Chapter 7
Operation of Ramp Signals
A general level of information is provided in this chapter relating to the operation of freeway ramp signals and the HERO suite of control algorithms. Further detailed information is in the Freeway Ramp Signals: System Operations Handbook (Internal VicRoads document).

7.1. Legal Basis for Ramp Signals
Freeway ramp signals are traffic lights as defined in Road Safety Road Rules 2009. Rule No. 56 defines a driver’s responsibilities when approaching, or at, a red or yellow traffic light. Other rules define responsibilities relating to the stop line and other regulatory signs and pavement markings associated with freeway ramp signals.

A traffic signal is a Major Traffic Control Device as defined in Road Safety (Traffic Management) Regulations 2009. VicRoads must give approval to erect, establish, display, maintain or remove freeway ramp signals.

7.2. Control Algorithms used by VicRoads
The signal control algorithm used by VicRoads on freeways in Victoria is based on the HERO / ALINEA suite of ramp metering control algorithms. The original ALINEA control philosophy which provides local control at an individual freeway entry ramp was developed by Markos Papageorgiou, Technical University of Crete, Greece (Papageorgiou et al., 1991, 1997). HERO which incorporates an ALINEA module was subsequently developed for coordination of ramp signals at a number of ramps along a length of freeway.

In cooperation with Markos Papageorgiou and Associates, VicRoads has been involved in development and enhancements to the algorithms since an initial trial which demonstrated significant benefits (refer Appendix B).

The algorithms which are field tested with proven results have the following features:
- Dynamic start up and shut down algorithms that ensure the system only operates when required
- Consistency with contemporary traffic theory for optimising freeway flow
- The contemporary control logic is based on feedback from downstream conditions in real-time to dynamically adjust signal cycle times
- Use of occupancy from the downstream freeway bottleneck locations as the optimising measure
- Transparent in operation with fully configurable parameters
- Integrated operation of local ramp control within a coordinated system based on sound operating rationale
- Incorporation of modules for adjustments to entry flow rates based on consideration of ramp queues, and arterial road queues in some cases, as well as ramp delays
- Potential to manage flow at freeway to freeway interchanges by linking upstream ramps on separate freeways
- Ability to manage bottlenecks many kilometres (3 to 4 km) downstream from the nearest ramp
- Potential for consideration of multiple bottlenecks to determine the critical bottleneck.

A summary of the operation of HERO suite of algorithms is outlined in Section 7.6.

Note:
The adoption of a most efficient control algorithm is of paramount importance for a successful ramp metering system. Designing and installing the necessary entry ramp layouts and equipment is necessary and important, but not a sufficient condition for successful operations unless controlled effectively.
7.3. Times of Operation
Freeway ramp signals operating at an isolated ramp or within a coordinated system may be activated in a number of ways.

7.3.1. Dynamic Activation and Deactivation
The dynamic switch-on and switch-off of ramp signals is based on the prevailing freeway traffic conditions. A dynamic system provides traffic responsive operation that activates the metering signals at any time when warranted by freeway traffic flow conditions that could lead to the onset of flow breakdown. The activation and deactivation thresholds are set for each ramp / bottleneck during the manual fine tuning of the system.

The switch-on criteria are based on a combination of speed, occupancy and/or volume. Different criteria are used for starting up and switching off the signals. The switching on criteria are usually set at a relatively low threshold to be sure that the signals start up before the freeway flow collapses. The criteria need to be comprehensive to avoid the signals switching on at an inappropriate time, e.g., high occupancy and low speeds may occur at night due to a slow moving maintenance vehicle.

Usually, stronger criteria are used for switching off the signals to ensure the signals will not start up again soon after the deactivation.

7.3.2. Time of Day Activation
Time of day activation may be used according to critical periods, generally morning and evening weekday peak periods. Scheduled start-up and close-down times are chosen following an analysis of freeway and entry ramp flows during the peak periods and their respective shoulder periods. Typical times of operation would be 6:00am to 10:00am for the AM peak period and between 3:00pm and 7:00pm for the PM peak period. Other times may also be scheduled to cover known occasions outside weekday peak periods where data shows that the freeway service is at risk, e.g., Saturday shopping periods or special events.

Time of day settings may also control the times within which dynamic activation and deactivation may occur. Under this operation the signals may or may not switch on, depending on whether the criteria are met. This form of control for activation is advisable during the initial operation of a new coordinated system and when testing criteria for full dynamic activation.

7.3.3. During Incidents and Events
During periods of light traffic flow on the freeway (when the metering signals would normally be off), there may be advantages in using the signals to manage the headway of entering traffic or to manage the freeway flow. This may be necessary at times of a lane closure or traffic flow breakdown due to planned or unplanned incidents, e.g., roadworks, crashes etc., to assist in traffic management and/or to facilitate service recovery (refer Section 3.7).

7.3.4. Manual Operation
Manual operation or over-ride by an operator is available as required, eg. to be activated to clear queues for access in an emergency.

7.4. Switching on /off Signs and Signals
7.4.1. Start-up Sequence
The sequence for switching on the ramp signals and associated ramp control and warning signs is shown in Figure 7.1 and described below. Prior to start up the signals and RC1 and RC2 signs have no display.
1. Switch Sign RC1 and Sign RC2 to ‘RAMP SIGNALS ON’ and activate the signals to ‘flashing yellow’ for 10 seconds. Activate the variable speed limit (if applicable).
2. Switch on the alternating messages on Sign RC2, if provided, and switch traffic signals to ‘solid yellow’ for 4 seconds.
3. Switch traffic signals to ‘solid red’ for 6 seconds.
4. Commence the metering cycle with the initial green and continue the metering.
### Start-Up Sequence

<table>
<thead>
<tr>
<th>Time</th>
<th>Sign RC1: Variable Ramp Control Sign</th>
<th>Sign RC2: Variable Signals Warning Sign (with Static Sign)</th>
<th>Signals: Standard 3-aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior to ‘Start Up’ Signs and Signals are off</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘Start up’ Period (10 seconds)</td>
<td>RAMP SIGNALS ON</td>
<td>RAMP SIGNALS ON</td>
<td>Flashing Yellow</td>
</tr>
<tr>
<td>Activate the variable speed limit (if applicable)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘Start up’ Period (next 4 seconds)</td>
<td>RAMP SIGNALS ON</td>
<td>RAMP SIGNALS ON PREPARE TO STOP</td>
<td>Alternating messages</td>
</tr>
<tr>
<td>‘Start up’ Period (next 6 seconds)</td>
<td>RAMP SIGNALS ON</td>
<td>RAMP SIGNALS ON PREPARE TO STOP</td>
<td>Solid Yellow (4 sec)</td>
</tr>
<tr>
<td>Signals commence metering of traffic</td>
<td>RAMP SIGNALS ON</td>
<td>RAMP SIGNALS ON PREPARE TO STOP</td>
<td>Alternating messages</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Solid Red (6 sec)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Figure 7.1: Start-up Control Sequence*
### 7.4.2. Close-down Sequence

The sequence for switching off the signals is shown in Figure 7.2 and described below.

1. Activate traffic signals to ‘flashing yellow’ and switch Sign RC2, if provided, to ‘Ramp Signals ON’ only (no alternating message) for 10 seconds.

2. Switch off Sign RC1, Sign RC2, the ‘flashing yellow’ of the signals and the variable speed limit (if applicable).

| Close-Down Sequence |
|---------------------|-----------------|-----------------|-----------------|
| **Time**            | **Sign RC1**    | **Sign RC2**    | **Signals**     |
|                     | Variable Ramp Control Sign | Combined Static Sign & Variable Ramp Control Sign | Standard 3-aspect |
| Prior to ‘Close Down’ (Signal metering traffic) | ![RAMP SIGNALS ON](image) | ![RAMP SIGNALS ON](image) | ![Green–Yellow–Red](image) |
| ‘Close Down’ Commences (10 seconds) | ![RAMP SIGNALS ON](image) | ![RAMP SIGNALS ON](image) | ![Flashing Yellow](image) |
| Switch off all devices ‘Close Down’ complete | ![RAMP SIGNALS ON](image) | ![RAMP SIGNALS ON](image) | ![RAMP SIGNALS ON](image) |

*Figure 7.2: Close-down Control Sequence*
7.5. Operating Sequence and Cycle Times

7.5.1. Signal Timings

Ramp metering operation has a variable cycle time generally in the range 4.0 to 20 seconds according to the determined metering rate. The sequence times based on one vehicle per green per lane are:

- **Red**: Variable – generally within the range 2.0 to 18 seconds
- **Green**: 1.3 seconds
- **Yellow**: 0.7 seconds

**Notes:**

1. When no vehicles are waiting at the stop line the signals are held on red. This prevents the signals cycling when there are no waiting vehicles and helps to avoid driver confusion in relation to timing their arrival and deciding whether to stop or not.

2. The operation of 2 or 3 vehicles per green per lane has not been trialled successfully in Australia, although used internationally (refer Note in Section 6.3.3). Generally, it is preferable to release a single vehicle per green per lane, even if shorter cycle times need to be adopted.

The entry ramp flows that result from a range of cycle times with varying lane arrangements at the stop line are shown in Table 7.1. In practice, within a dynamic system the cycle time is based on the ability of the freeway to accommodate inflow traffic. The signals apply to all lanes at the stop line.

Time of day signal cycles are used as a ‘fall back’ mode when a dynamic system experiences a fault and fail safe mode is activated.

7.5.2. Minimum Cycle Time

The general minimum cycle time that provides a high entry ramp flow is 5 seconds for a ramp leading to a freeway merge. A general minimum cycle time of 4 seconds could be considered when ramp traffic enters the freeway via an added lane(s) – shaded yellow in Table 7.1. The minimum cycle time would generally operate under light mainline conditions, e.g., during the fringe of the peak periods or where the upstream mainline freeway flow is interrupted due to an unplanned incident. However, the low values are not appropriate in design as an average value over the design hour (refer Section 6.3.3).

Cycle times lower than the minimum indicated are not generally recommended as this could approach a situation where the discharge of vehicles is almost continuous and the metering is relatively ineffective in managing headway. However, lower cycle times may be appropriate subject to trial and assessment of driver behaviour.

7.5.3. Maximum Cycle Time

The general maximum cycle time that provides a low entry ramp flow is 16 seconds and would be implemented when freeway mainline flow is close to or above critical values of occupancy.

Higher cycle times, shaded pink in Table 7.1, may be implemented subject to adopted operational management strategies and driver acceptance, in situations of very heavy freeway congestion, during an incident or when the freeway is recovering from an incident (refer Sections 3.7 and 7.7).
Table 7.1: Equivalent Hourly Ramp Flows relative to Cycle Time and Lanes at the Stop Line

<table>
<thead>
<tr>
<th>Cycle Time (sec)</th>
<th>Cycles per hour (No.)</th>
<th>Equivalent Ramp Flow per hour (veh/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>4.0</td>
<td>900.0</td>
<td>900</td>
</tr>
<tr>
<td>4.5</td>
<td>800.0</td>
<td>800</td>
</tr>
<tr>
<td>5.0</td>
<td>720.0</td>
<td>720</td>
</tr>
<tr>
<td>5.5</td>
<td>654.5</td>
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</tr>
<tr>
<td>6.0</td>
<td>600.0</td>
<td>600</td>
</tr>
<tr>
<td>6.5</td>
<td>553.8</td>
<td>554</td>
</tr>
<tr>
<td>7.0</td>
<td>514.3</td>
<td>514</td>
</tr>
<tr>
<td>7.5</td>
<td>480.0</td>
<td>480</td>
</tr>
<tr>
<td>8.0</td>
<td>450.0</td>
<td>450</td>
</tr>
<tr>
<td>8.5</td>
<td>423.5</td>
<td>424</td>
</tr>
<tr>
<td>9.0</td>
<td>400.0</td>
<td>400</td>
</tr>
<tr>
<td>9.5</td>
<td>378.9</td>
<td>379</td>
</tr>
<tr>
<td>10.0</td>
<td>360.0</td>
<td>360</td>
</tr>
<tr>
<td>10.5</td>
<td>342.9</td>
<td>343</td>
</tr>
<tr>
<td>11.0</td>
<td>327.3</td>
<td>327</td>
</tr>
<tr>
<td>11.5</td>
<td>313.0</td>
<td>313</td>
</tr>
<tr>
<td>12.0</td>
<td>300.0</td>
<td>300</td>
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<tr>
<td>12.5</td>
<td>288.0</td>
<td>288</td>
</tr>
<tr>
<td>13.0</td>
<td>276.9</td>
<td>277</td>
</tr>
<tr>
<td>13.5</td>
<td>266.7</td>
<td>267</td>
</tr>
<tr>
<td>14.0</td>
<td>257.1</td>
<td>257</td>
</tr>
<tr>
<td>14.5</td>
<td>248.3</td>
<td>248</td>
</tr>
<tr>
<td>15.0</td>
<td>240.0</td>
<td>240</td>
</tr>
<tr>
<td>15.5</td>
<td>232.3</td>
<td>232</td>
</tr>
<tr>
<td>16.0</td>
<td>225.0</td>
<td>225</td>
</tr>
<tr>
<td>16.5</td>
<td>218.2</td>
<td>218</td>
</tr>
<tr>
<td>17.0</td>
<td>211.8</td>
<td>212</td>
</tr>
<tr>
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<td>205.7</td>
<td>206</td>
</tr>
<tr>
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<td>200.0</td>
<td>200</td>
</tr>
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<td>194.6</td>
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</tr>
<tr>
<td>19.5</td>
<td>184.6</td>
<td>185</td>
</tr>
<tr>
<td>20.0</td>
<td>180.0</td>
<td>180</td>
</tr>
</tbody>
</table>

Note:
Providing separate alternating green signals for each lane to separate the departure of vehicles from the stop line is not endorsed for use at this stage. Although this practice has been used in some instances overseas, evidence is lacking on what is to be gained. Observations of current operation with the simultaneous release of vehicles from the stop line indicates that motorists are able to adjust their position relative to other vehicles leaving the stop line and that separation and merging when entering the mainline is also satisfactory.
7.6. HERO Ramp Metering Operation

7.6.1. Overview

The HERO suite of algorithms used for dynamic coordinated ramp metering control on freeways in Victoria is based on control philosophy developed by Markos Papageorgiou’s group, Technical University of Crete, Greece. The ramp metering operation has two parts:

- ALINEA algorithm and other related kernel algorithms to provide local control at an individual freeway entry ramp, and
- HERO to provide coordination between entry ramps along a length of freeway.

The algorithms use real-time measurements to dynamically adjust signal cycle times based on feedback from downstream freeway bottleneck locations as well as data from ramps. The algorithms are consistent with contemporary traffic theory for optimising freeway flow and are transparent in operation with fully configurable parameters to suit the geometry and traffic conditions on the freeway and at each ramp.

The mainline bottleneck is typically at the merge of an entry ramp but may also be a result of other downstream geometric factors such as merging at a lane drop, a steep upgrade, a tight radius curve, reduced lane widths or areas with high weaving or lane changing movements, e.g., just upstream of a lane gain or high flow exit ramp.

Occupancy at the mainline bottleneck is the principal measure used to manage traffic flow on the freeway to optimise throughput and prevent flow breakdown, i.e., congested flow. As average lane occupancy on the mainline approaches a value that may be unstable, ramp entry flow is controlled to regulate the mainline occupancy at an optimum value. Accurate and reliable data from detectors is essential.

7.6.2. HERO Operation

The HERO suite of algorithms manage the ramp traffic flow entering the freeway by monitoring and controlling the freeway flow at the ramp merge or other downstream bottleneck. Ramp exit flow calculations are based on modules providing outputs for local and coordinated operation as shown in Figure 7.3.

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**Local Ramp Control**

- Data processing
- Fail safe checks
- Activation / deactivation
- ALINEA operation
- Critical occupancy estimation
- Queue estimation
- Queue control
- Queue override
- Ramp delay (waiting time)

**Ramp Coordination**

- Hero operation
- Minimum queue control

**Ramp Entry Flow Implementation**

- Assessment of module outputs
- Consideration of ramp waiting times
- Cycle time implementation

![Figure 7.3: HERO Coordinated Ramp Control](image-url)
The algorithm uses flow, speed and occupancy data in various modules that include:

7.6.2.1. Activation / Deactivation
This module switches the freeway ramp signals on according to preset traffic flow, occupancy and speed thresholds at the mainline bottleneck location downstream of the ramp. The ramp signals are switched off according to preset occupancy and speed thresholds. Activation and deactivation is independently controlled at each ramp within a coordinated system. The thresholds are set with the intention of turning on the signal control before the onset of flow breakdown and turning the metering signals off when traffic flow conditions indicate that flow breakdown is unlikely.

7.6.2.2. ALINEA Core Module
This module calculates the desired ramp flow at each entry ramp for local maximisation of mainstream throughput according to the ALINEA feedback control algorithm. The calculation uses the average mainstream occupancy measurement downstream of the merge (or other downstream bottleneck) relative to a targeted critical occupancy value. The targeted critical occupancy at the mainline bottleneck is either set for each ramp by the user or it is dynamically calculated by the critical occupancy estimation module.

7.6.2.3. Critical Occupancy Estimation Module
This module calculates the critical occupancy at the downstream bottleneck. Where this module is activated the calculated value is used in the ALINEA core module as the targeted critical occupancy value. The adjustment of the critical occupancy value considers the flow / occupancy relationship that optimises capacity and prevents flow breakdown (refer Figure 3.5), as well as the path of flow recovery if flow breakdown has occurred (refer Section 2.3.3).

7.6.2.4. Queue Estimation Module
For each controlled entry ramp, this module uses the flow measurements of the ramp entrance detectors and the ramp exit as well as the average occupancy of the detectors in the middle of the ramp to calculate an estimate of the queue length on the ramp.

7.6.2.5. Queue Control Module
For each controlled ramp, this module uses the estimate of the queue length of the ramp (calculated by the queue estimation module) and the average flow measurement of the detectors located at the ramp entrance (ramp demand) in order to calculate a desired ramp exit flow to minimise the risk of queue overspill. This flow value needs to be determined so that traffic can still be absorbed into the mainline and to minimise the potential for causing flow breakdown on the mainline.

7.6.2.6. Queue Override Module
This module enables the ramp entrance/arterial road interface to be managed. In the event that the ramp queue will exceed the available ramp storage, a pre-specified ramp exit flow is activated to increase the metering rate. This ramp exit flow value needs to be determined to avoid an excessive inflow of traffic to the mainline that may trigger flow breakdown. While optimising the freeway throughput has benefits to the road network as a whole, consideration may also need to be given to the implications of ramp queues extending onto the arterial road.

7.6.2.7. HERO Coordinated Operation
The HERO module coordinates local ramp metering actions in order to balance queues and provide equity between ramps in a coordinated system.

HERO is activated when a ramp operating under local control experiences queues that meet pre-set thresholds, based on the available ramp storage. In this event the ramp becomes a ‘master’ and engages the first upstream ramp as a ‘slave’. The algorithm then balances queues between the ramps. The engagement of further upstream ramps as slaves continues within a coordinated group, as required.

While the system is operating in a coordinated manner under HERO, control using ALINEA and related algorithms at each individual ramp continues according to local needs at the ramp merge bottleneck.
7.6.2.8. Minimum Queue Control Module
When coordinated ramp metering is in operation, i.e., HERO has been activated, this module uses the estimate of the ramp queue length and the flow at the ramp entrance to calculate a desired metered flow rate so that the minimum queue calculated by HERO is implemented. This calculation aims to make best use of available storage on coordinated ramps and to balance queues between the ramps.

7.6.2.9. Final Ramp Flow Specification Module
This module calculates the final ramp exit flow to be applied to a ramp at the next control period. In the case of local ramp metering the final ramp flow decision is based on exit flow values calculated by ALINEA as well as consideration of the various flow values to address ramp queues. In the case of coordinated ramp metering the final ramp flow is based on ALINEA as well as individual ramp queues and the balancing of queues between ramps. The final ramp flow calculation also considers the current waiting time on the ramp relative to a pre-specified maximum wait time value. The final flow rate may also be adjusted to be within pre-specified minimum and maximum flow rates.

7.6.2.10. Implementation Module
The implementation module calculates the cycle time (the sum of green, yellow and red) that corresponds to the final ramp flow, considering the number of lanes at the stop line. The implemented cycle time is changed for each control period within pre-specified increments for cycle time increases and decreases.

7.6.3. Enhancements to Provide Advanced Bottleneck Control (ABC)
At the time of writing this handbook a number of additional enhancements are under development to provide advanced bottleneck control (ABC). These include:

- Managing freeway flow by considering data at multiple downstream bottlenecks simultaneously. For example, this will enable superior freeway control by considering flow at a steep grade, tight curve, weaving area or uncontrolled freeway to freeway merge as well as the entry ramp merge. This will also enable automated substitution of data in the event of a mainline data station fault.

- Managing entry flows from dual branch entry ramps. This will optimise and balance the ramp flows from each ramp based on queues and waiting time yet still manage the total entry flow based on a single critical downstream bottleneck. This form of operation could also be applied to providing a higher metering rate for a metered priority access lane.

Note: VicRoads has entered into a licence agreement with the developers of ALINEA and HERO, Markos Papageorgiou and Associates, for the use of the algorithms. Since initial trials of the algorithms, VicRoads has worked closely with the developers in regard to further development and improvement.

7.7. Ramp Signals Response to Emerging Congestion
7.7.1. General Principles
The management of freeway flow with ramp signals is intended to maintain free flowing conditions and to prevent flow breakdown. However, there are times when freeway delays become excessive due to congestion caused by an event, e.g., an incident or roadworks, or a situation where the freeway ramp signals are unable to prevent the congestion occurring. The activation of other managed freeway tools, such as a lane use management system closing a lane or a variable speed limit system activating lower than normal speed limits, creates travel conditions that require targeted strategies for managing the freeway and operating the ramp metering signals.

For example, during increasing freeway flow the ramp signal algorithms manage the traffic to prevent congestion. The usual operation of the algorithms would reduce flows into the freeway and increase ramp queues, including engagement of upstream ramps and balancing of queues.
Subsequent queue management would generally increase the metering rate into the freeway to prevent the queue overflowing onto the arterial road. With increasing congestion, increasing the metering rate would generally worsen freeway conditions, as vehicles enter the freeway at a rate that cannot be accommodated. Modifying the operation of the ramp signals improves the effectiveness of traffic management during congestion and facilitates recovery from congestion to free flowing conditions. Section 3.7 provides further background relating to managing congestion and incidents.

Automated strategies and actions\(^4\) to modify the ramp metering operation as well as provide special traveller information signing to assist in diversion of traffic away from the freeway, is required. This includes freeway management system enhancements to:

- Override the calculated output from the ramp signal algorithms. This works to restrict over supply of entering traffic when the freeway travel time on the downstream travel time segment reaches preset thresholds
- Provide real time information signs (RC3) that will give advice relating to the freeway condition and travel time. These signs enable motorists to make an informed decision regarding route choice. Examples of sign messages are in Figure 7.4 and further information is provided in traveller information guidelines
- Adjust inputs to the control algorithms relating to abnormal circumstances during an event, e.g., a lane closure, and provide appropriate traffic control actions.

\[^4\] Under development at the time of writing. Principles are outlined in Section 7.7.2 and Appendix D.

**Figure 7.4: Examples of RC3 Freeway Condition and Congestion Messages**

7.7.2. Ramp Signals Control

When a freeway becomes congested the HERO suite of algorithms initially minimises entry ramp flows into the freeway. However, as the entry ramp queues develop on one or more ramps, the long vehicle queues activate the Queue Control and Queue Override Modules which take control of the entry ramp flows. The higher flows entering the freeway can cause mainline flow breakdown and / or increase congestion along the freeway.

To manage the freeway during heavy congestion, additional strategies are employed outside of the HERO operation in which the ramp flows are restricted to lower values. This intervention will reduce the extent of worsening congestion and facilitate faster recovery from congestion. This results in the achievement of higher overall productivity from the freeway asset. Different strategies are progressively applied depending on the level of congestion. The modified operation will also cause longer ramp queues which may affect arterial roads for a limited period of time.

The travel time algorithm considers a number of downstream detector stations that provide a valuable indication of congestion over a significant length of freeway. Operation to reduce the metering rate and advise motorists of long delays on the freeway is based on the relationship of the estimated travel time to the nominal travel time for the downstream section of freeway.

Further detail relating to modifying the metering rate is in Appendix D.
7.8. Ramp Signals Integration with other Managed Freeway Operations

7.8.1. Ramp Signals Response to a Lane Closure

When an incident results in a lane closure, this induces a significant bottleneck that would generally have a major adverse impact on traffic flow. Lane closures of this nature are random and variable in relation to nominated (pre-set) bottlenecks within the set up of the freeway ramp signals. A lane closure activated by the lane use management system (LUMS) or at other locations not controlled by LUMS, restricts the number of lanes for the traffic flow.

When a lane closure occurs, the freeway management system provides the number of lanes available at a location relative to the number of lanes normally available. The lane closure situation is addressed within the control algorithm to determine the critical bottleneck from a number of potential downstream bottlenecks. The multiple bottleneck capability within the algorithm will automatically evaluate the critical flow conditions and regulate the ramp flow accordingly.

7.8.2. Ramp Signals Response to Changing Speed Limits

Freeway ramp signals switch on and off automatically within thresholds based on freeway flow, travel speed and occupancy. When the freeway speed limit is reduced by a variable speed limit system (VSL), the ramp signals could activate unnecessarily under fixed value activating parameters.

In a managed freeway, a variable speed limit lower than the default speed may be activated in concert with LUMS or for other reasons, e.g., high winds on a bridge. The lower travel speed of traffic affects pre-set values for activation and deactivation of the freeway ramp signals. To ensure that ramp metering is not falsely triggered by a speed limit lower than the default limit, the freeway management system provides the current speed limit value for calculations associated with the ramp signals.

7.8.3. Ramp Signals Response to a Freeway Closure

When an event requires a ramp closure, either of the ramp or the downstream section of freeway, the following operation will occur:

- The Real Time Information Signs (RC3) will display the appropriate freeway closed message as outlined in the handbook for traveller information and incident management, and
- The RC1 sign will display a FREEWAY CLOSED message alternating with a symbolic No Right Turn / No Left Turn / No Entry sign or Special message as appropriate, and
- The freeway ramp signals will switch off by initiating the usual close-down sequence. Switching off the signals enables vehicles already on the ramp to clear so that an emergency vehicle can enter, if necessary. Switching the signals off also avoids vehicles being trapped on the ramp. Further entry of vehicles is restricted by the RC1 and RC3 signs.

The ramp closure operation may be activated manually or automatically as part of an incident response. Reopening of the ramp may also be initiated manually or automatically when there is no longer a need for the closure. When the freeway ramp is reopened to traffic the system would return to default ramp operation, i.e., subject to traffic needs at the time, the ramp signals start up operation may or may not occur.

7.8.4. Emergency Vehicle Access when Ramp Signals are Operating

The queues at ramp signals may present problems for emergency vehicle access during an incident where the ramp is not closed as part of the incident response. Where an emergency vehicle requires access at a particular ramp, the emergency service will need to contact the Traffic Management Centre (TMC).

To provide uninterrupted access for the emergency vehicle the TMC operator will manually turn off the ramp signals to clear the ramp queue. After entry of the emergency vehicle the operator would then re-enable the ramp signals to continue the metering.