained at all times, unit starts and stops will not be reported for environmental purposes.

The balance of the river flow will be used for generation up to plant capacity. When the balance available for generation is below the minimum operating limit for the plant, the plant shall be shut down and the total river flow bypassed around the turbines or spilled at the weir.

When the inflow to the headpond exceeds the maximum plant flow and MRF, the plant shall operate at full capacity and the excess water will be spilled over the weir crest gate. The crest gate will be automatically adjusted down to maintain the headpond level at FSL.

The small headpond storage volume cannot be used for shaping energy output. Headpond storage within the level control deadband shall be used to buffer turbine-generator with respect to natural river flow fluctuations

The plant is not required to be dispatchable, provide grid support, or operate in an isolated load state – output change rate will be a function of conveyance system pressure limits. This plant does not coordinate its output with other plants normally.

Power output change rate will be a function of natural river flow change rates, conveyance system pressure limits, and flow ramping requirements, whichever governs.

### 4.1.3 Start-Up Procedures

This section describes the manual and automatic start up procedures.

The plant is started up in a controlled safe manner following operating procedures MQ-OP-1 & 2. The procedure breaks the startup down into a number of steps summarized as follows:

1. Contact the Lower Mainland Control Centre (BCTC) to inform the system operator that the unit will be coming online. This is not required for starting the second unit.
2. Confirm that the oil levels to the Upper Guide, Lower Guide, Turbine Guide and the Thrust bearings are within normal limits.
3. Turn on the Cooling water to each of the three guide bearings to full. The cooling water to the Thrust bearing is set to 300 gpm. The water for the stator air coolers is set to 150 gpm. (40% open)
4. Confirm that the turbine brakes are in Auto, confirm that the forebay level is at 297.0m and that the Intake PLC is controlling the level in Auto.
5. Place the wicket gates, Turbine Inlet Valves(TIV) and Pressure Relief Valve (PRV) in Auto
6. Check that the turbine bearing temperatures as well as the stator cooling temperature are within acceptable limits. If necessary, adjust the flow to the stator cooling until the temperature is within limits ~45°C. Note the stator temperature will continue to rise for several hours after startup.
7. The unit is prepared to start. If the unit is in power mode press the start button otherwise place the unit in auto and it will start if there is sufficient water.
8. Check that the forebay level is above 297.0 m and that the air coolers and the stator cooler are within normal limits. The controls will automatically bring the machine up in load based

on the head pond level. This will include going through the rough zone when enough water is available.

Prerequisites for Unit Start

1. Turbine Inlet Valve must be in auto mode.
2. Turbine brake must be in auto mode.
3. Shaft seal must be in auto mode or the seal close solenoid must be off and seal open sensor activated.
4. Cooling water variable speed drive must be in auto mode or running.
5. Air cooling water valve must be in auto mode.
6. Bearing cooling water valve must be in auto mode.
7. Hydraulic pump 1 or 2 must be in auto mode.
8. Wicket gate axis must be in auto mode.
9. Pressure relief valve axis must be in auto mode or closed.
10. Generator MCB must be in auto mode.
11. Transformer MCB must be in auto mode and closed.
12. Transformer isolating switch DTx and generator isolating switch DGx of the respective unit must be closed or transformer isolating switch DTx, generator isolating switch DGx and tie circuit breaker of the other unit must be closed.
13. An active shutdown must not be in progress

Unit Start

Unit start is a fully automatic procedure. When a start is requested, and providing the unit start prerequisites have been met, the controller will perform the following checks and functions.

1. Shaft seal is commanded to open.
2. Service seal is verified to be open.
3. Lubrication pump is started.
4. Cooling water variable frequency drive is started.
5. Air cooling water valve begins to regulate as necessary.
6. Bearing cooling water valve is opened.
7. Wicket gate is closed (should already be closed).
8. Turbine brake is released.
9. Pressure relief valve is ramped closed (held open at 3% after a unit shutdown).

Synchronization

Synchronization is a fully automatic procedure. When a start is requested, and providing the unit start prerequisites have been met, the unit will enter run mode by performing the following checks and functions.

1. Overhaul seal is verified to be open.
2. Shaft seal is verified to be open.
3. Service seal is verified to be open.
4. Lubrication system pressure is verified.
5. Head cover cooling water level is verified.

6. Discharge cooling water flow is verified.
7. Turbine, lower, upper and thrust bearing cooling water flow is verified.
8. Turbine brake release is verified.
9. Adequate penstock water elevation is verified.
10. Wicket gate closure is verified.
11. Pressure relief valve closure is verified.
12. Turbine inlet valve is opened.
13. Governor will ramp open the wicket gate using a PID loop to attain 60 Hertz. Wicket gate maximum position is limited during synchronization to mitigate the possibility of an over speed condition.
14. When the frequency, voltage and phase of the generator match the grid the Line Synchronization will initiate a generator main breaker closure.
15. Governor will ramp open the wicket gate using a PID loop to attain the target KW. Initial target following a successful synchronization will be the KW minimum setting.
16. Hydraulic system pressure is verified to be above 1100 PSI.

### 4.1.4 Shut-Down Procedures

This section provides the shut-down sequence and procedures for the following four scenarios.

#### *4.1.4.1 __Normal Shutdown__*

This section describes normal shutdown procedures.

In a normal shutdown the machine is brought offline and then to a full stop in a safe controlled manner with minimal impact to the river downstream of the powerhouse. During a shutdown the PRV ramps at the allowable ramp rates. Otherwise, the river would see drastic changes in water level if the flow was suddenly cutoff by shutoff the water from the turbine and the bypass at the same time. In a normal shutdown, the equipment operates in the following manner:

The “Stop” button on the Unit screen brings the unit down to the minimum setpoint in preparation for going offline. When at the minimum setpoint water flow will be transferred to the PRV.

In a normal shutdown the operator follows at sequence to safely bring the unit to standstill in a controlled and safe manner. Plant procedures MQ-OP11 and 12 detail the steps in bringing a unit to safe stop, it can be summarized as follows:

1. The Lower Mainland Control Centre (BCTC) is contacted to inform the system operator that the unit will be coming offline.
2. The “Stop” button on the Unit screen brings the unit down to the minimum setpoint in preparation for going offline. When at the minimum setpoint water flow will be transferred to the PRV.
3. The cooling water valves to the upper guide, lower guide, turbine guide and trust bearings should be closed. The water supply to the stator cooling water should be closed.

#### *4.1.4.2 __Forced Outage__*

This section describes shutdowns procedures associated with forced outages. A forced outage is associated with an unplanned, unscheduled outage that disrupts normal operation.

The same procedure as a normal shut down is followed

#### 4.1.4.3 ***Emergency Shutdown***

This section describes emergency shutdown procedures, including procedures for restarting the plant following satisfactory resolution of concerns. Emergency shutdown refers to plant shutdown under controlled conditions, i.e. vibration concerns, bearing temperature.

The same procedure as a normal shut down is followed, unless there is risk of human injury or major damage to plant equipment. If there is risk of injury or major equipment damage, the operator will hit the emergency shutdown (ESD) button for the unit or both units if necessary. This will initiate the immediate closing of the turbine inlet valve (TIV) which closes in 90 seconds. Once closed this valve stops all flow through the plant and will dewater the river below the plant.

A normal restart is always used to synchronize the plant online. Depending on the problem, plant MW output may be controlled in 1 MW steps as the unit ramps upwards.

#### 4.1.4.4 ***Long Term Outage***

This section describes shutdown procedures associated with long term outages. A long term outage is defined as an outage lasting more than four hours. It is typically associated with unplanned major equipment failures, scheduled maintenance, and/or extreme low-flow conditions.

The normal shut down procedure is used for long term outages. This leaves the generator ready for automatic restart if flows increase. If there is a scheduled outage for maintenance, a unit lockout is used to secure the unit for safety reasons

## 4.2 OPERATIONS

### 4.2.1 Headpond Filling and Flushing/Sediment Transport (sluicing)

#### 4.2.1.1 General

Head pond sluicing is an annual fall event performed during periods of very high rain and river flows. Annual sluicing prevents excess build-up of sediment and must be completed annually. Inform the statutory decision maker (SDM) at MLFNRO and DFO region officer to inform them of planned sluicing. Since high river levels cannot be predicted in advance, provide the information in October and inform the regulators that sluicing will occur during the next high river event.

There are also other operational reasons to open the sluice gate. During high river flows and other storm events, flows can increase to the point where even deflating the weirs will not allow enough flow through the intake and cause head pond levels to be dangerously high. The sluice gate is designed to be opened during these flood events to prevent overflow of the intake structure with potential catastrophic damage. The sluice gate can flow 200+ CMS.

In addition, occasionally large trees/logs and other debris finds its way into the sluiceway and can damage trash rack cleaning equipment and plug the intake screens. This typically happens during high flow events. Opening the sluice gate is the only way to flush out these objects.

Before initiating sluicing, river flows must be above 80 cubic meters/second (CMS). This normally indicates extreme turbidity approaching 6000 NTU's as measured on the downstream of intake turbidity meter. The meter maxes out at 6000 NTU. In addition, at flows above 50 CMS the river is bank full with no chance of fish stranding. Duration of head pond sluicing and turbidity levels prior to and during will be included in the annual compliance report.

**Commented [IWM7]:** Ok?

4.2.1.2 Take plant offline. Be certain to keep downstream of powerhouse flows above 50 CMS at all times to allow for unlimited ramping.

4.2.1.3 Depending on river flows the head pond level will drop. Upon the initial drop, conduct a fish stranding search by the sand bar upstream of the intake on the south side of the river. If any fish are found return them to the river.

4.2.1.4 If the Radial Gate is in service…

1. To initiate sluicing, crack open the sluice gate either manually at the gate, or through the HMI. Watch for an immediate increase in turbidity downstream upon opening the sluice gate through the intake camera or in person.
2. *Ensure that there is no sediment plume. If the sediment released is darker than the existing river flows close the sluice gate sufficiently until it is the same color as the water overtopping the weirs.*
3. *Slowly and incrementally open the sluice gate allowing more and more water to flush away accumulated sediment, always being mindful not to increase sediment transport above the existing river flows. This can be determined by comparing the color of the water as noted above. Since the turbidity meter is pegged at 10000 NTU turbidity is not measured.*
4. *At some point all water will flow through the sluice gate which will transport all sediment in the sluice way downstream. The sediment in the sluiceway is mostly sand.*

4.2.1.5 If the South Weir is in service…

1. *Deflate the south weir slowly. Using the same procedure for the sluice gate watch for excess sedimentation release and re-inflate as necessary. Normally the head pond has less sedimentation than the sluice way and the release consists mostly of gravels and larger rocks.*
2. *Once the south weir is fully deflated, slowly close the sluice gate which will transfer the water flow from the sluice way to the south weir. Keep an eye on sedimentation release through this process and re-inflate the weir to control release as necessary.*
3. *Once the sluice gate is fully closed all flow is going through the south weir. Maintain this flow until all noticeable sediment transfer is complete.*

4.2.1.6 If the North Weir is in service…

1 *Deflate the north weir, again watching for excess sedimentation release. Inflate as necessary to control the release.*

2 *Once the north weir is fully deflated, start inflating the south weir (if in service) to transfer all the flow though the north weir. Keep an eye on sedimentation release through this process and re-inflate the weir to control release as necessary.*

3 Once all flow is going through the north weir, maintain this flow until all noticeable sediment transfer is complete.

4 *Once observed sediment release tapers to nil, the sluicing process is complete.*

4.2.1.7 Initiate the head pond refill program on the HMI. This program slowly inflates the weirs until normal head pond elevation is complete at the allowable ramp rate. Always check to ensure there is 50+ cms flow downstream of the intake to ensure downstream fish are not stranded

4.2.1.8 Restart plant.

4.2.1.9 Record date and duration of flushing event, and turbidity readings before during and after flushing from the downstream turbidity gauge.

### 4.2.2 Intake Water Level Management

This section describes how headpond water level is being recorded and managed below and above full plant capacity.

During normal operations the headpond level is 297.0 meters of elevation above sea level. There are 3 level gauges in the head pond, 3 level gauges in the sluice way, and 3 level gauges downstream of the intake screen in the forebay.

The intake PLC monitors intake levels. If the level starts to rise, unit output is increased to maintain 297.0 meters of elevation. If the intake level starts to decrease, unit output is decreased to maintain 297.0. The second unit can be automatically started and stopped based upon intake level conditions.

Once both units are at full production, the intake is used to regulate head pond level.

### 4.2.3 Water Conveyance Filling

#### ***4.2.3.1 <u>Filling/pressurizing of water conveyance system</u>***

This section describes the procedures for filling and pressurizing the water conveyance system and assumes the head pond is fully drained.

If the tunnel and penstock (water conveyance system) are drained for maintenance, these are the steps for refilling:

- Install stop logs. The stop log with the 3 valves goes in first at the bottom. The other stop logs stack on top. Install all stop logs.
- Start the automated intake fill program on the HMI which fills the intake at the correct ramp rate. Fill the head pond to normal elevation of 297.0 meters of elevation
- Manually open the valves in the bottom stop log one at a time. Ensure that spill over the weirs being ramped downwards doesn't exceed the allowable ramp rate of depending on river flows.
  - <10cms – 7.5 cm/hr,
  - >10 < 24cms 19.9cm/hr
  - >24cms unrestricted
- The maximum allowable rate of fill in the tunnel is 10 meters of elevation per hour.

### 4.2.4 Flood Handling

The head works are designed to pass the inflow design flood (IDF) without sustaining significant rebuild-type damage.

| | |
|---|---|
| ***Inflow design Flood:*** | ***600 $m^3$/s instantaneous peak inflow Annual*** |
| ***Exceedance Probability:*** | ***Designed for 1 in 500 year flood*** |

The plant is designed for a one in 500 year flood event and flows to 600CMS. Increasing flows will cause the weirs to deflate. With the 2 weirs fully deflated, 200 CMS can flow through each weir channel. The sluice gate can fully open allowing another 200 CMS capability if necessary.

The flood flow rating of the head works is reduced if *Stoplogs* are present in front of either the North Weir, the South Weir, or the Radial Gate.

### 4.2.5 Debris Management

This section describes how organic and woody debris will be accommodated and handled

A dual cleaning head, automated trash rake is installed on the intake screen. When measured differential across the screen exceeds the designated set point, the trash rakes are automatically started. They rake the intake screen and pull leaves and woody debris to the surface and dump the debris onto the intake deck.

On an as required basis, the debris is stock piled at the end of the intake deck. It is then loaded into a trailer and dumped into the woods along the intake road where it serves as biomass material as it decomposes.

### 4.2.6 *Diversion Stoplogs*

4.2.6.1 Use and Handling

*4.2.6.1.1* General

Inspect the Stoplog sections prior to and following each use. Note in particular the following items:

- Condition of seals
- Condition of the valve and operating mechanism
- Possible structural damage
- Follower beam
- Condition of bumpers
- A hook release mechanism
- Tiller rope

If a Stoplog section becomes jammed while lowering through guides, i.e., main hoist rope goes slack, attempt to raise the section and re-lower. Should the section jam again, do not attempt to move the section again until the condition has been thoroughly investigated and the jam rectified.

If a crane overload device trips while the stop-log is being raised, the section may have jammed in the guides. Do not bypass the overload device or attempt to raise the section farther. Lower the section, verifying the movement, i.e., the rope does not slack. If the section can be lowered, attempt to raise it again. If the overload device operates again, or if the section will not lower, do not attempt any further movement of the section until the conditions have been thoroughly investigated and the situation rectified.

*4.2.6.1.2* Installation

Under no circumstances are the Stoplogs to be installed under flowing water conditions. There must be a general absence of differential pressure across the Stoplog in order to prevent binding.

Installation of the intake structure Stoplog set is accomplished by the procedure outlined below:

*4.2.6.1.2.1* Notify the following agencies:

- Ministry of Forests, Lands and Natural Resource Operations – Water Stewardship Division
- Ministry of Forests, Lands and Natural Resource Operations – BC Dam Safety

*4.2.6.1.2.2* Attach the crane hook to the follower beam. Connect tiller rope to the tiller

*4.2.6.1.2.3* Using the follower beam, raise the bottom stop log section (the one with a valve)

*4.2.6.1.2.4* Wet sealing surfaces to minimize abrasion

*4.2.6.1.2.5* Guiding the follower by the stop-log guide, carefully lower the section until it rests on the sill beam and crane ropes become slack

*4.2.6.1.2.6* Using the tiller mechanism, unhook the follower

*4.2.6.1.2.7* Using the follower beam, raise next Stoplog section.

*4.2.6.1.2.8* Repeating steps 3 – 6, install the remaining sections

*4.2.6.1.3* Removal

Under no circumstances are the Stoplogs to be removed under flowing water conditions. There must be a general absence of differential pressure across the Stoplog in order to prevent binding.

Removal of the Stoplog shall be accomplished in the opposite order to installation procedures set out in 4.1.3.1.2.

4.2.6.2 Operation with Stoplogs in Place

*4.2.6.2.1* General

The generating station was specifically designed to permit continuing commercial operation with Stoplogs in place.

*4.2.6.2.2* Both Weir Stoplogs in Place

Installation of these Stoplogs reduce the rated flow of the diversion works and increases the risk of damage should a significant river flow event occur. The following procedure is only valid for inflows to the diversion works below 254 m3/s.

*4.2.6.2.2.1* Retain a professional hydrologist to provide monitoring of weather patterns and inflow changes to address risk management of the reduction in intake flow rating arising from the presence of the Stoplogs. This shall continue until such time that the Stoplogs are removed. The Stoplogs may require removal in advance of forecast periods of heavy river flow.

*4.2.6.2.2.2* Station a crane suitable of handling the Stoplogs at the diversion works for the duration that the Stoplogs are installed.

*4.2.6.2.2.3* Fill the head pond manually using the Radial Gate. This shall meet the ramping requirements set out in section 3.1.2.

*4.2.6.2.2.4* Continue until the Radial Gate is closed. This will result in water overtopping the Stoplogs.

*4.2.6.2.2.5* Restart the plant using standard operating procedures.

*4.2.6.2.3* One Weir Stoplog in Place

*4.2.6.2.3.1* Retain a professional hydrologist to provide monitoring of weather patterns and inflow changes to address risk management of the reduction in intake flow rating arising from the presence of the Stoplogs. This shall continue until such time that the Stoplogs are removed. The Stoplogs may require removal in advance of forecast periods of heavy river flow.

*4.2.6.2.3.2* Station a crane suitable of handling the Stoplogs at the diversion works for the duration that the Stoplogs are installed.

*4.2.6.2.3.3* Restart the plant using standard operating procedures.

*4.2.6.2.4* Radial Gate Stoplog in Place

*4.2.6.2.4.1* Retain a professional hydrologist to provide monitoring of weather patterns and inflow changes to address risk management of the reduction in intake flow rating arising from the presence of the Stoplogs. This shall continue until such time that the Stop Logs are removed. The Stoplogs may require removal in advance of forecast periods of heavy river flow.
*4.2.6.2.4.2* Station a crane suitable of handling the Stoplogs at the diversion works for the duration that the Stoplogs are installed.
*4.2.6.2.4.3* Restart the plant using standard operating procedures

## 4.3 MAINTENANCE AND INSPECTION PROGRAM

The plant has a computerized maintenance management system (CMMS). The plant employs certified millwrights and electricians who follow the CMMS requirements to ensure the plant is properly maintained as per schedule. For larger projects, outside contractors are utilized.

There are daily, weekly, and monthly inspections and all checklist information is recorded. In addition there is a requirement for an annual civil engineer led dam inspection, and an annual third party engineering inspection of all plant equipment. The annual third party engineering inspection consists of three professional engineers in the mechanical, civil, and electrical disciplines.

They submit a report to the plant manager who then must submit the report by month end February to BC Hydro.

### 4.3.1 Diversion Structures

#### *4.3.1.1* ***Weekly Inspections***

To ensure integrity of the structures, weekly inspections of the following equipment and structures are conducted by Atlantic Power staff. The weekly inspections include:

**WEEKLY INSPECTION CHECKLIST**

**Table 9 Weekly Inspection Checklist**

| **Inspection Location / Item** | **Checked** | | **Comments** |
|---|---|---|---|
| **Generator Floor** | | | |
| • *Portable filter cart to alternate bearing-Indicated weekly change. Switched to:* | UGB | LGB | |
| | | | |
| • *Turbine thrust bearing stationary oil filtration unit-switch weekly if both units running* | | | |
| • *Check HVAC system for proper operation* | | | |

| **Yard** | | |
|---|---|---|
| • *Test backup generator for powerhouse (1/2 hr)* | | |
| • *Check building structure for structural integrity & security* | | |
| • *Check fence line integrity* | | |
| • *Check and record fuel level on diesel generator* | | |
| • *Check Transformer yard oil & temperature gauges* | T1 Oil Level | T2 Oil Level |
| | T1 Oil Temp | T2 Oil Temp |
| | T1 Winding Temp | T1 Winding Temp |
| • *Run fire pump* | | |
| • *Check deluge valves* | | |
| | | |
| **Intake** | | |
| • *Riparian bypass gate measurement 89 5/16"* | | |
| • *Check and record fuel level on diesel generator* | | |
| • *Run intake diesel generator 30 min.* | | |
| • *Check radial gate for leaks* | | |
| • *Inspect weirs for leaks or damage* | | |
| • *Check HVAC system for proper operation* | | |
| • *Perform radio/phone check* | | |
| • *Clean Trashrack* | | |
| • *Check building structure for structural integrity & security* | | |
| • *Check fence line integrity* | | |

#### *4.3.1.2 Annual Inspections*

Annual inspections are conducted by a third party engineering firm. Knight Piesold has been retained for the past several years.

The annual inspection occurs in February, with the report submission to BC Hydro by March 1st. The engineering team employs civil, electrical and mechanical engineers to review all aspects of the site.

#### *4.3.1.3 Dam Safety Inspections and Activities*

This section provides details on the dam safety inspections and activities. The status of the dam is regulated and the dam failure consequence classification is Low as defined in BC DSR 44/2000 and as verified by the Dam Safety Officer.

The Dam safety inspections and activities will be performed according to the schedule (annually) for each activity as itemized in Table 11.

**Table 10 Frequency of Dam Safety Inspections and Activities**

| Item | Activity | Frequency |
|---|---|---|
| 1 | Site surveillance | Quarterly |
| 2 | Formal inspection | Annually |
| 3 | Monitor instrumentation | As requested by the Dam Safety Officer |
| 4 | Test operation of outlet facilities, spillway gates and other mechanical components | Annually |
| 5 | Update the emergency contact information in the EPP | Not Applicable |
| 6 | Review, and revise if necessary, the OMS manual and the EPP | Not applicable |
| 7 | Conduct dam safety review and submit dam safety report | Not applicable |
| 8 | Review downstream conditions, as set out in section 6.1 of BC DSR 44/2000, and notify a dam safety officer of any change in classification | Annually |

#### *4.3.1.4 Seepage Monitoring*

Seepage Monitoring is conducted as part of the semi-annual inspection by. The plant maintenance staff inspect the dam in February and a civil engineer formally inspects the dam in September. The margins of the dam are inspected, as well as the downstream toe.

#### *4.3.1.5 Maintenance*

The plant has a CMMS system covering all aspects of plant maintenance. Some maintenance items are performed on an hourly or calendar basis. Other items are maintained on a predictive maintenance philosophy (higher vibration, temperatures, etc.)

### 4.3.2 Water Conveyance System

This section describes the maintenance and inspection program for the various components associated with the Tunnel.
The water conveyance system consists of the trash rake, intake screen, tunnel, penstock, and turbine inlet valve.

***4.3.2.1 Trash Rake***

The trash rake is visually inspected weekly to ensure proper operation. On an annual basis a more detailed inspection is performed (hydraulic oil levels checked, filters changed, lubricated, any adjustments to the range of operations, etc.)

***4.3.2.2 Intake screen***

The intake screen is visually inspected once per year when the head pond is lowered during sluicing operations. Normally no maintenance is required

***4.3.2.3 Tunnel***

Historically the tunnel has been inspected every 5 years. Normal maintenance includes cleaning material out of the two rock traps, and visual inspection of the tunnel rock and tunnel plug area.

***4.3.2.4 Penstock***

The penstock is now inspected annually on the exterior, and every 5 years on the interior. Maintenance staff look for corrosion, pitting, and security.

***4.3.2.5 Turbine Inlet Valve***

The TIV's are visually inspected annually. Leakage, corrosion, seal filters, cavity flushes and correct operation are normal inspection points.

### 4.3.3 Powerhouse Civil Works

No specific inspection is done on the powerhouse civil works. However any issues noted in day to day operations are reported and repaired if necessary.

### 4.3.4 Tailrace

The tail race equipment is inspected annually. The tail race crane, draft tube stop log, and PRV isolation gates operators are inspected to ensure proper operation

### 4.3.5 Access Roads

The plant and intake access roads are inspected annually. Grading, tree pruning, ditching, etc. are performed on an as required basis.

### 4.3.6 Turbines/Generators

The turbines and generators are monitored through the plant PLC's /HMI,s, and are visually inspected on a daily basis. Most maintenance is performed on as required basis with requirements noted on the HMI's (high differentials, high temperatures, etc.). The brush gear is tested weekly, the turbine wet end components (runner, wicket gates, etc.) are inspected annually, and the generators are inspected bi-annually by GE.

#### 4.3.7 Energy Dissipation System

The PRV's (pressure reducing valves) are visually inspected weekly, and after every load rejection. Annually a more in depth inspection is performed that includes the hydraulic system (servo's, intensifiers, filters, piping and hoses) as well as mechanical systems.

#### 4.3.8 Mechanical & Hydraulic Systems

The mechanical and hydraulic systems are inspected daily during the operator rounds. Depending on the equipment, maintenance is performed annually or on an hourly basis and includes filter changes, lubrication, and component replacement

#### 4.3.9 Back-up System

The plant back up diesel generators are tested weekly for proper operation and maintained annually (oil, filter changes, adjusting valves, testing glycol for proper additives, etc.) or as required. The plant UPS (uninterruptable power system) systems are inspected annually or as required. UPS batteries are replaced at the following frequencies:
Communications UPS – 3 years,
Intake UPS– 5 years,
Powerhouse main station UPS – 10 years

#### 4.3.10 Controls and Protection

Protective relays are serviced by outside contractors every three years. The plant PLC cabinets are cleaned on an annual basis

#### 4.3.11 Switchyard and Substations

The transmission line is inspected annually and brushing or repairs are completed on an as required basis. Pruning is conducted with a qualified electrical worker or a certified utility arborist to ensure safe distances are maintained.

The high voltage switch gear and plant substation is serviced by outside contractors every three years. Maintenance consists of checking for proper operation and repairing if necessary, cleaning, and lubricating of equipment.

### 4.4 TROUBLESHOOTING AND REPAIR

### REPORTING REQUIREMENTS

This section provides a list of annual operational reporting requirements and commitments.

**Table 11 List of annual operational reporting requirements**

| Report | Author | Submit To | Submission Date |
|---|---|---|---|
| Third party Engineering Inspection | External Engineer | BC Hydro | *March 1* |

# Section 5.0 - OPERATING STAFF

### 5.1 STAFFING LEVELS

The plant is currently staffed with a plant manager and a plant administrator, as well as one certified electrician, an electrical apprentice, and two certified millwrights. The Electricians and Millwrights also operate the plant as necessary. Plant staff normally work Monday to Friday 8 hours per day during normal business hours. During the off hours and weekends one operator is always on call on a rotating basis.

### 5.2 TRAINING

The plant has a detailed annual training plan for health, environment and safety. Typically 20 in-house or outside training courses per year are completed annually as required by corporate policy or regulatory agencies. On the job mentoring is performed by experienced operators to less experienced workers, and procedures have been developed for more complicated processes. Each new hire required is required to go through a thorough corporate orientation

### 5.3 SAFETY

Safety is addressed by monthly safety meetings, and weekly safety inspections. There is an annual plant safety audit to ensure the plant is up to current regulatory standards. Plant visitors and contractors are required to go through a thorough corporate orientation as well as a site specific orientation. All contract work requires a safe work plan before starting work and daily tail gates talks with all details recorded.

# Section 6.0 - SAFETY PROCEDURES

### 6.1 EMERGENCIES

#### 6.1.1 General

An emergency may be potential, imminent or realized failure of some component of the Project. This section provides details on how to respond to potential emergencies, such that personnel can be prepared in the remote chance that such a situation does occur.

***Emergency numbers:***

**Table 12 Emergency Numbers**

| Mamquam Emergency Telephone List<br>Powerhouse 604 898 2761 | Intake 604 898 1736 | |
|---|---|---|
| **Contact** | **Phone Number** | **Emergency Type** |
| Connections Call Centre | **604 815 6090** | Working Alone |
| Ambulance | 911 | Medical Emergency |
| BCTC | **1 604 455 1710** | Outage/Isolation |
| Fire | 911 | Fire |

| | | |
|---|---|---|
| Hospital - Squamish | **604 892 5211** | Medical Emergency Alert |
| **RCMP** | 911 | Security |
| Hazco | **1 800 327 7455** | Spill Response |
| **Plant & Atlantic Power Contacts** | **Cell** | **Home** |
| Scott Ronaldson | s.22 | |
| David Griffioen | | |
| David Carlin | | |
| Jason Tyrrell | | |
| Mike Rafferty | | |
| Rachel Dacosta | | |

| **Contact** | **Phone Number** | |
|---|---|---|
| Dan Rorabaugh - VP Operations | s.22 | Work: 617 977 2494 |
| Terry Shannon - EHS | | |
| **Other** | **Cell** | **Other** |
| PLC Support- Brad Ingram<br>-Ken Hanson | s.22 | Work: 604 210 9617 |
| **Regulatory Agencies** | **Phone Number** | **Emergency Type** |
| Fisheries & Oceans | 1 800 465 4336 | Fishery Regulation Reporting |
| Ministry of Environment | 1 250 387 1161<br>1 800 663 9453 | Regulatory Issue Reporting<br>Dangerous Wildlife |
| Transport Canada (TDG) | 1 613 996 6666 | Emergency Involving Dangerous Goods |
| Work Safe BC M-F 8:30-4:3<br>After Hours | 1 888 621 7233<br>1 866 922 4357 | Serious Injury or Fatality Reporting |

**Emergency contacts In the case of a dam failure:**

Provincial Emergency Program http://embc.gov.bc.ca/em/index.html

Water Management Branch http://www.pep.bc.ca

Dam Safety Branch 1-800-663-3456

### 6.1.2 Notification

**24 Hour Access Telephone Numbers**

The following is a list of 24 hour telephone numbers that may be applicable for the activation of the emergency plan. The site's emergency plan administrator is responsible for maintaining this list.

***Telephone numbers in this emergency response plan must be reviewed every 6 months***

**Table 13 Mamquam Generating Station Internal Contact Numbers - 24 HRS**

| **Mamquam Generating Station**<br>1 604 898 2761<br>**39241 Powerhouse Springs Rd, Squamish, BC**<br>**Intake** | | |
|---|---|---|
| **Internal Contacts** | **Type of Emergency** | **Phone Number** |
| Connections Call Centre<br>**24 Hours** | As Indicated in Procedures | 604 815 6090 |
| **Plant Manager**<br>Scott Ronaldson | All | Work: 604 898 2761<br>Cell: s.22 |
| **Plant Operators:**<br>David Carlin<br>David Griffioen<br>Jason Tyrrell<br>Mike Rafferty | As Needed | Cell: s.22<br>Cell:<br>Cell:<br>Cell: |
| **Senior Advisor, Health & Safety**<br>Ron Ewan | Occupational Health & Safety & Environment | Cell: s.22 |
| **Environmental Health & Safety**<br>Terry Shannon | Environmental spills, releases, permit violations | Work: 858 492 5484<br>Cell: s.22 |
| **VP Operations**<br>Dan Rorabaugh | As per notification guidelines | Work: 617 977 2494<br>Cell: s.22 |
| **Computer Support – Helpdesk** | Computers | 877 832 3695 |

### 6.1.3 Emergency Conditions and Response

This section describes emergency events and necessary course of action (response). Emergencies are defined as unusual situations that can lead to one or more significant consequences. A list of potential emergencies and appropriate responses is provided in Table 15.

**Table 14 Potential Emergencies and Response**

| Event | Response |
|---|---|
| Excessive leakage at diversion structures | Call plant manager<br>Plant manager to determine next actions |
| Movement or severe cracking of concrete diversion structures | Report to Dam safety officer.<br>If necessary, start to gradually lower head pond |
| Rupture of penstock, surge tank or tunnel | Call<br>Provincial Emergency Program<br>http://embc.gov.bc.ca/em/index.html<br><br>Water Management Branch http://www.pep.bc.ca<br><br>Dam Safety Branch 1-800-663-3456 |
| Equipment Fire/explosion | Squamish Fire Department (911) |
| Forest Fire | 911 |

### 6.1.4 Loss of Control or Failure of the Works

Procedures are located in the Operations Manual, with additional information within the Operations, Maintenance and Surveillance (OMS) Manual .

> **NOTE**: In the event that the works are damaged or operation controls are damaged and non-functional, the operator must contact the FLNRO Regional Water Manager within 24 hours.

In the event that the works are damaged, or operational controls are damaged as to be non-functional, The Lower Mamquam Hydroelectric project shall contact the Regional Water Manager [Remko Rosenbloom @ 604 586 5629 within 24 hours (see Section 6.1.2).

The Lower Mamquam Hydroelectric project provides the following commitment:

"if the loss of control or failure of the works increases the potential for additional damage, or become potentially hazardous to public safety, the licensee or his operators shall contact the RWM, the Regional Dam Safety Officer and the Provincial Emergency Program within Emergency Management British Columbia (PEP-EMBC) within 24 hours, The incident report shall clearly state that there has been a failure of the works, or that operational controls for the facility have been damaged, and what emergency procedures are underway".

### 6.2 WARNING SYSTEMS

***This section describes the safety measures and procedures required and committed to, to ensure public safety including navigational safety, warning systems, or other.***

An air powered fog horn at both the intake and the powerhouse provides a very loud audible warning to recreational users of the river to warn them of possible changes in river flow. These devices are tested annually

# Section 7.0 - KEY CONTACTS

### 7.1 PROJECT OWNERS

Table 16 provides the key contact information for the Project owners.

**Table 15 Contact Information for Project Owners**

| Title | Name | Contact Numbers |
|---|---|---|
| VP Operations | Dan Rorabaugh | Work: 617 977 2494<br>Cell: s.22 |
| Environmental | Terry Shannon | Work: 858 492 5484<br>Cell: s.22 |
| Safety | Ron Ewan | Work: 617 977 2703<br>Cell: s.22 |

## 7.2 PROJECT OPERATORS

Table 17 provides contact details for the key Project operational staff.

[Table 14 should provide contact information for:

- Plant control room;
- Plant Operators; and
- Operations Manager (if available).

**Table 16 Contact Information for Project Operators**

| Title | Name | Contact Numbers |
|---|---|---|
| Control Room | Operations | 604 898 2761 |
| Plant Manager | Scott Ronaldson | Cell: s.22 |
| Plant Foreman | Dave Griffioen | Work: 604 898 2761<br>Cell: s.22 |
| Operator | Dave Carlin | Work: 604 898 2761<br>Cell: s.22 |
| Operator | Jason Tyrrell | Work: 604 898 2761<br>Cell: s.22 |
| Operator | Mike Rafferty | Work: 604 898 2761<br>Cell: s.22 |
| Plant Administrator | Rachel Dacosta | Work: 604 898 2761 |

## 7.3 PROVINCIAL AND FEDERAL AGENCIES

**Table 17 Contact Information for provincial and federal agencies**

| Title | Name | Contact Numbers |
|---|---|---|
| FLNRO Regional SDM | Remko Rosenbloom | 604 586 5629 |
| FLNRO Regional Dam Safety Officer | Mike Bristol | 604 582 5200 |
| DFO | Murray Manson | 604 666 0129 |

### 7.4 OTHER STAKEHOLDERS

Table 19 provides the key contact information for the key Project operational staff.

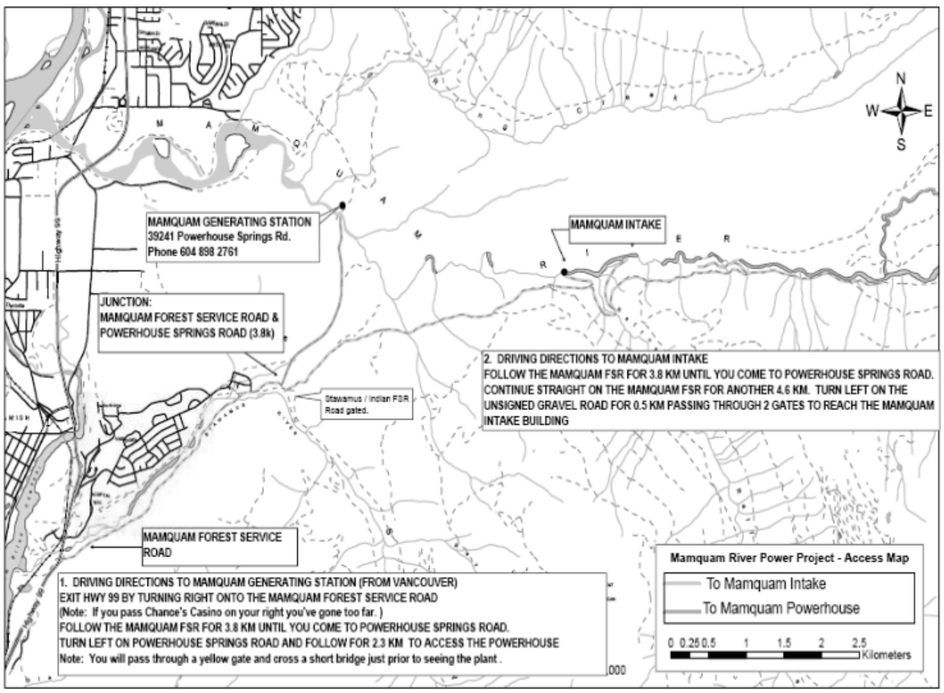
**Table 18 Contact Information for Other Stakeholders**

| Stakeholder Name & Contact Title | Name | Contact Numbers |
|---|---|---|
| Upper Mamquam Hydroelectric | Sal Luengo | Work: 604 898 8297<br>Cell: s.22 |
| District of Squamish Public Works | Foreman | Work: 604 815 6868 |
| Skookum Creek Power | Steve McKay | Cell s.22 |

TransAlta AtlanticPower Corporation SKOOKUM CREEK POWER PROJECT

# APPENDICES

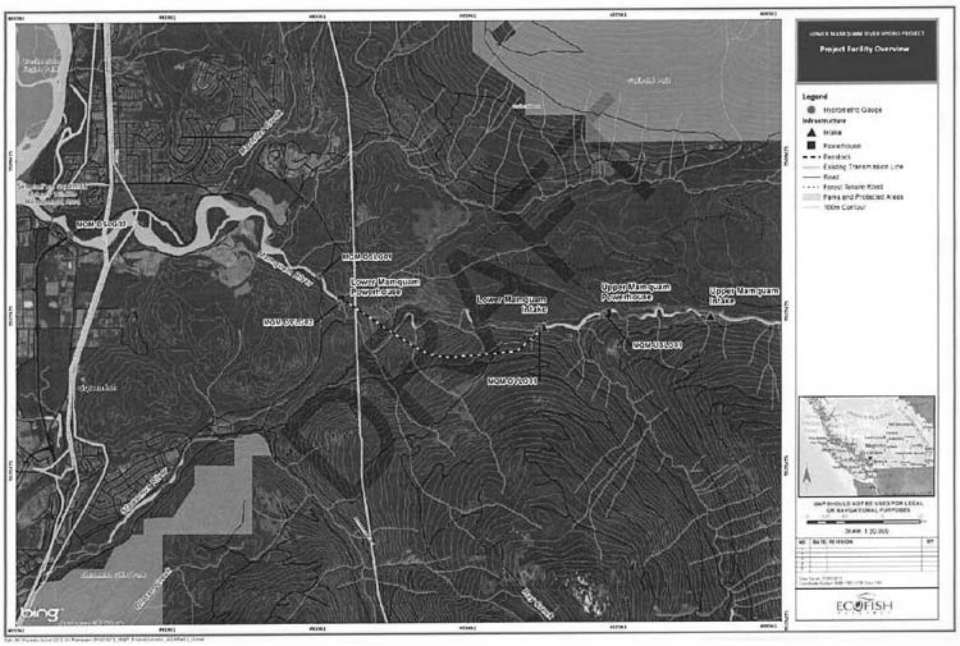
## Appendix A – General Access Map



## Appendix B River Gauging Locations

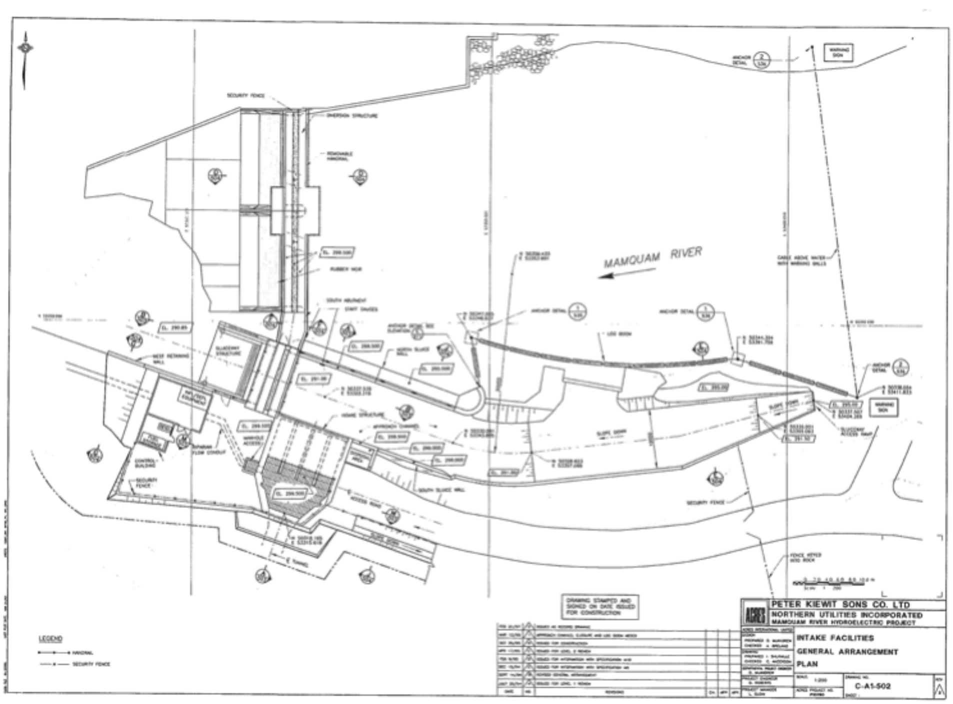


**Map 1.** Location of the Lower Mamquam River Hydroelectric Project, showing project infrastructure and gauging stations.

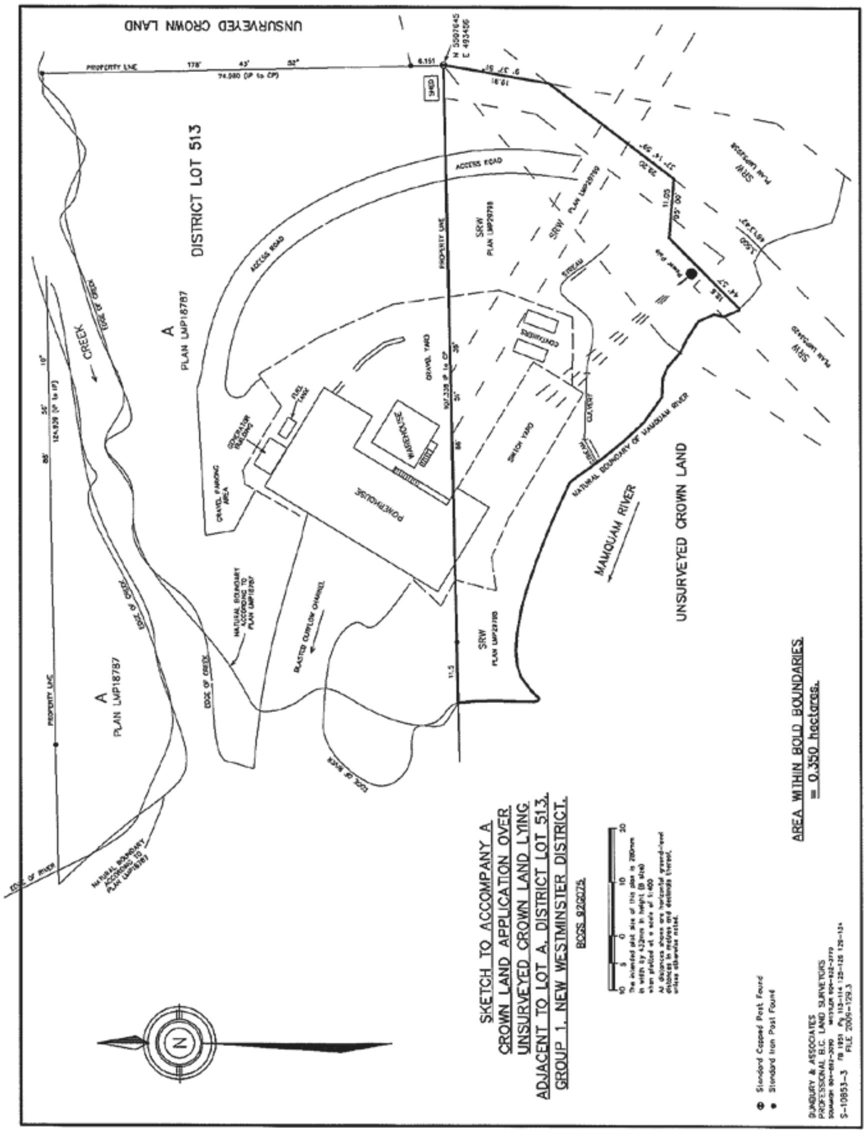


# Appendix C – General

# Arrangement Drawings



TransAlta AtlanticPower Corporation SKOOKUM CREEK POWER PROJECT



# Appendix D – Conditional Water License

BRITISH COLUMBIA
The Best Place on Earth

March 5, 2009 File: 2003040

Coastal Rivers Power Limited Partnership
c/o Kelly Lail, Regional Director
EPCOR Power L.P.
215 – 10451 Shellbridge Way
Richmond, BC V6X 2W8

Dear Mr. Lail:

**Re: Conditional Water Licence 123692 on Mamquam River**

Enclosed please find a copy of Conditional Water Licence 123692. Please make careful note of its conditions. Any error in the licence should be brought to the attention of the issuing office as soon as possible.

If additional fees are required, you will be advised by our Victoria office, in due course.

You are hereby informed that the Water Act does not guarantee quality or quantity of water.

Please note the following:

1. Water licences do not authorize entry on privately owned land for the construction of works. Permission of the affected landowner must be obtained or an easement expropriated. For your protection, permission should be in writing and registered with the appropriate Land Title Office.

2. Permission for crossing roads or lands under the jurisdiction of any Government agency must be obtained from the agency concerned.

3. In order for you to keep your water licence in good standing, the following must be observed:
   a) continued beneficial use of water, as authorized under your licence;
   b) payment of annual rentals;
   c) compliance with the terms of your licence;
   d) compliance with the terms of the Water Act.

**Ministry of Environment** **Water Stewardship Division Management & Standards Branch** **Mailing Address/Location** 10470 – 152nd Street, 2nd Floor Surrey BC V3R 0Y3 Telephone: 604-582-5200 Fax: 604-582-5235 **Web Address:** http:\\www.env.gov.bc.ca

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4. In order to protect your interests, please notify the Regional Water Manager, in the event of any of the following:
   a) there is any change in your mailing address;
   b) you sell the land to which the licence is appurtenant;
   c) you propose to subdivide the land to which the licence is appurtenant; and/or
   d) you propose to alter the works authorized under the licence.

5. In accordance with condition (j) of your license, an In-stream Flow monitoring program and Operational Environmental Monitoring Plan shall be submitted to and approved by the Ministry of Environment within 6 months of the date of this letter (September 5, 2009).

You have the right to appeal this decision to the Environmental Appeal Board. Notice of any appeal must (1) be in writing, (2) include grounds for the appeal, (3) be directed by registered mail or personally delivered to the Chair, Environmental Appeal Board, 4th Floor, 747 Fort Street, Victoria BC V8W 9V1, (4) be delivered within 30 days from the date notice of the decision is given, and (5) be accompanied by a fee of $25.00, payable to the Minister of Finance and Corporate Relations.

If you have any questions or concerns please contact the Portfolio Administrator, Water Stewardship Division, at 604-582-5200.

Yours truly,

Julia Berardinucci

Julia Berardinucci
Regional Water Manager

Enclosure

pc: Water Revenue, Ministry of Environment, Victoria

06/01JUN 01 '94 04:55PM Q C POWER CORP P.2

WATER MANAGEMENT DIVISION

MINISTRY OF ENVIRONMENT, LANDS AND PARKS

THE PROVINCE OF BRITISH COLUMBIA—WATER ACT

# CONDITIONAL WATER LICENCE

The owners of the land to which this licence is appurtenant are hereby authorized to divert and use water as follows:

(a) The stream on which the rights are granted is Mamquam River.

(b) The point of diversion is located as shown on the attached plan.

(c) The date from which this licence shall have precedence is May 26, 1994.

(d) The purpose for which this licence is issued is power (general).

(e) The maximum quantity of water which may be diverted is 23.45 cms (828.1 cfs) for use in a powerplant with an authorized capacity of 50 MW, subject to a water reserve established by Order in Council No. 0714 dated, May 25, 1994.

(f) The water may be used throughout the whole year.

(g) The land within which the water is to be diverted and to which this licence is appurtenant is the intake site situated on that parcel of land in the vicinity of Raffuse Creek held under Licence of Occupation No. 235520 on Lands file 2406037. The water is to be used for the power undertaking of the licensee.

(h) The works authorized to be constructed are diversion weir, intake structure, stream gauges, tunnel, powerhouse, tailrace, transmission works, access roads and bridge, which shall be located approximately as shown on the attached plan. Works shall be installed to measure and record the flow of water diverted under this licence and instream flow in the Mamquam River immediately below the point of diversion.

(i) The construction of the said works shall be completed and the water beneficially used prior to the 31st day of December, 1997. Thereafter, the licensee shall continue to make a regular beneficial use of water in the manner authorized herein.

(j) Design plans for the works authorized by this licence must be prepared by a professional engineer registered in British Columbia and submitted to the Comptroller of Water Rights.

(k) Construction of the works authorized shall not be commenced until leave is given in writing by the Comptroller of Water Rights.

(l) An interim Operation Plan must be submitted to and leave in writing received from the Comptroller of Water Rights for interim commissioning of the powerplant prior to start-up of power production.

(m) As-built drawings must be submitted to the Comptroller of Water Rights within one year of interim commissioning.

(n) Within two years of interim commissioning an Operation and Maintenance Plan must be submitted to and leave in writing received from the Comptroller of Water Rights prior to final commissioning of the powerplant.

J. E. Farrell
Deputy Comptroller of Water Rights

File No. 2000966 Date issued: May 26, 1994 Conditional Licence 102850

## Appendix E – 5 Year Environmental Monitoring Program

Included with Hard Copy due to length

**Appendix F – Ramping Parameters**

Table 23. Recommended ramping rates for the Lower Mamquam Hydroelectric Project (as per Lewis *et al.* 2011).

| MQM-DVLG01 Discharge ($m^3/s$) | Maximum recommended stage change rate (cm/hr) at MQM-DVLG01 during flow | MQM-DSLG01 Discharge ($m^3/s$) | Maximum recommended stage change rate (cm/hr) at MQM-DSLG01 during flow |
|---|---|---|---|
| ≤ 10 | -7.5 | ≤ 30 | -3.6 |
| > 10 to ≤ 24 | -19.9 | > 30 to ≤ 50 | -9.9 |
| > 24 | unrestricted | > 50 | unrestricted |

## Appendix G – Integrated Incident Management Plan

# Integrated Incident Management Plan
# Between
# Skookum Power Plant
# Upper Mamquam Hydro Facility
# Lower Mamquam Hydro Facility

**August 12, 2014**

## Introduction:

The report describes the communication protocol and procedures between the three hydro electric generating facilities that operate in the Mamquam River watershed. These being, in order of flow, the Skookum Creek Plant (Skookum), the Upper Mamquam hydro facility (Upper Mamquam) and the Lower Mamquam hydro facility (Lower Mamquam).

Skookum, owned by SCPP Holdings Inc. is a 25 MW run-of-the-river hydropower project with a design flow of 9.9 m3/s. Upper Mamquam, owned by Transalta, is a 49 MW powerplant with a 27 m3/s design flow. Lower Mamquam, owned by Atlantic Power Corp., is a 60 MW powerplant with a 30 m3/s design flow.

The Skookum has the potential to impact both Upper Mamquam and Lower Mamquam operations and consequently related sensitive downstream fish habitat for both of these facilities. Upper Mamquam has the potential to impact Lower Mamquam and consequently related sensitive downstream fish habitat for this facility.

## Overview

1. Skookum Creek flows into the Mamquam River at approximately the "9-Mile bridge" on the Mamquam Forest Service Road (FSR).
2. Plant shutdown scenarios that have the potential to impact downstream facilities include an emergency unit or full plant shutdown (ESD) in which ramping protocol are not followed.
3. Mitigation measures pertaining to the Operations of the facilities have been incorporated into the design and reduce the potential magnitude and probability of an ESD (Unit ESD more likely than a Full Plant ESD).
4. The communication and emergency response protocol between the three facilities has been implemented to further reduce the potential effects of an ESD and forms the core of this document.
5. The impacts to fish that may be experienced in downstream habitats include the possibility of temporary stranding of fish to mortality due to dewatering. The impacts are dependent on time of year of the event, habitat, species present, magnitude and duration of the event. The highest likelihood of impacts resulting from an ESD is during the late summer. The greatest potential impacts are to fry followed by parr. Impacts to eggs in gravel and adult salmon are considered low.
6. During the commissioning of Skookum an increased potential for an emergency shutdown exists that could impact Mamquam and Lower Mamquam.

# Shutdown Scenarios

The probability of a cascading emergency shutdown scenario is extremely low with only a serious earthquake scenario being a plausible cause. The reason for this is that both facilities on the Mamquam are equipped with turbine bypass valves that permit the controlled release of water during shutdown of the facilities, even under low water conditions that have a low probability of being induced by an emergency shutdown at the Skookum facility. In addition, none of the facilities share transmission line infrastructure prior to interconnecting with the BC Hydro electrical grid. Even in the extremely unlikely case of a load rejection from BC Hydro or transmission line trip to all three facilities would result in all of the facilities shutting down in a controlled fashion.

Please note that instream flow requirements (IFR) are maintained through Skookum Creek and each of the downstream diversion reaches under all operating scenarios described below.

**1. Normal Operation**

Normal operation for a run-of-river hydroelectric facility is defined as generation at a facility based on available flows in excess of instream flow requirements and not more than the stipulated maximum diversion rates.

**2. Controlled Shutdowns**

A controlled shutdown of any of the facilities is initiated for scheduled maintenance, during most plant trips, errors and malfunctions. Potential events that could lead to a controlled shutdown of a unit or entire plant include a transmission line outage, load rejection, equipment malfunction, sensor error, minor equipment failure or operator error.

In the event of a controlled shutdown, flow to the units is redirected away from the turbine to allow immediate de-energization of the generator without cessation of flow to the tailrace and downstream reaches. Flow from the tailrace is gradually reduced at predetermined increments such that licensed ramping rates are maintained downstream and through the diversion reaches.

Any impact to downstream facilities is expected to be of short duration and allow them to continue to operate within the terms of their water licenses so long as their respective controls systems do magnify and operational anomaly. .

**3. Skookum Unit Emergency Shutdowns**

A unit emergency shutdown at Skookum is initiated by an equipment failure/malfunction, sensor error from a critical operating element or critical operator error on one of the two turbine-generator units. There are a limited number of elements that force an emergency unit trip. These include the following:

- A serious plant electrical or control system malfunction
- Activation of the emergency stop button
- Catastrophic failure of a generating unit and failure of the deflectors to engage

During a unit emergency trip a single unit is affected and shut down using emergency measures (i.e. fast nozzle closure or TIV closure) which halts flow through the unit in approximately 2-5 minutes. This will

alter the downstream flow by the amount previously being used by the shutdown unit.
The loss of flow from one unit will reduce flow by up to 4.95 $m^3/s$ in Skookum Creek immediately below the powerhouse until the flows from the intake catch up. This flow reduction will persist until flows from the intake have reached the powerhouse which is expected to take 60 – 80 minutes depending on flow conditions.

**4. Skookum Full Plant Emergency Shutdowns**

An emergency shutdown that influences the entire plant is initiated by an event that places significant risk to the facility, its occupants or the environment. For example a penstock rupture or major electrical failure of components common to both units may initiate this. As with a unit shutdown, a full plant shutdown can also be caused by equipment failure/malfunction, sensor error from a critical operating element or operator error. In the event of an emergency shutdown flow from the facility is ceased in approximately 2-5 minutes.
During a plant wide emergency shutdown a flow reduction of up to 9.9 $m^3/s$ will occur in Skookum Creek immediately downstream of the powerhouse. This flow reduction will persist until flows from the intake have reached the powerhouse which is expected to take 60 – 80 minutes depending on flow conditions.

**5. Earthquake**

An earthquake event would probably trip the units offline under a controlled shutdown but may induce an emergency shutdown of the facilities depending on the magnitude of the event. The seismic event used for the design of the Project has a 2% probability of exceedance in 50 years (equivalent to a typical return period interval of 1 in 2,475 years). Damage to the facility also could occur during a lesser event. Due to the widespread influence of an earthquake on infrastructure this is likely a scenario in which all facilities will be tripped offline by their internal protection and control systems or due to interruptions in BC Hydro's transmission system. It is anticipated that an event of this magnitude would also trigger natural events that would have significant impacts on the both Skookum Creek and the Mamquam river.

**Mitigation Measures**

**SKOOKUM MITIGATION MEASURES**

There are several design features that have been incorporated into the Project to reduce the potential for an ESD and particularly a full plant ESD.
Pelton units – Deflectors at the end of each nozzle have the ability to redirect water away from the turbine to allow immediate de-energization of the generator without cessation of flow to the tailrace and downstream reach. The nozzles are then gradually closed such that flow from the tailrace is gradually reduced at predetermined increments such that licensed ramping rates are maintained downstream and through the diversion reaches.
Two turbines – Using two turbines allows flows to be transferred from one to the other in the event of a single unit failure. In the case of Skookum having two units limits the maximum flow reduction caused by a single unit failure to half of the full design flow as a worst case scenario. Both downstream facilities also operate with multiple units.
Independent TIV/HPU – Having independent turbine inlet valves (TIV) and hydraulic power units (HPU) reduce the potential impact of an ESD associated with equipment failures or sensor malfunctions by limiting the flow reduction to a single unit.

Independent transmission line – An independent transmission line following an alternate alignment alleviates the potential for a multi-facility trip caused by localized line faults or load rejections.

**UPPER MAMQUAM AND LOWER MAMQUAM MITIGATION MEASURES**

The downstream facilities also have attributes that could be used to mitigate the downstream propagation of a Project ESD that are still to be explored as part of the Operating Protocol agreement and acceptance by the respective Agencies because they may cause short term violation of ramping and other permitted operating criteria.

Headpond – Both downstream facilities have headponds that can be drawn down to allow them some time to ramp down plant operations in a controlled manner and buffer potential impacts from incoming flow changes. A rough approximation using measurements taken from orthophoto images and allowing for sedimentation of the upstream headpond / river interface suggests the upper facility has about 6,000 $m^3$ of active storage (approximate headpond dimensions: 150m x 40 m x 1m) while the lower facility has about 8,500 $m^3$ (approximate headpond dimensions: 65 m x 70 m x 1 m + 130 m x 30 m x 1 m).

In the event of an ESD at Skookum, a coordinated response from the downstream facilities that utilized this stored volume could largely mitigate the impact of an ESD originating at Skookum. The details around this plan will be developed as the dynamics of the river system are better understood with some real time historical operating data.

Bypass Valves – Downstream plants are equipped with bypass valves that redirect water away from the turbine to allow de-energization of the generator without cessation of flow to the downstream reach. The bypass valves are then gradually closed such that flow from the tailrace is gradually reduced at predetermined increments such that licensed ramping rates are maintained.

# Potential Impacts to habitats downstream of Skookum Creek

**Eggs and Alevin in Gravel:**

There is potential for eggs to be in gravel throughout the year. The hydrologic modeling exercise found that there were no instances where an ESD at the Skookum project would result in a reduction of flows below the IFR of either of the Mamquam sites. Since the range of flows in the diversion reaches is within the range which may be experienced under normal plant operations, there is likely limited additional risk to eggs or alevin in gravel due to an ESD event.

Downstream of the tailraces, during events which cause a shutdown of either of the downstream plants, the potential for dewatering of redds will depend on the depth of the water over the redd, the egg burial depth in the redd and the magnitude of the flow reduction.

For the salmonid species which may be present below the Lower Mamquam project tailrace, the water depths over the redd at time of spawning range from 15 cm to >24 cm (Bjornn and Reiser 1991). Most salmonids bury their eggs in gravel, typically 10 to 15 cm below the surface of the streambed for the top of the egg pocket and 25-50 cm below the surface of the streambed for the bottom of the egg pocket (DeVries 1997). Therefore stage changes would likely need to be in excess of 25 cm to cause dewatering of eggs in gravel, however this will vary depending on river stage, location and depth of the redd. Larger fish, such as Chinook, are more likely to utilize deeper and faster water for spawning than resident species (Beamish 1978) and thus may be less susceptible to dewatering of redds. Becker et al. (1986) found that eggs which were dewatered for 12 days had a 97% survival rate. This is attributed to the eggs ability to acquire oxygen via diffusion. Given the expected short duration of any dewatering which may result from a plant shutdown, mortality of eggs in gravel is unlikely.

Mortality rates of in-gravel eleutheroembryos or alevins are much higher than eggs due to their need for flowing water to provide their oxygen. Becker et al. (1986) found that eleutheroembryos had a 43% survival rate after 6 hour of dewatring and alevins had a 36% survival rate after 2 hours of dewatering. The potential for dewatering of alevins may be somewhat lessened by the downward movement of alevins through the substrate after hatching (Bams 1969; Dill 1969; Fast et al. 1981, Godin 1981). This may not occur until up to half way through their inter-gravel life history (Groot and Margolis 1991). Should an event occur from early February through late September after hatching, if inter-gravel alevins are dewatered for the expected period of an emergency plant shutdown some mortality would be expected.

**Fry:**

Fry emergence from eggs in the downstream reach spans a considerable range given the numerous species that may spawn in the lower Mamquam River. Juvenile salmonids often take cover in the interstitial spaces between gravel and cobbles on the bed of the stream (Chapman 1966) and are known to occupy habitat with low velocities and depths during the early stages of their life. These areas are often found in stream margins and side channels. This increases the potential for impacts to young of the year fry from a large stage change in excess of permitted ramping rates or a full plant shutdown. Potential impacts to fry are greatest for resident species and salmon with longer stream rearing phases of their life histories including chinook and coho. Pink salmon, which outmigrate to Howe Sound upon emergence and chum which outmigrate within several days to weeks have a lower probability of being present during an ESD event. A dewatering event may result in the stranding of fry, which have lower swimming capabilities than latter life stages. Should the stranding occur in isolated pools of water, which persist until the lag time passes through the diversion reach and regular flow are restored (maximum estimated 142 minutes below the lower tailrace), survival is likely however there would be the increased potential for predation during that time. The pools must be of sufficient size to prevent excessive warming and oxygen deprivation of fry during the stranding. Mortality would be expected for dewatered fry.

#### Parr

Salmon, trout and char parr may occupy margin habitat susceptible to dewatering effects. Their presence in these habitats is more likely during the overnight period when they move into these habitats to feed (Needham and Jones 1959). They are also more likely to occupy these habitats in the summer growing season than in the winter (Bustard and Narver 1975, Cunjak 1996). Due to their improved swimming capabilities, parr will also have a higher potential to respond to dewatering events by moving away from margins as they are dewatering. As with fry, should an emergency shutdown result in stranding of parr in isolated pools, they may survive in isolated pools of sufficient size. The potential for mortality exists for fish which are not able to avoid stranding by moving into habitats which remain wetted.

#### Adult Salmon

Due to their high mobility and preference for deeper water habitats, adult salmon are less likely than other life stages, to be subject to stranding due to emergency shutdowns. Should dewatering occur while they are in shallow water habitats such as margins, they will likely react by moving to deeper water habitats. Studies have shown that if spawning salmon have to abandon an active redd site due to dewatering, they may attempt to return the site after the water levels recover (Smith 2010).

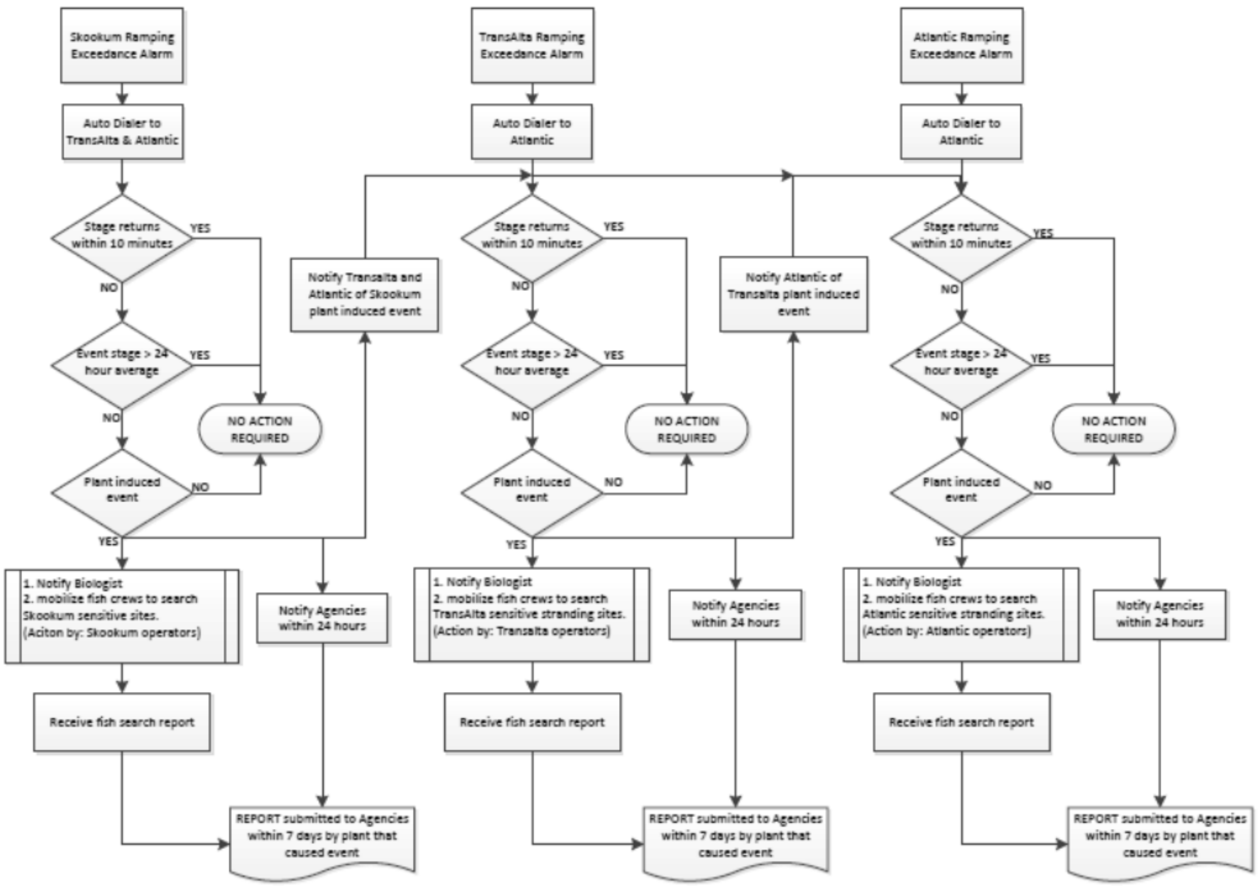
#### Downstream Impacts

The downstream extent below the Lower Mamquam tailrace which a ramping event and cessation to tailrace flows may be experienced is expected to be mitigated with distance downstream due to tributary inputs and dispersal of flows. The Mamquam and Blind channel habitat channels are not predicted to be subject to impacts due to their distance downstream and expected lack of hydrologic connectivity.

# Ramping and Emergency Event Protocol

The following flow diagram outlines the protocol that will be followed by the facilities in the event of a river incident that is caused naturally or is plant induced at any of the facilities. Contact names and numbers are provided in the section following the flow chart.

Integrated Incident Management Plan Flow Chart



# Communication Contact Information

| SKOOKUM | | |
|---|---|---|
| Skookum Power Plant (Skookum Creek Power Partnership) | Plant Operators (on site) - Spearhead Operating Services Ltd<br>Steve McKay<br><br>Cliff Bell<br><br>Patrick (Pat) Skinner | Plant:<br>Cell:s.22<br>s.22<br>Plant:<br>Cell:s.22<br>s.22<br>Plant:<br>s.22 |
| | Plant Operations Manager – Lucas Paczek | Office: 604-940-0402<br>Cell s.22<br>lpaczek@runofriverpower.com |
| **UPPER MAMQUAM** | | |
| | | |
| Upper Mamquam Hydropower Facility (TransAlta Corp) | Plant Operator – Salvadore (Sal) Luengo | Cell:s.22<br>Power Plant: 604-898-8297 |
| | Environment - Glenn Isaac | 403-267-7273<br>Glenn_Isaac@transalta.com |
| | Plant Manager – Norris McLean | Office: 250 837 8754<br>Norris_mclean@transalta.com |
| **LOWER MAMQUAM** | | |
| Mamquam Power Plant – (Atlantic Power Corporation) | Plant Manager<br>Scott Ronaldson | Cell: s.22<br>Power Plant: 604-898-2761<br>sronaldson@atlanticpower.com |
| Plant Administrator | ller | Power Plant: 604-898-2761<br>tmacdonald@atlanticpower.com |
| Plant Operators | David Carlin<br><br>David Griffrioen<br><br>Wayne Moffatt | Office: 604 898 2761<br>Cell: s.22<br>Office: 604-898-2761<br>Cell: s.22<br>Office: 604 898 2761<br>Cell: s.22 |

## BIOLOGISTS

| | | |
|---|---|---|
| Ecofish | Ian Murphy | Phone:<br>Office: 778-346-3933<br>Office 2: 250-334-3042<br>Cell:s.22<br>Email: imurphy@ecofsihresearch.com |
| EDI Environmental Dynamics Inc. | Ian Redden | Phone: (250) 751-9070<br>Cell:s.22<br>Email: iredden@edynamics.com |

## PROVINCIAL AND FEDERAL AGENCIES

| | | |
|---|---|---|
| FLNRO Regional Water Manager<br>Regional Hydrologist<br>Regional Water Manager | James (Jim) Davies, Engineer Under the Water Act | Phone: (604) 586-5637<br>Fax: (604) 582-5235<br>email: James.Davies@gov.bc.ca |
| FLNRO Regional Dam Safety Officer | Mike Bristol | (604)586-5637 |
| Fisheries and Oceans Canada<br>Pacific Region HQ | | Phone: (604) 666-0384<br>Fax: (604) 666-1847<br>Phone: (604) 666-3491 (Habitat Branch) |
| Fisheries Protection Program<br>Fisheries and Oceans Canada | Murray Manson, MSc., R.P. Bio.<br>Fisheries Protection Program | Phone: (604) 666-0129<br>Email : murray.manson@dfo-mpo.gc.ca |
| | Don Knoop<br>(Compliance Occurrences) | Phone: (604) 666-0282<br>Email: don.knoop@dfo-mpo.gc.ca |
| Coast Forest Region<br>Squamish Forest District | | Phone: (604) 898-2100<br>email:<br>forests.squamishdistrictoffice@gov.bc.ca |
| Canadian Wildlife Service<br>Pacific Wildlife Research Centre | | Phone: (604) 940-4700<br>Fax: (604) 946-7022<br>Phone: (604) 940-4600<br><br>http://cwfis.cfs.nrcan.gc.ca/en/index_e.php |
| Severe Weather<br>Pacific Region | | Phone: 1-800-66STORM<br>1-800-667-8676 |

| | | |
|---|---|---|
| | | www.weatheroffice.ec.gc.ca/warnings/<br>warnings_e.html |
| Transport Canada<br>Navigable Waters<br>Protection Program<br>Regional Manager<br>Pacific Regional Office | | Phone: (604) 775-8867 |
| Ministry of Forests, Lands<br>and Natural Resource<br>Operations<br>Conservation Officer | | Phone: (604) 740-5858 |
| Water Allocation | Aman Ullah<br>Water Power Engineer | Phone: (604) 586-5636<br>Fax: (604) 586-4444<br>email: Aman.Ullah@gov.bc.ca |
| Report a Wildfire | | Phone: 1-800-663-5555 or<br>*5555 from cellular phone |
| Wildfire Information | | Phone: 1-888-3FOREST or<br>1-888-336-7378<br>http://bcwildfire.ca/ |
| Archaeology Branch | | Phone: (250) 953-3338<br>Fax: (250) 953-3340<br>Email: ARCWEBFEEDBACK@gov.bc.ca |

# SIGNATURES

This report was reviewed and approved by the undersigned:

Skookum Power Plant Signatory

Upper Mamquam Hydropower Facility Signatory

Mamquam Power Plant Signatory

# Appendix H - Operation Maintenance and Surveillance Plan

**OPERATION, MAINTENANCE & SURVEILLANCE PLAN**

| Dam Name | *Lower Mamquam* |
|---|---|
| Water License No.: | *102850* |
| Owner's Name | *Atlantic Power Preferred Equity Ltd*<br>Phone: *604 898-2761* |
| Stream Name: | *Mamquam River* |
| Reservoir Name: | *Run of River* |
| Dam Location: | *GPS Co-ordinates North 49 43 296, West 123 05 025*<br>*Latitude: N50358.000 Longitude: E53320.000* |

**LIST OF RESPONSIBLE INDIVIDUALS**

| | Name | Title | Phone | Mobile |
|---|---|---|---|---|
| **Operation** | *Scott Ronaldson* | Operations Manager | *604 898-2761* | s.22 |
| **Maintenance** | *David Griffioen*<br>*Wayne Moffatt* | Plant Operator<br>Plant Operator | *604 898-2761* | |
| **Inspections** | *David Griffioen*<br>*Wayne Moffatt* | Plant Operator<br>Plant Operator | *604 898-2761* | |
| **Instrumentation** | *David Carlin* | Electrician/Operator | *604 898-2761* | |

**PHYSICAL DESCRIPTION**

Dam Height: *3.35m*

Dam Type: *Inflated Rubber Weir*

Length: *48.3m*

Crest Width: *Approx. 1.0m*

Reservoir Capacity: *6,375 cubic metres*

Reservoir Area: *4,800 square metres*

Spillway Capacity: *600 cubic metres/second*

Design Flood Inflow: *1:500 Year*

Watershed Area: *260 square kilometres*

Purpose of Dam: *Power Generation*

Consequence Classification: *MEDIUM*

**ACCESS TO DAM:** *(describe road access to dam from nearest center, attach map to this Plan)*

Access is from Highway 99 south of Squamish via Mamquam Forest Service Road, East on Mamquam Forest Service Road for 5.5 miles. Turn left at 5.5 Miles onto Intake access road (see attached map).

**LIST SIGNIFICANT STRUCTURES DOWNSTREAM OF DAM:** *(i.e. access road, railroad)*

- None

**LIST ALL HYDRAULIC WORKS***: (i.e., spillway, outlet, stop-logs, gates, valves etc. (include capacity, dimensions, locations etc.)*

- *Inflatable Weirs*
- *1 Radial Sluicegate*
- *1 Riparian Bypass Sluicegate*
- *1 Tunnel Adit*
- *1 Stop-log Set (performs isolation for tunnel, radial sluicegate and inflatable weirs)*
- *1 Intake Screen*
- *1 Sluiceway/Intake Channel*
- *1 Spillway*

**LIST PROCEDURES FOR RESERVOIR OPERATION***: (i.e., how is Reservoir level controlled? what is the anticipated reservoir level for any given time of year? when are the drawdown and filling periods? what are the operation procedures during floods?)*

The intake PLC maintains reservoir elevation at 297.0 metres (+ 0.20/-0.02). The inflatable weirs are inflated or deflated to maintain the reservoir level within that range, regardless of river flows.

There are no draw-down or filling periods as the reservoir level remains constant.
The PLC controls the two inflatable weirs and the radial sluicegate as required during flood events. If required, the weirs and radial sluicegate can be manually controlled.

**LIST ALL ITEMS REQUIRING ROUTINE MAINTENANCE***: (include type of maintenance to be performed, scheduling of maintenance, record keeping, etc.)*

| | |
|---|---|
| Back-up diesel generator | – inspected weekly, serviced annually or more often if required |
| Blowers | – inspected weekly, serviced annually |
| Trash-rack Cleaner | – inspected weekly, serviced annually |
| Radial Gate | – inspected weekly, full inspection annually, serviced every 3 years |
| UPS Batteries | – serviced quarterly, full service annually |
| Weirs | – inspected weekly, inspected semi-annually |
| Fire Detection Equipment | – serviced annually |
| Riparian Bypass | – inspected weekly, full inspection semi-annually |
| HVAC | – inspected weekly |
| MCC | – inspected every 2 years |

All weekly inspection items are recorded on Weekly Intake Inspection Forms.
Semi-annual inspections are recorded on the Dam Inspection Checklists.
Maintenance records are kept in the Preventative Maintenance Plan binder for the year during which the service work was performed.

**LIST ALL INSTRUMENTATION, FREQUENCY OF MONITORING, AND METHOD OF RECORD KEEPING:** *(i.e., seepage measurement weir, reservoir level gauge, piezometers, etc.)*

Headpond/Forebay level – continuously monitored
Upstream Sluiceway (before trash-rack) – continuously monitored
Downstream Sluiceway (after trash-rack) – continuously monitored
Trash-rack differential (Upstream-Downstream readings) – continuously monitored
Radial Sluicegate position – continuously monitored
Riparian Flow measurement – continuously monitored
Approximately 2 weeks of the most recent trending data is available at all times, before being overwritten.

**LIST OF EQUIPMENT TO BE PERIODICALLY TEST-OPERATED:** *(i.e., gates, valves, hoists, etc., include frequency of test operation)*

Radial Gate – tested during sluicing operations (minimum semi-annually)
Diesel generator – tested weekly
Communications systems – tested weekly

**LIST ALL COMPONENTS REQUIRING ROUTINE VISUAL INSPECTIONS:** *(include schedule) (e.g. weekly, monthly, quarterly, annually etc.)*

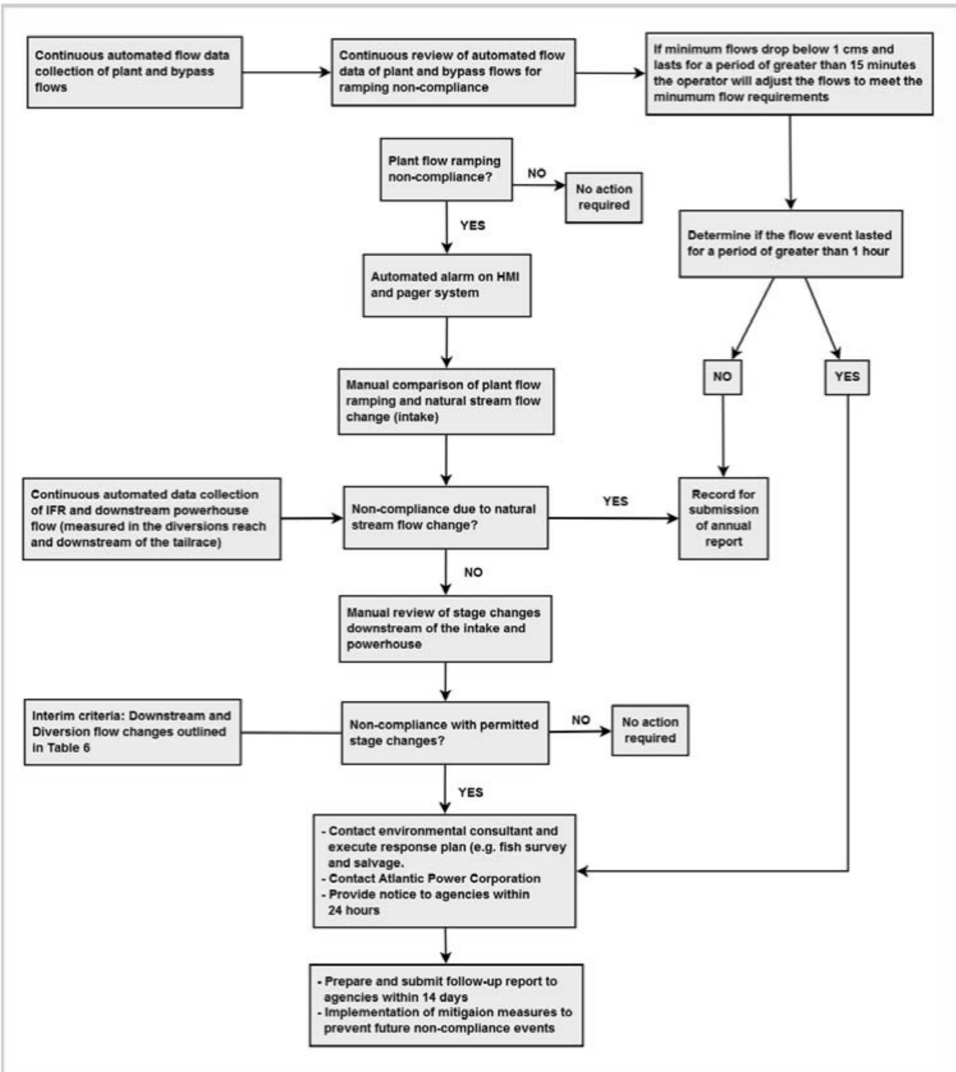
Weirs – inspected weekly
Radial Gate – inspected weekly
Spillways and structures – inspected semi-annually
Powerline – inspected annually

**ANNUAL FORMAL INSPECTIONS BY OWNER***: (include; time of year when performed, special items to be examined, reviewed, and/or test operated)*

The BC Dam Inspection Checklist is completed by a professional engineer. This is normally performed in the summer months when there are no access restrictions. Any deficiencies are closely monitored (eg. spillway erosion).

# ADDENDUMS

### ADDENDUM A – Ramping Rate Compliance Monitoring Flow Chart



# ADDENDUM B –Calculations of Ramping Rate Exceedances

**1. Determine if ramping rate criteria were exceeded (Rule 1, the exceedance rule):**

Ramping rates will be calculated for each data point in the time series as the maximum stage change in the preceding hour. If the difference between a data point and the maximum stage observed in the previous hour exceeds the Project's recommended ramping criterion (e.g., -2.5 cm), the ramping event is flagged. The two-minute average data from the hydrometric compliance point should be used to undertake the calculations, as follows:

a) Calculate the maximum stage observed over the past hour for each data point $i$ as:

$$hmax(t_i) = \max\big(h(t_{i-k}), \ldots, h(t_{i-1})\big)$$

where $h$ is stage, $k$ is the number of data points recorded per hour, and $t$ is time.

b) Calculate the maximum stage decrease over the past hour relative to time $t_i$, $\Delta hmax(t_i)$, as:

$$\Delta hmax(t_i) = h(t_i) - hmax(t_i)$$

c) Determine if the ramping criteria was exceeded (Rule 1, the exceedance rule):

$$if\ \Delta hmax(t_i) < -2.5,\ \ exceedance = 1, else\ exceedance = 0$$

**2. Determine if the habitat was dewatered (Rule 2, the dewatering rule):**

If the stage returns to within the ramping criterion (e.g., -2.5 cm) of the previous maximum stage within 10 minutes of the moment it was in exceedance of the criterion, the event is not flagged. Habitats will not instantly dewater following a significant decline in stage, and fish will survive when stranded for such a short period of time. The time to asphyxiation has been estimated to be 10 minutes considering both air exposure and the time needed for the substrate to drain. This is the dewatering rule (Rule 2) and is evaluated as follows:

a. Calculate the maximum value of $\Delta hmax$ over the next 10 minutes as:

$$max(\Delta hmax) = max\ (\Delta hmax(t_{i+1}), \Delta hmax\left(t_{i+\left(\frac{k}{6}\right)}\right))$$

b. Determine if this maximum value of $\Delta hmax$ is in compliance (e.g. ≥ -2.5 cm):

$$if\ (\max(\Delta hmax)) < -2.5, \qquad dewatering = 1, \qquad else\ dewatering = 0$$

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# MEMORANDUM

**TO:** Atlantic Power Corporation, Squamish, BC

**FROM:** Pamela Dinn, M.Sc., R.P.Bio, Ian Murphy, B.Sc., EP, and Adam Lewis, M.Sc., R.P.Bio., Ecofish Research Ltd.

**DATE:** June 27, 2017

**FILE:** 1071-04

**RE: Lower Mamquam Hydroelectric Project 2017 Freshet Sluicing: Water Quality Monitoring Program**

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