Chapter Overview

Context
Intersection Design Fundamentals is a core training program that supports and reinforces Thiess' processes for managing mine traffic across its global operations.

Results
The outcome of this program is to provide a deeper understanding of key intersection design principles.

Approach
This program was designed to provide an understanding of why key principles are fundamental, and how these are related to the physiology of human information perception in conjunction with applicable collision theorems.

Discussion
By providing an understanding of the 'why' to front-line management staff, implementation and proactive maintenance of intersection design standards is improved.

Alignment with new control management thinking
One of the primary controls for preventing a collision at an intersection is the quality of the decision that a driver makes when proceeding into that intersection. This is a human act. Intersection design principles are key in supporting decisions which inform acts.

Alignment with EMESRT Model
The work involved developing and applying a process that baselined a multiple-site business approach aligned with levels 1-3.

Contributors
The project team included Thiess operations and safety teams along with public road safety experts

Presenter Notes:

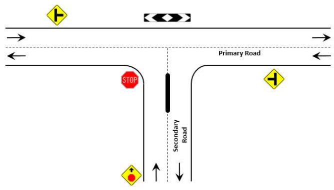
For further Information Contact SHANE FLEMING – Thiess (email: safleming@thiess.com.au   Ph: +61 438 175 901)

Thiess Disclaimer - Every site is different

- At every site the optimum traffic intersection design is different
- Thiess has developed this presentation to assist in the implementation of best practice intersection design, to:
  - minimise the risk of harm to our people; and
  - maximise the efficiency of operations.
- Please make your own enquiries and challenge your existing design using your own professional advisers - you should not rely on this presentation

Intersection collision – preventative controls

- Picture a typical mine intersection in your mind….
- What are the controls that prevent a collision at that intersection?



Stop signs, speed limits, other signage, sight distances, centre bunds, orientation, etc.

Are they really controls?

1. Elimination of Vehicles and
2. The decision a driver makes whether to proceed into the intersection or not – **A human act**.

Presenter Notes:

A control can be defined as an Act, an Object or a Technological System. A control must directly arrest an unwanted event.

Explain how these previously considered controls in themselves cannot arrest the unwanted event – They only support the decision making process of a driver or in some circumstances such as speed restrictions may reduce the consequences

Remember to keep bullet point 2 at the front of your mind as we progress through this presentation

Fundamentally everything we need to do is to enable a driver to make the best and right decision at an intersection

How our eyes work and how we are wired

- Consider your experience driving on public roads. Have you ever experienced a situation where a car or a bike just seemed to come out of nowhere?
- What is the problem, vision impaired?
- Well, yes for small but significant period of time you are not able to see anything at all
- This is generally not a problem for us, but if another vehicle is about to occupy the same space as you, this is not good.

17/11/2018 P5

DELIVERING **SUSTAINABLE** MINING SOLUTIONS

THIESS

Presenter Notes:

The next few slides contain some background information on how our eyes work, how we process images in our brain and how this may impact our ability to make decisions when driving a vehicle

How our eyes work and how we are wired (cont.)

- Evolution - we have evolved as predators. Our eyes and the way our brains process images are well suited to creeping up on prey and monitoring movement in our periphery
  - Only a small part of our retina, in the center called the fovea, can generate a high resolution image – focus test
  - The rest of the retina contributes by adding peripheral detail
- How we build an image in our brain:
  - Saccades and fixations, think of a camera being moved as you take a photo – mirror test
  - Our brains fill in the gaps with a combination of peripheral vison and an assumption that what is in the gaps is the same as what is seen during the pauses
  - Our brain and eyes prioritise what to focus on and move fast to generate a high resolution image
  - Without the saccade/fixation mechanism our brains would be overloaded with unnecessary detail and blurred images.

Presenter Notes:

When we move our head and eyes to scan a scene, our eyes are incapable of moving smoothly across that scene and seeing everything. This makes perfect sense, just like trying to take a picture without holding the camera still, the image would be blurred. So, our brain overcomes this by moving our eyes (really fast) in a series of jumps (called saccades) with very short pauses (called fixations), and it is only during the pauses that an image is effectively 'taken' and processed. Our brains fill in the gaps with a combination of peripheral vision and an assumption that what is in the gaps must be the same as what you see during the pauses. Your brain actually blocks the image that is being received while your eyes are moving.

The faster you move your head, or the faster you travel and are required to process more information the larger the jumps, or saccades, and the shorter the pauses, or fixations. So you are more likely to jump over an oncoming vehicle and less likely to detect any movement in your peripheral vision (because there is even less time available for any relative movement to become apparent).

Focus test

Look at some large lettering or a picture ay 5-10m away, no shift your eyes just to the side of that say half to one metre away and focus on that spot. The lettering or picture will be blurry, or stand just 10m from a car, look just one car's width to one side, and try and read the number plate - without moving where your eyes are looking! Try again from 5m. Clinically, you are blind in your peripheral vision

Mirror test

Okay, go to a mirror, look repeatedly from your right eye to your left eye. Can you see your eyes moving? You cannot. Now have a friend or partner do the same thing while you watch them. You will see their eyes moving quite markedly.

You couldn't see your own eyes move because your brain shuts down the image for the instant that your eyes are moving. Experiments have shown that it is impossible to see even a flash of light if it occurs within a saccade.

How our eyes work and how we are wired (cont.)

- There are times that we don't see anything at all, and what we see may not be what is actually there
- It does get worse:
  - Peripheral vision is very good at detecting movement
  - Vehicles travelling at a constant speed will stay in the same position relative to each other as they approach a point of collision – i.e. no detectable movement in the windscreen.

Presenter Notes:

How our eyes work and how we are wired (cont.)

And even worse

- There is the phenomenon of ‘expectation’ and your brain is less likely to recognise something that you are not expecting to see.
- This means that if you think the road is empty, you are less likely to register that a vehicle is actually present
  - Situational blindness – looked but failed to see i.e. what you’re not ‘expecting’ to see.

Presenter Notes:

Discuss the ‘Invisible Gorilla” psychology experiment by Christopher Chabris and Daniel Simons

How our eyes work and how we are wired (cont.)

And even worse still…

- We cannot see through solid objects, but we also struggle to look or focus near the edges of a framed scene
- That is, we tend not to look near the edges of a windscreen, this is known as 'windscreen zoning'
- Not only do pillars form a physical blind spot, but our eyes tend not to fixate near to them
- The equipment visibility diagrams we typically utilise are actually worse than depicted.

Presenter Notes:

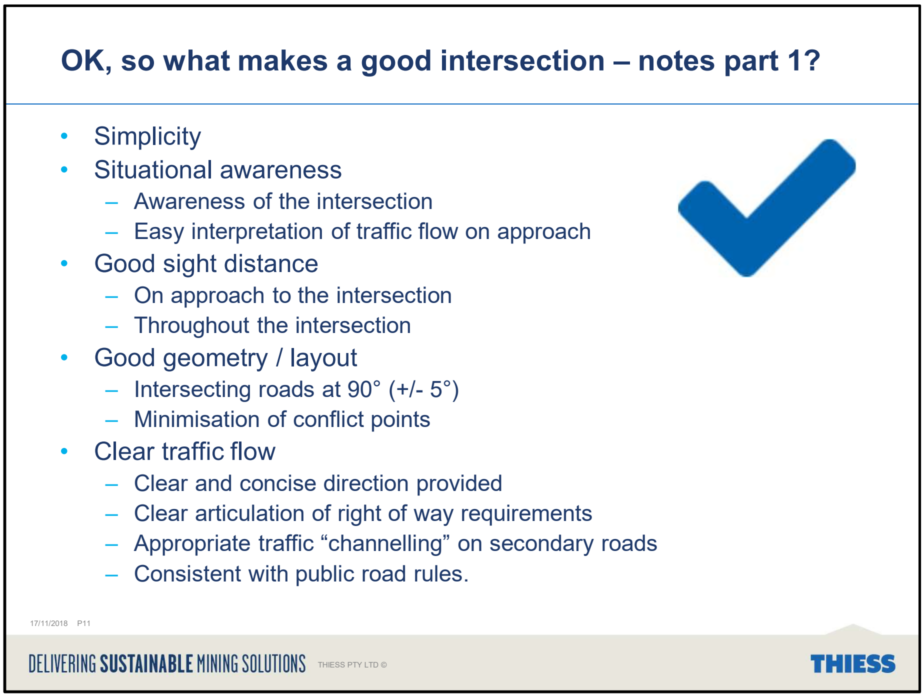
Application of this knowledge

- Although this sounds like we shouldn't be able to get out of bed without running into things, it is not all doom and gloom
- An understanding of how we see and process images along with the primary preventative control at an intersection being the human act of whether to proceed into an intersection or not are fundamental considerations and elements of the intersection design process
- Fundamentally, everything we need to do is to enable a driver to make the best and right decision at an intersection.

Presenter Notes:

Although this presentation focuses on Intersection Design Fundamentals, some other important factors that need to be considered to assist drivers are as follows in relation to the previous slides:

- An important consideration in focusing our eyes onto an important object (i.e. another vehicle) in our peripheral vision if no movement is detected is CONTRAST. White light vehicles, headlights on, flashing beacons, bright flags, lighted barber poles, high vis stripes, etc. all assist with this
- Training drivers, particularly heavy mobile equipment operators to look next to and also to 'clear pillars'. This is fundamental in overcoming windscreen zoning and some of the impact of pillar blind spots
- Training drivers to always look right and left methodically, deliberately focusing on at least 3 different spots along the road to the right and 3 to the left - search close, middle-distance and far. With practice, this can still be accomplished quickly, and each pause is only for a fraction of a second, but this means that you are now overriding the natural limitations of the eye and brain (Training drivers to look , not glance)
- Training drivers, to look TWICE to increase their chances of seeing something that may have been in a saccade
- Overcoming expectation but alerting heavy mobile equipment operators that an LV is in their circuit, etc.



Presenter Notes (part 1)

Simplicity

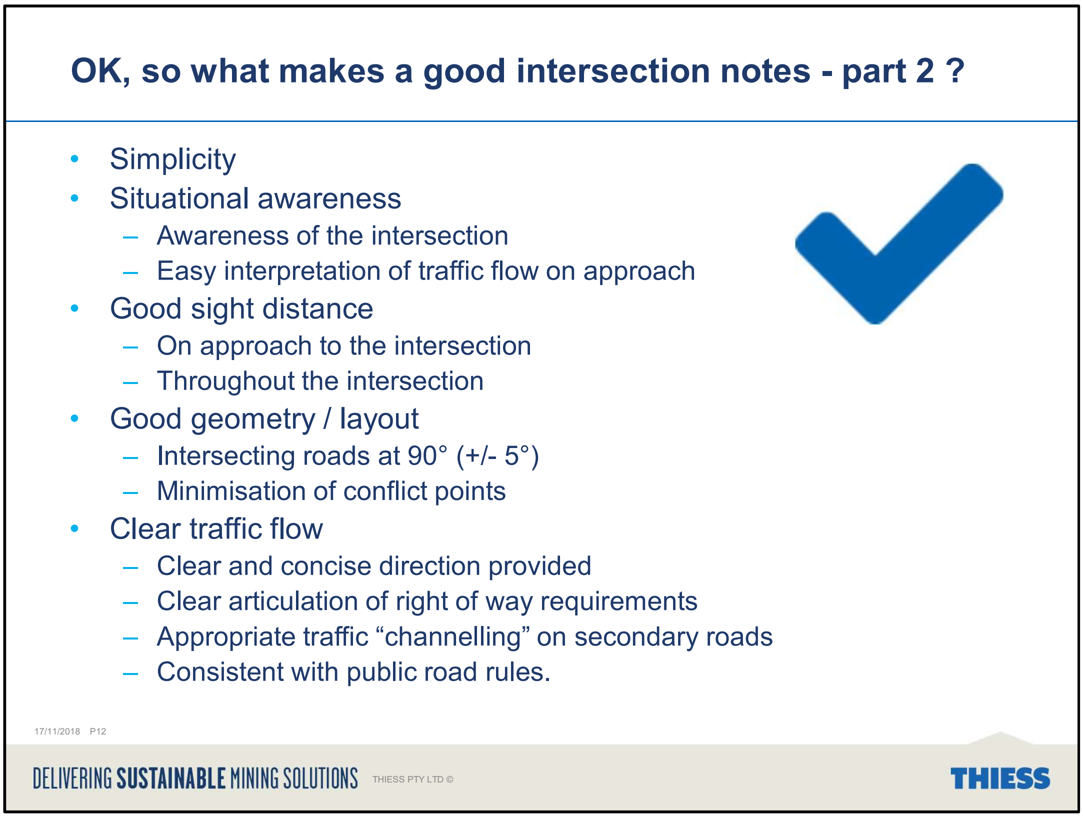
- Intersections should be designed so that they are as simple as possible, this reduces ambiguity and confusion for drivers that approach and travel through and intersection. Simplicity will be discussed in the following dot points.

Situational Awareness

- It is important that drivers are given cues and mentally acknowledge that they are approaching an intersection and that they react accordingly. In addition it is very important that drivers can easily interpret what the anticipated traffic flow through the intersection is before reaching the intersection.
- Ask how we achieve this on site?
    - Median bunds to separate and channel traffic;
    - Increased density of delineators;
    - Different style of delineator or coloured delineator reflective sleeve;
    - Signage;
    - Training and awareness discussion on the road network layout (in pre-starts etc);
    - Others

Good Sight Distance

- Drivers must be able to adequately see other vehicles as they approach an intersection so that they can react accordingly. It is important that sight distance considers different vehicle types and their associated visibility restrictions. In addition sight distance needs to be considered on approach to the intersection and as a vehicle traverses the intersection.
- Ask what our standards are on site with respect to this?
    - Intersection site distance envelope – SISD along the primary road and 10m along the secondary road(s);
    - Median separation bunds restricted to 1m high;
    - Bunds alongside the road edge within the sight distance envelope restricted to 1m high (unless otherwise required for risk control, e.g. edge drop off);
    - Speed restriction on approach to reduce the sight distance envelope requirement;
    - Intersection geometry (roads intersecting at 90°);
    - Etc.
- Ask what considerations do we make for sight distance from different vehicles using the road network?
    - Haul truck cab on the left hand side;
    - Very restricted vision from HV's particularly to the right (discuss HV visibility restriction diagrams);
    - Light vehicles interacting with HV's (size of vehicle and height of the operators eye ~1.5m).



Presenter Notes (part 2)

Geometry

- Orientation of the intersecting roads can have a significant impact on a drivers sight distance to vehicles approaching an intersection. Roads that intersect at 90° provide the most favourable orientation to maximise sight distance. In addition the position of the intersection in relation to vertical alignment needs to be considered.
- Conflict points will be discussed later. However, minimising the amount of points where vehicles can collide will improve the safety of an intersection. An example of this is using ‘T’ intersections (9 potential points for vehicles to collide) as opposed to ‘Cross’ or multi-leg intersections (32+ potential points for vehicles to collide). Typically the less conflict points the simpler an intersection will be (refer back to the first dot point).

Clear Traffic Flow

- Drivers must be provided with clear and concise direction on paths of travel and right of way requirements at an intersection. Paths of travel need to be unambiguous and easily interpreted (this must also include paths of travel where other vehicles may come from and result in a potential collision).
- Any form of ambiguity or confusion may distract drivers from critical decision making process associated with rights of way etc.
- Typically some of this direction is provided by clear and appropriately positioned signage however a simple and easily interpreted intersection is paramount to reducing ambiguity and confusion (refer back to the first dot point).
- It is important that on the secondary road approach vehicles are “channeled” into the correct orientation (square) to maximise sight distance. This will be discussed later.
- It is important that traffic management controls are consistent with public road rules as these are what drivers are most familiar with.

How do we achieve this?

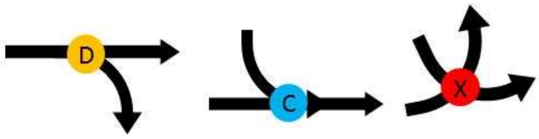
- Understanding that the primary preventative control at an intersection is the human act of whether to proceed into an intersection or not
- Effective intersection design processes:
  - Conflict point analysis
  - Sight distance analysis
  - Appropriate orientation and treatments
- Effective intersection traffic control measures
- Effective change management processes
- Effective maintenance to the original intersection design parameters.

Presenter Notes:

- We will discuss these elements in much more detail as we progress through this presentation

Conflict point analysis

- Conflict points are locations where possible collisions may occur between vehicles
- Three types of conflict points are important for intersection analysis (diverging conflict point, converging conflict point, and a crossing conflict point)

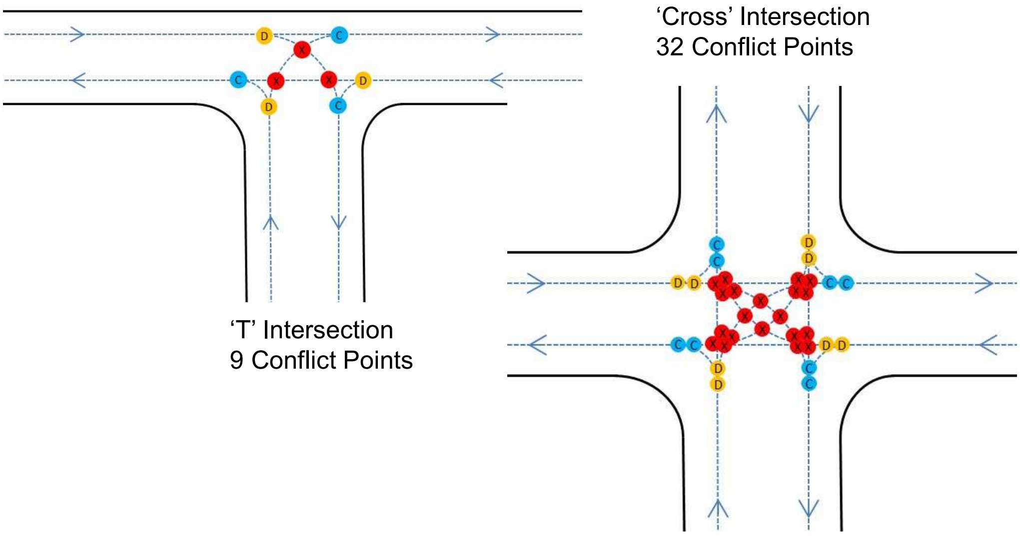


- Conflict point analysis aims:
  - Ensure the total number of conflict points is kept to a minimum
  - Ensure conflict point frequency is minimised
  - Reduce the complexity of a driver's decision process by introducing appropriate controls at conflict points specifically for driver judgments of clearance time and distance to potentially conflicting traffic.

Presenter Notes:

- Conflict point analysis drives the majority of our design process
- Semi-quantitative analysis (design process is based on measurements as opposed to subjective design process. I.e. Number of conflict points assessed as opposed to I think this design should be ok)

Conflict point analysis



17/11/2018 P15

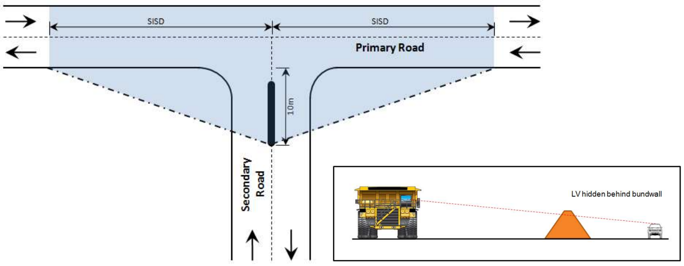
DELIVERING **SUSTAINABLE** MINING SOLUTIONS THIESS PTY LTD ©

Presenter Notes:

- Discuss number of CP's, frequency of CP's and complexity
- This type of analysis can be done on site existing site intersections

Sight distance

- Ensure intersections are positioned and designed to maximise sight distance on approach and throughout the intersection
- Give consideration to sight distance in both the horizontal and vertical planes
- A sight distance envelope of 10m on the secondary road
- approach and the required Safe Intersection Sight Distance
- (SISD) either way along the primary road is desirable.



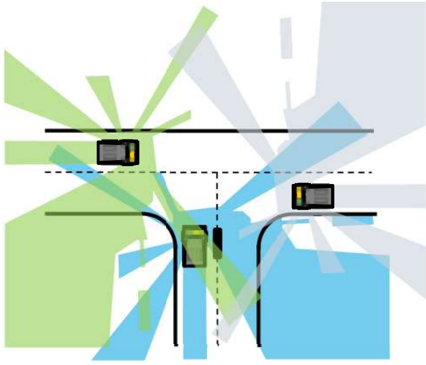
Speed (km/hr)	Safe Intersection Sight Distance (SISD)
10	10 m
20	30 m
30	50 m
40	70 m
50	90 m
60	110 m
70	145 m
80	185 m

Presenter Notes:

- Safe Intersection Sight Distance (SISD) is based on the following calculation assumptions:
    - 0.4 coefficient of friction for a dry mine road
    - 2.5 sec driver reaction time
    - 0.5 sec brake activation time
    - 1.5 sec addition to safe stopping distance calculation to SISD
    - No allowance for grade effects
- SISD values shown in the table are calculated for a dry mine road, in order to maintain SISD in wet conditions (0.2 coefficient of friction assumption) speed must be reduced by a minimum of 10 km/hr (this must be catered for in the Mine Traffic Rules & Wet Weather TARP processes)
- With stop signs controlling right of way obligations, sight distance is also required to cater for starting distance (i.e. the time taken for a haul truck to pull away from a stop sign and move into an opposing lane can be in the order of 5-10 secs)
- Any obstruction within the sight distance envelope should be removed where possible
- Restrict bundwall heights in these areas (unless otherwise required for risk control, e.g. Drop off hazards etc). Ensure centre median bunds are kept at 1m to maximise sight distance
- If SISD requirements cannot be achieved for the design speed of the primary road, speed restrictions must be adopted to lower the SISD to a value that matches the physical sight distance available at the intersection
- Consideration must be given to driver eye height when assessing the sight distance envelope – typically a driver eye height of 1.5m is suitable for light vehicles (mine 4WD)

Sight distance

- Where required utilise scaled equipment visibility diagrams to assist in the design process
- Model vehicle movements along all identified travel paths with these diagrams to identify potential sight distance and visibility issues
  - Remember visibility diagrams are actually worse than depicted (windscreen zoning).



17/11/2018 P17

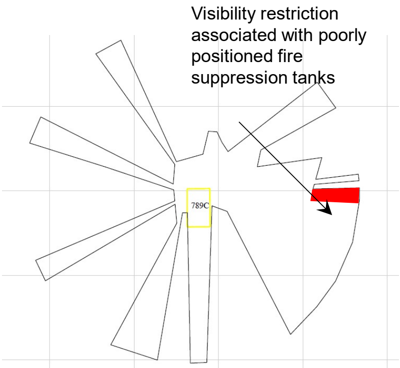
DELIVERING SUSTAINABLE MINING SOLUTIONS THIESS

Presenter Notes:

- Consideration should be given to other road side obstructions and the vertical alignment when identifying potential sight distance and visibility issues
- Consideration should also be given to other vehicle types (e.g. light vehicles) utilising the roadway
- Note: Indicative 'Equipment Visibility' diagrams utilised for demonstration purposes

Sight distance

- Give consideration to retro-fitted accessories e.g. fire suppression tanks, access systems etc. on mobile equipment when considering equipment visibility diagrams and sight distance
- If possible, move poorly positioned accessories to increase visibility.

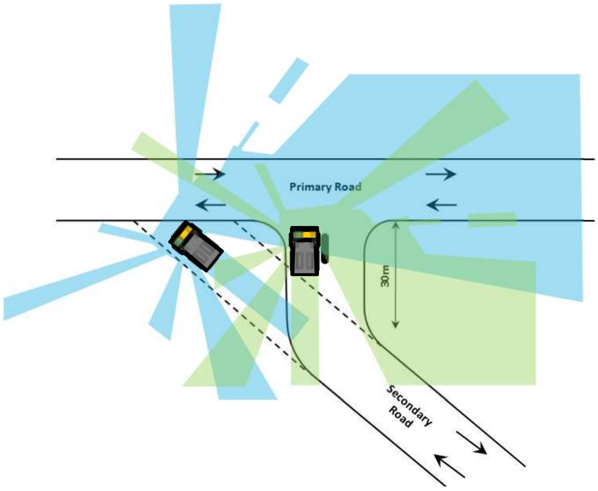


  THIESS

Presenter Notes:

Geometry and treatments

- Ensure roads intersect at 90° (square) to each other
- Common ‘Y’ intersections treatment.

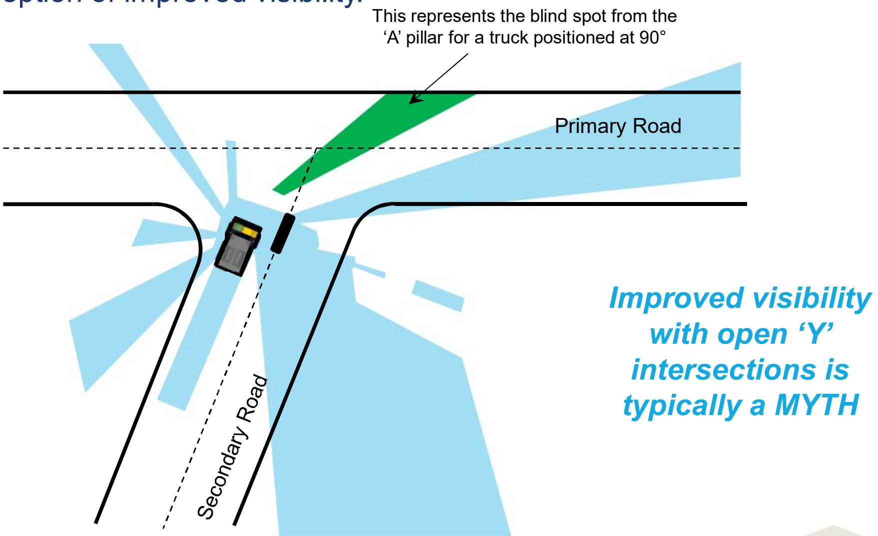


Presenter Notes:

- Related to sight distance and vehicle approach speed from secondary road
- Discuss haul truck sight distance restrictions
- Note: Indicative ‘Equipment Visibility’ diagrams utilised for demonstration purposes

Geometry and treatments

- ‘Y’ intersections orientated in this direction result in a ‘false’ perception of improved visibility.



17/11/2018 P20

DELIVERING SUSTAINABLE MINING SOLUTIONS THIESS PTY LTD © THIESS

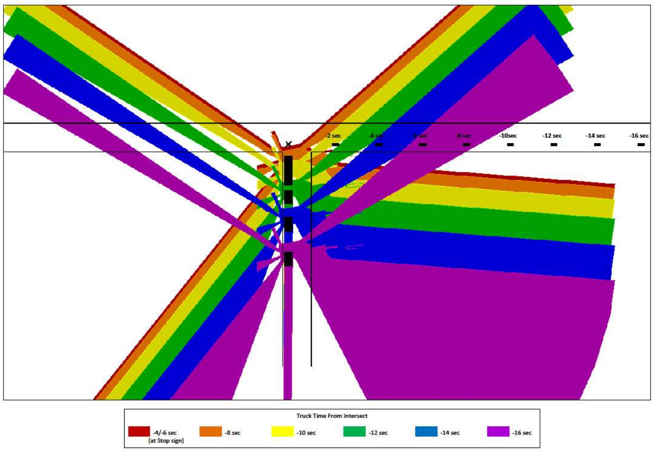
Presenter Notes:

- An open Y intersection towards the off side of the truck provides a perception of increased visibility by opening up that off side to the on coming traffic from the primary road
- This however is conundrum that leads to a false sense of increased visibility, where in fact in most circumstances it orientates the A pillar subtended angle of the cab along the primary road way severely reducing visibility over a longer distance and greater surface area of the road
- The green shape represents where the A pillar blind spot would be positioned for a vehicle at 90 degrees to the primary road
- Note: Indicative ‘Equipment Visibility’ diagrams utilised for demonstration purposes

Geometry and treatments

- This details a truck constantly decelerating to a stop sign at a 90° and a LV travelling at 60km/hr on approach to an intersection and associated visibility restrictions.

Road Angle @ 90 degrees



17/11/2018 P21

DELIVERING SUSTAINABLE MINING SOLUTIONS

THIESS

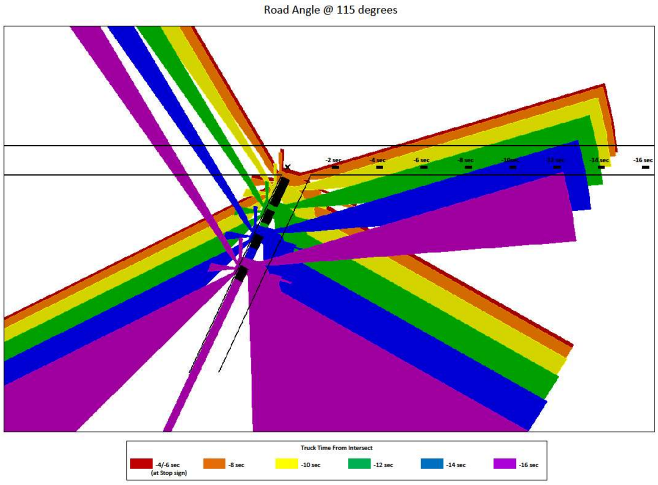
Presenter Notes:

- In this diagram the roads intersect at 90°
- The truck is constantly decelerating at -1.5g on approach to the intersection (-1.5g is what most people perceive as a comfortable deceleration rate)
- 2 seconds has been allowed at the stop sign and a further 4 seconds to reach a potential collision point where both lanes intersect.
- The LV is travelling at a constant speed of 60km/hr (16.67m/s)
- Note the approach at 90° provides good visibility and minimal affect of the 'A' pillar blind spot

- Whether in the blind spot or not, remember our earlier discussion around relative movement and our limited ability to detect this in our peripheral vision

Geometry and treatments – symmetry of collision

- For an open 'Y' intersection at 115°, the LV remains in the 'A' pillar blind spot for the entire time as both vehicles approach a collision at the 0 sec mark.



17/11/2018 P22

Presenter Notes:

- In this diagram the roads intersect at 115° presenting an open 'Y' intersection scenario
- The truck is constantly decelerating at -1.5g on approach to the intersection (-1.5g is what most people perceive as a comfortable deceleration rate)
- 2 seconds has been allowed at the stop sign and a further 4 seconds to reach a potential collision point where both lanes intersect.
- The LV is travelling at a constant speed of 60km/hr (16.67m/s)
- Note the approach at 115° orientates the 'A' pillar blind spot along the length of the road. The surface area of the road covered by the 'A' pillar blind spot is significantly increased due to this orientation
- The LV remains hidden in the blind spot for the entire approach leading right up to the collision point – this is know as a symmetry of collision
- A symmetry of collision is very similar to the lack of relative movement discussion earlier, whereas in this situation if the vehicle remains in the subtended angle of the blind spot the vehicle will stay in that blind spot up until the point or just before the point of collision. This is compounded by the size of mining equipment blind spots, that also accommodates a greater range of speed changes for each vehicle
- Whether in the blind spot or not, remember our earlier discussion around relative movement and our limited ability to detect this in our peripheral vision
- This is why it is fundamental that intersections are orientated at 90˚ (+/- 5˚) to each other and why stops signs are so important as changing approach speed will immediately generate relative movement against a vehicle that was otherwise on a collision course - not only are you then more likely to see it, but you are no longer on a collision course (the change of approach speed for a giveway sign may not be enough to take the vehicle out of the blind spot due to the size of the blind spot on heavy mobile equipment (specifically haul trucks)

Geometry and treatments

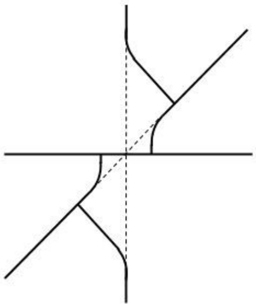
- This represents the view form an operators perspective stopped at a stop sign of an intersection orientated at 115°.

Presenter Notes:

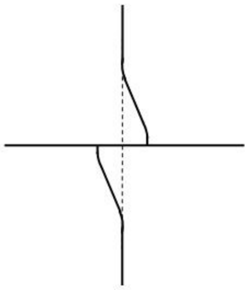
- This is the view from the operator stopped at the stop sign
- In relation to the previous diagram this represents -6 seconds to -4 seconds before impact of a collision with a light vehicle travelling at 60 km/hr

Geometry and treatments

- Common treatments for multi-leg intersections (Staggered 'T's)
- Ensure intersections within close proximity to each other are appropriately separated by an offset (70m CL to CL).



79 Conflict points reduced to 36 conflict points (4 separate intersections with 9 conflict points each)



32 Conflict points reduced to 18 conflict points (2 separate intersections with 9 conflict points each)

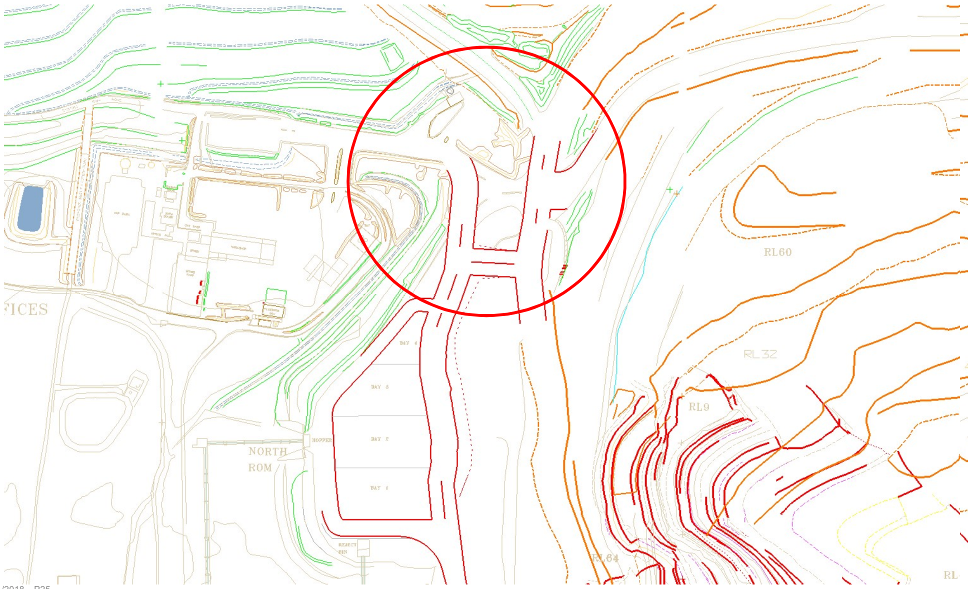
17/11/2018 P24

DELIVERING **SUSTAINABLE** MINING SOLUTIONS THIESS

Presenter Notes:

- Are there complex intersections that could be improved on your site – Are they just accepted, how would you go about it?

Geometry and treatments
Industry case study



Presenter Notes:

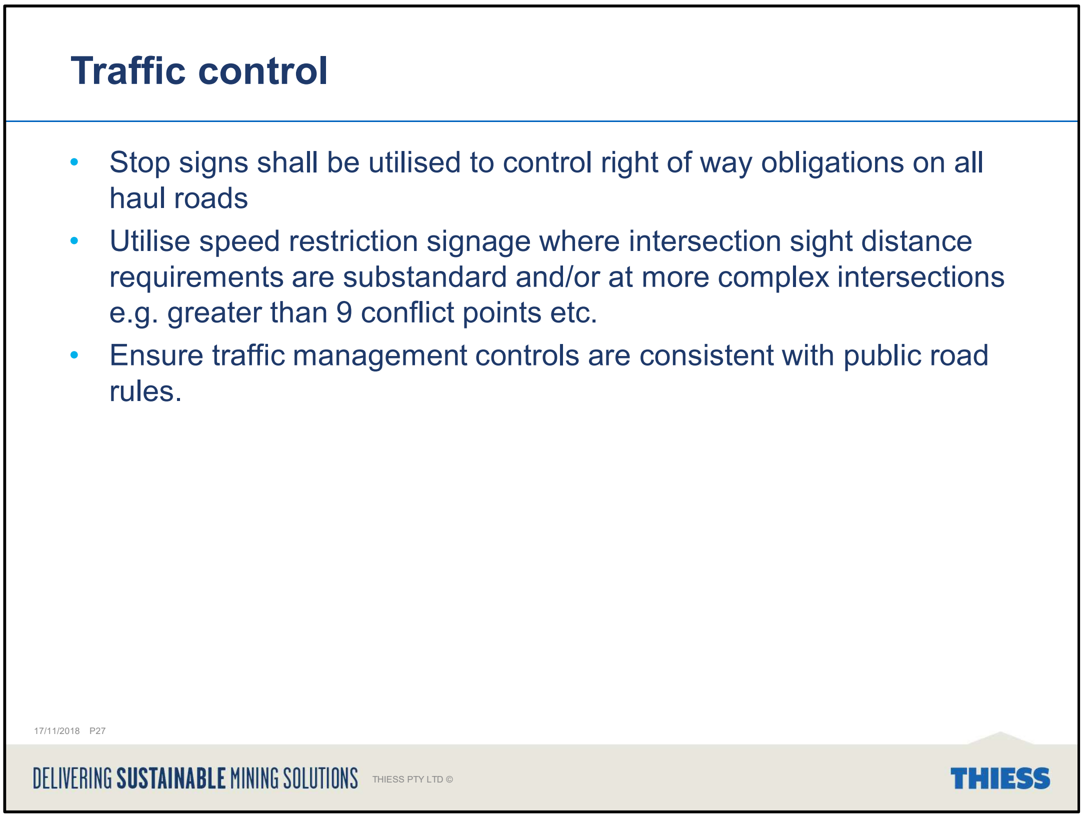
- Point out MIA, Pit areas, ROM etc. Show intersection in question and all the roads that come into it
- Very complex intersection with at least 8 roads intersecting, close to MIA, ROM, Pit access ramps, dump ramps etc
- All manner of vehicles using this intersection, LV, service vehicles, Haul trucks etc
- Very poor sight distance with roads intersecting at acute angle (Y)
- Accepted as Ok over time
- Challenged to produce a better solution

Traffic control

- Ensure appropriate traffic controls are provided to enable the safe and efficient movement of vehicles through an intersection
- Consider traffic volumes and loaded haulage routes when determining traffic flow priority
- Appropriately positioned and sized median bundwalls should be used to provide traffic separation within an intersection
- Ensure that median bundwalls are positioned to appropriately 'channel' vehicles into the required orientation i.e. square on the secondary road approach
- Adequate signage shall be installed to provide warning on approach to an intersection and to provide clear direction within the intersection.

Presenter Notes:

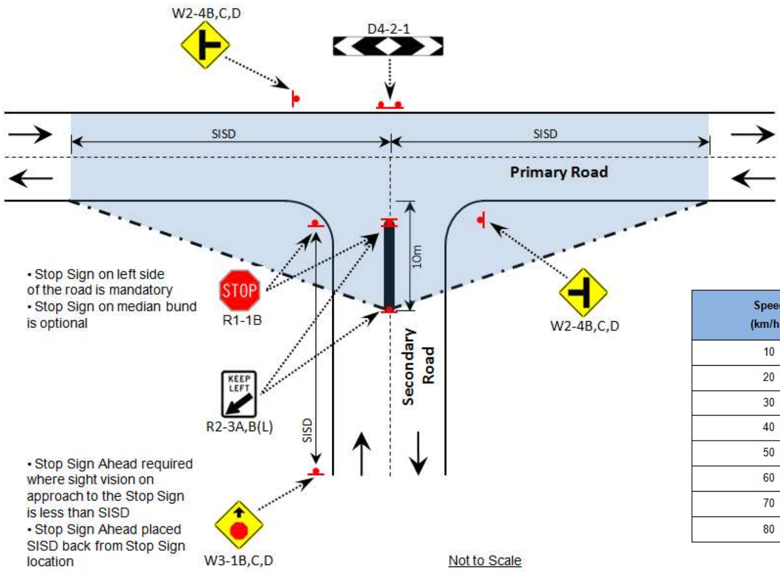
- Drivers must be provided with clear and concise direction on paths of travel and right of way requirements at an intersection. Paths of travel need to be unambiguous and easily interpreted (this must also include paths of travel where other vehicles may come from and result in a potential collision).
- Any form of ambiguity or confusion may distract drivers from critical decision making process associated with rights of way etc.
- Typically some of this direction is provided by clear and appropriately positioned signage however a simple and easily interpreted intersection is paramount to reducing ambiguity and confusion.
- Ensure median bundwalls used to provide traffic separation within an intersection are appropriately positioned and sized (max. 1m high) so that they do not restrict sight distance on approach and throughout an intersection
- It is important that on the secondary road approach vehicles are "channeled" into the correct orientation (square) to maximise sight distance. Median bundwalls can be used to do this. They must be long enough and the lane narrow enough to provide an adequate orientation channel. There is no point having a 90° intersection if vehicles can skew themselves in preparation for moving through the intersection (effectively turning a 90° intersection into a Y intersection)
- In general Stops signs reduce collision probability greater than give way signs by:
    - Reducing the complexity of a driver's decision process for judgments of clearance time and distance to potentially conflicting traffic
    - Reducing approach speeds of potentially conflicting traffic
    - Changing approach speed will immediately generate relative movement against a vehicle that was otherwise on a collision course - not only are you then more likely to see it, but you are no longer on a collision course



Presenter Notes:

- Drivers must be provided with clear and concise direction on paths of travel and right of way requirements at an intersection. Paths of travel need to be unambiguous and easily interpreted (this must also include paths of travel where other vehicles may come from and result in a potential collision).
- Any form of ambiguity or confusion may distract drivers from critical decision making process associated with rights of way etc.
- Typically some of this direction is provided by clear and appropriately positioned signage however a simple and easily interpreted intersection is paramount to reducing ambiguity and confusion.
- Ensure median bundwalls used to provide traffic separation within an intersection are appropriately positioned and sized (max. 1m high) so that they do not restrict sight distance on approach and throughout an intersection
- It is important that on the secondary road approach vehicles are “channeled” into the correct orientation (square) to maximise sight distance. Median bundwalls can be used to do this. They must be long enough and the lane narrow enough to provide an adequate orientation channel. There is no point having a 90° intersection if vehicles can skew themselves in preparation for moving through the intersection (effectively turning a 90° intersection into a Y intersection)
- In general Stops signs reduce collision probability greater than give way signs by:
  - Reducing the complexity of a driver’s decision process for judgments of clearance time and distance to potentially conflicting traffic
  - Reducing approach speeds of potentially conflicting traffic
  - Changing approach speed will immediately generate relative movement against a vehicle that was otherwise on a collision course - not only are you then more likely to see it, but you are no longer on a collision course

Traffic control – intersection signs

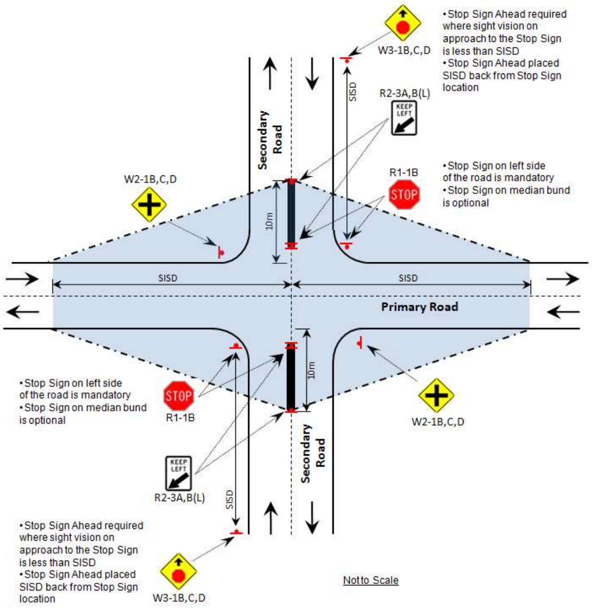


Speed (km/hr)	Safe Intersection Sight Distance (SISD)
10	10 m
20	30 m
30	50 m
40	70 m
50	90 m
60	110 m
70	145 m
80	185 m

Presenter Notes:

•

Traffic control – intersection signs



17/11/2018 P29

DELIVERING SUSTAINABLE MINING SOLUTIONS

THIESS

Presenter Notes:

•

Change management

- Ensure effective change management processes are followed
- Refer to site change management procedure
- Ensure that intersections are maintained to preserve the intersection design parameters.

Presenter Notes: