Memorandum

To	Gary Bedford, Director of Environmental Quality
	Fiza Hafiz, Scientific officer – State of Environment
From	Brian Cheyne, Scientific officer – Air Quality
File	FRODO #1559205
Date	23 November 2015

Amended January 2019 to include corrections for blank (limits of detection) in BTEX results

Air monitoring survey (BTEX, NOx and CO) at New Plymouth Girls High School near the major road realignment works

Introduction

In January, February and March 2015 a survey of ambient air quality sampling was carried out by the Taranaki Regional Council in New Plymouth's busy traffic intersection near the major road realignment works. The main objectives were to measure:

- The concentrations of the volatile organic compounds (VOC) benzene, toluene, ethylbenzene and xylenes (BTEX) using a passive sampling method that gives a result for average exposure;

- To measure also the concentrations of the nitrogen oxides (NOx) using a passive sampling method, that gives a result for average exposure;

- And to measure carbon monoxide (CO) using a portable multi gas meter, that provides instantaneous data throughout the monitoring period.

Measurement of PM2.5 and PM10 (on a moment by moment basis) was also carried out during this monitoring period, but the confirmation of the results will depend on validation of the equipment calibration, which is presently under way.

The locations of the monitoring sites are presented in Figure 1.

The findings of this study are presented in this report.

1. BTEX

Benzene

Benzene occurs naturally in fossil fuels and is produced in the course of natural processes and human activities that involve the combustion of organic matter such as wood, coal and petroleum products. Natural sources of benzene emissions to the atmosphere are estimated in order of 3-5% while more than 90% are estimated to come from anthropogenic sources (gasoline vapours and vehicle exhaust which would apply at the monitoring site. Chemical production also releases benzene.

Toluene

Toluene occurs naturally as a component of crude oil and is a major aromatic constituent of petrol which contains about 5-7% toluene by weight. It is produced in the process of making gasoline and other fuels from crude oil, in making coke from coal, and as by-product in the manufacture of styrene. It is used as an intermediate in the manufacture of many end products. Toluene is also used in a mixture added to gasoline to improve octane ratings. Toluene is released into the atmosphere principally from the volatilization of petroleum fuels, from motor vehicle exhaust and from toluene-based solvents and thinners with the largest sources of release the production, transport, and use of gasoline.

Ethylbenzene

Ethylbenzene is naturally present in crude petroleum. It is also a by-product of biomass combustion. Ethylbenzene is almost exclusively (>99%) used as an intermediate for the manufacture of styrene monomer. Ethylbenzene will enter the atmosphere primarily from fugitive emissions during the use of fuel and solvents (which account for the bulk of emissions) and exhaust connected with its use in gasoline.

Xylenes

Xylenes exist in ambient air as a mixture of ortho (o-), meta (m-) and para (p-) isomers (the term "xylenes" refers to all three isomers). Xylenes are primarily synthetic chemicals produced from petroleum but also occur naturally in petroleum and coal tar.
In this survey concentrations of o-, p-, and m-xylene were summed and reported as xylene total. Xylenes are released to the atmosphere primarily as fugitive emissions from industrial sources (e.g., petrochemical and chemical plants), in automobile exhaust, and through volatilization from there use as solvents.

The term BTEX reflects that benzene, toluene, ethylbenzene and xylenes are often found together.

Health effects

Exposure to BTEX can occur by ingestion (consuming water contaminated with BTEX), inhalation (exposure to BTEX present in the air) or absorption through the skin. Inhalation of BTEX can occur while pumping gasoline. Absorption of these chemicals can occur by spilling gasoline onto one's skin. Acute exposures to high levels of gasoline and its BTEX components have been associated with skin and sensory irritation, central nervous system depression, and effects on the respiratory system. These levels are not likely to be achievable from drinking contaminated water, but are more likely from occupational exposures. Prolonged exposure to these compounds has effects on the kidney, liver and blood systems. According to the United States Environmental Protection Agency (USEPA), there is sufficient evidence from both human and animal studies to believe that benzene is a human carcinogen. Workers exposed to high levels of benzene in occupational settings were found to have an increased incidence in leukaemia.

The primary source of BTEX, NOx and CO at the monitoring sites would be motor vehicle emissions and that the site was chosen for its high traffic flows and current roadwork programme (which involves heavy vehicles).

1.1 Summary of method

Passive absorption samplers that absorb the target gas into activated carbon and are subsequently analysed using gas chromatography, are employed to determine the average concentration of the gas in the air during the time of exposure. BTEX concentration is reported as µg/m^3 (mass of BTEX per volume of air).

1.2 Guidelines

In New Zealand, benzene is the only member of the BTEX group subject to a national guideline value. The Ministry for the Environment guideline, based on benzene's known mutagenic and carcinogenic properties, was 10µg/ m3 as an annual average, reducing to 3.6µg/m3 in 2010. There are no national ambient air quality guidelines for toluene, ethylbenzene or xylene. The Ministry for the Environment had prepared an internal technical document "Health Effects of Eleven Hazardous Air Contaminants and Recommended Evaluation Criteria" (October 2000) that suggested a 1 hour average value of 22 µg/m3 for Benzene, 500 µg/m3 for Toluene and 1000 µg/m3 for Xylene as recommended guidelines values. However, these recommendations were not carried through to the final Ministry for the Environment guidelines published in 2002.

Figure 1 Locations of the monitoring sites at NPGHS

1.3 Results

The duration of sampling for VOCs lasted 21 days or (504 hours) from 21 January to 11 February 2015. The absorption activated carbon badge method provides an average concentration over the period of exposure. It does not provide a range (eg maximum or minimum concentrations). The laboratory analysis includes a step of measuring the quantity of BTEX compounds collected on the passive badges, and converting this to an equivalent ambient concentration. Because analysis of the field blank shows the presence of some BTEX compounds, it is appropriate to consider subtracting this blank result from the quantities detected on other samples, before calculating ambient concentrations. Unadjusted results give the maximum concentration that could have been present; results adjusted for blank corrections will give the more likely result. In Table 1 below, the adjusted results are shown alongside the uncorrected results. A conservative approach will be to consider the 'actual' concentration lies between the two figures. *(Text added in January 2019)*

The issue is therefore that of estimating an indicative equivalent exposure concentration over alternative time periods of interest (eg as referenced in guidelines or other criteria). For comparison with the Ministry for the Environment guideline for BTEX, from the average concentration measured, it is desirable to calculate an indicative theoretical one hour concentration. There are mathematical equations used by air quality scientists to predict equivalent concentrations over varying time periods. These are somewhat empirical, in that they take little account of local topography, micro-climates, variations in activity processes, diurnal variation, etc. Nevertheless, they are conservative (they tend to over-estimate) and have some recognition of validity as a screening tool. One formula in general use is of the form:

$$C(t_2) = C(t_1) \times \left(\frac{t_1}{t_2}\right)^P$$

where C(t) = the average concentration during the time interval t, and p = a factor lying between 0.17 and 0.20. When converting from longer time periods to shorter time periods, using p = 0.20 gives the most conservative estimate (i.e. the highest calculated result for time period t2 given a measured concentration for time period t1).

Using the 'worst case' factor of p = 0.20, the monitoring data reported herein have also been converted to equivalent 'maximum' one hour exposure levels (Table 1).

Table 1 Actual and recalculated (p0.2) BTEX results at NPGHS

Site	Site ID / Where	Time total hrs.	Benzene			Toluene			Ethyl Benzene	o,m,p – Xylene Total		
			Lab. Results	1 hr. Calc¹	1 hr Calc²	Lab. Results	1 hr. Calc¹	1 hr Calc²	Lab. Results	Lab. Results	1 hr. Calc¹	1 hr Calc²
1	AIR000012 NW corner	504	0.65	2.25	1.94	1.49	5.17	4.72	0.37	1.39	4.82	4.44
2	AIR000012 NE corner	504	0.53	1.84	1.56	1.25	4.34	3.92	0.30	1.20	4.16	3.75
3	AIR000012 SW corner	504	0.56	1.94	1.67	1.50	5.20	4.75	0.28	1.12	3.89	3.50
4	AIR000012 SE corner	504	0.88	3.05	2.77	2.06	7.15	6.70	0.44	1.62	5.62	5.24
MfE recommended **guidelines** (2000), one -hour average.				**22**			**500**				**1000**	

* All results in µg/m³ Calc¹ 1-hour average ambient concentration, no blank correction
Calc² 1-hour average ambient concentration adjusted for blank recovery (*This data added in January 2019)*

1.4 Discussion

The calculated 1-hour theoretical maximum concentrations of benzene (using a power law exponent of 0.2) ranged from 1.84 µg/m³ to 3.05 µg/m³ (uncorrected values) The results from monitoring of toluene, ethylbenzene and xylene have all been extremely low. All values were well within the Ministry for the Environment recommended guidelines (2000). This continues the pattern found in previous years.

1.5 Environmental Performance Indicator

Ministry for the Environment uses an environmental performance indicator to categorise air quality. These categories are set out in Table 2 and further details of the BTEX results are set out in Table 3.

Table 2 Environmental Performance Indicator air quality categories

Measured value	**Less than 10% of guideline**	**10-33% of guideline**	**33-66% of guideline**	**66-100% of guideline**	**More than 100% of guideline**
Category	*excellent*	*good*	*acceptable*	*alert*	*action*

Table 3 Categorisation of results - Benzene (2015)

MfE guideline (2000) Benzene = 22 µg/m³- 1 hour average.		
Category	**Measured values**	
Excellent	<10% of the guideline, (0-2.2µg/m³)	**2** (50%)
Good	10-33% of the guideline, (2.2-7.3µg/m³)	**2** (50 %)
Acceptable	33-66% of the guideline, (7.3-14.5 µg/m³)	**0** (0%)
Alert	66-100% of the guideline, (14.5-22 µg/m³)	**0** (0%)
Total number of samples		**4** (100%)

The levels of Toluene and Xylene obtained in the current work are far below ambient guideline values, and all results fall into 'excellent' Ministry's air quality category. Two of the four benzene results were within 'excellent' MfE's category and another two results fell within the 'good' category.

The Council has previously undertaken BTEX monitoring in Taranaki region. The outcomes of those previous BTEX studies were discussed in the "Air monitoring survey of hydrocarbon compounds (BTEX) in the Taranaki Region" report which may be found at http://www.trc.govt.nz/assets/Publications/state-of-the-environment-monitoring/environmental-monitoring-technical-reports/1262809w.pdf

One additional BTEX monitoring was undertaken in year 2014 at Bell Block Bypass. The discussions of the results of this monitoring may also be found at http://www.trc.govt.nz/assets/Publications/state-of-the-environment-monitoring/environmental-monitoring-technical-reports/1368892.pdf

2. Nitrogen Oxides (NOx)

2.1 Measurement of nitrogen oxides

The Taranaki Regional Council has been monitoring nitrogen oxides (NOx) in the Taranaki region since 1993 using passive absorption discs. Research to date indicates that this is an accurate method, with benefits of simplicity of use and relatively low cost. To date more than 500 samplers of nitrogen oxides have been collected in Taranaki region. Discs are sent to EUROFINS ELS Ltd. Lower Hutt for analysis. Passive absorption discs are placed at the nominated sites. The gases diffuse into the discs and any target gases (nitrogen dioxide or others) are captured.

Ambient Nitrogen Oxides (NOx) monitoring was conducted from 26 January to 16 February 2015 at four stationary sites spaced evenly on four corners of the Northgate and Mangorei Road intersection near the NPGHS.

Nitrogen oxides (NOx), a mixture of nitrous oxide (N2O), nitric oxide (NO) and nitrogen dioxide (NO2), are produced from natural sources, motor vehicles and other fuel combustion processes. Indoor domestic appliances (gas stoves, gas or wood heaters) can also be significant sources of nitrogen oxides, particularly in areas that are poorly ventilated. NO and NO2 are of interest because of potential effects on human health.

Nitric oxide is colourless and odourless and is oxidised in the atmosphere to form nitrogen dioxide. Nitrogen dioxide is an odorous, brown, acidic, highly corrosive gas that can affect our health and environment. Nitrogen oxides are critical components of photochemical smog – nitrogen dioxide produces the yellowish-brown colour of the smog.

2.2 Environmental and health effects of nitrogen oxides

Nitrogen dioxide is harmful to vegetation, can fade and discolour fabrics, reduce visibility, and react with surfaces and furnishings. Vegetation exposure to high levels of nitrogen dioxide can be identified by damage to foliage, decreased growth or reduced crop yield.

Nitric oxide does not significantly affect human health. On the other hand, elevated levels of nitrogen dioxide cause damage to the mechanisms that protect the human respiratory tract and can increase a person's susceptibility to, and the severity of, respiratory infections and asthma. Long-term exposure to high levels of nitrogen dioxide can cause chronic lung disease. It may also affect sensory perception, for example, by reducing a person's ability to smell an odour.

2.3 National Environmental Standards and guidelines

In 2004, National Environmental Standards (NES) for ambient (outdoor) air quality were introduced in New Zealand to provide a guaranteed level of protection for the health of New Zealanders. The national standard for the nitrogen dioxide (NO2) is set out below.

In any 1-hour period, the average concentration of nitrogen dioxide in the air should not be more than 200 $\mu g/m^3$.

Before the introduction of the NES, air quality was measured against the national air quality guidelines. The national guidelines were developed in 1994 and revised in 2002 following a comprehensive review of international and national research and remain relevant. The national guideline for the nitrogen dioxide (NO2) is set out below.

In any 24-hour period, the average concentration of nitrogen dioxide in the air should not be more than 100 $\mu g/m^3$.

2.4 Conversion of exposure result to standardised exposure time period

From the average concentration measured, it is possible to calculate a theoretical maximum daily or one hour concentrations that may have occurred during the exposure period. Council data on NOx is gathered over a time period other than exactly 24 hours or one hour. There are mathematical equations used by air quality scientists to predict the maximum concentrations over varying time periods. These are somewhat empirical, in that they take little account of local topography, micro-climates, diurnal variation, etc. Nevertheless, they are applied conservatively and have some recognition of validity.

One formula in general use is of the form:

$$C(t_2) = C(t_1) \times \left(\frac{t_1}{t_2}\right)^P$$

where C(t) = the average concentration during the time interval t, and p = a factor lying between 0.17 and 0.20. When converting from longer time periods to shorter time periods, using p = 0.20 gives the most conservative estimate (i.e. the highest calculated result for time period t_2 given a measured concentration for time period t_1). Using the 'worst case' factor of p = 0.20, the monitoring data reported above has been converted to equivalent 'maximum' 1-hour and 'maximum'24-hour exposure levels.

2.5 Results

Table 3 presents the actual levels found and theoretical maximum daily and hourly concentration of NOx.

Table 3 Actual (laboratory) and recalculated ambient NOx results, NES and MfE guideline.

Site code	Site description	NOx (µg/m³) Lab. results	NOx/1hr (µg/m³) (Theoretical maximum)	NOx/24hr (µg/m³) (Theoretical maximum)
AIR000012	NW crn of the intersection	7.5	26.0	13.8
AIR000012	NE crn of the intersection	5.4	18.7	9.9
AIR000012	SW crn of the intersection	6.2	21.5	11.4
AIR000012	SE crn of the intersection	8.2	28.5	15.1
National Environmental Standard (NES)* and MfE guideline**			**200***	**100****

2.6 Discussion

The calculated 1-hour and 24-hour theoretical maximum concentrations (using a power law exponent of 0.2) for the four monitoring sites are similar and ranged from 18.7 µg/m³ to 28.5 µg/m³ and 9.9 µg/m³ to 15.1 µg/m³ respectively. Comparable results have been found in other studies previously at sites beside major highways in Taranaki region. All values found in this study were well within the NES and Ministry for the Environment Ambient Air Quality Guidelines being about 12% of both limits.

2.7 Environmental Performance Indicator

Ministry for the Environment uses an environmental performance indicator to categorise air quality. These categories are set out in Table 4 and further details of the NOx results are set out in Table 5.

Table 4 Environmental Performance Indicator air quality categories

Measured value	Less than 10% of guideline	10-33% of guideline	33-66% of guideline	66-100% of guideline	More than 100% of guideline
Category	*excellent*	*good*	*acceptable*	*alert*	*action*

Table 5 Categorisation of NOx results

National Environmental Standard for NO2 = 200 µg/m³ - 1 hour average		
Category	**Measured values**	
Excellent	<10% of the guideline, (0-20 µg/m³)	**1** (25%)
Good	10-33% of the guideline, (20-66 µg/m³)	**3** (75 %)
Acceptable	33-66% of the guideline, (66-132 µg/m³)	**0** (0%)
Alert	66-100% of the guideline, (132-200 µg/m³)	**0** (0%)
Total number of samples		**4** (100%)

The monitoring showed that 100% of the 1-hour average results fell into Ministry's 'good' and 'excellent' category. This continues the pattern found in previous years at other sites.

The Council has previously undertaken NOx monitoring in Taranaki region. The outcomes of those previous NOx studies were discussed in the "Monitoring of nitrogen oxides (NOx) levels in Taranaki, year 2011-12" report which may be found at http://www.trc.govt.nz/assets/Publications/state-of-the-environment-monitoring/environmental-monitoring-technical-reports/NOxMonitoring11-2.pdf

And also in the "Monitoring of nitrogen oxides (NOx) levels in Taranaki near the NOx emitting sites, year 2014-2015" report which may also be found at http://www.trc.govt.nz/assets/Publications/state-of-the-environment-monitoring/environmental-monitoring-technical-reports/1541533.pdf

3. Carbon monoxide (CO)

Carbon monoxide (CO) monitoring was carried out in January, February and March 2015, on five occasions by the Taranaki Regional Council with the total recorded time of 340 hours. During this monitoring period a QRAE multi-gas analyser was used. The location of the monitoring site is shown in Figure 1.

Carbon monoxide (CO) is a colourless, odourless gas, which has potential to be poisonous to humans if they are exposed to high concentrations. Many natural processes produce CO, including fires, eruptions and metabolic processes of some organisms. Of most concern however is the production of CO by human activities, in particular from vehicles. The most significant source of CO is from motor vehicles, and anywhere where there is a large concentration of vehicles such as car parks, tunnels, motorways and bushy urban areas can potentially accumulate high concentrations of CO. Motor vehicles are the major producers of CO in Taranaki.

3.1 National Environmental Standards and guidelines

In 2004, National Environmental Standards (NES) for ambient (outdoor) air quality were introduced in New Zealand to provide a guaranteed level of protection for the health of New Zealanders. The national standard for the carbon monoxide (CO) is set out below.

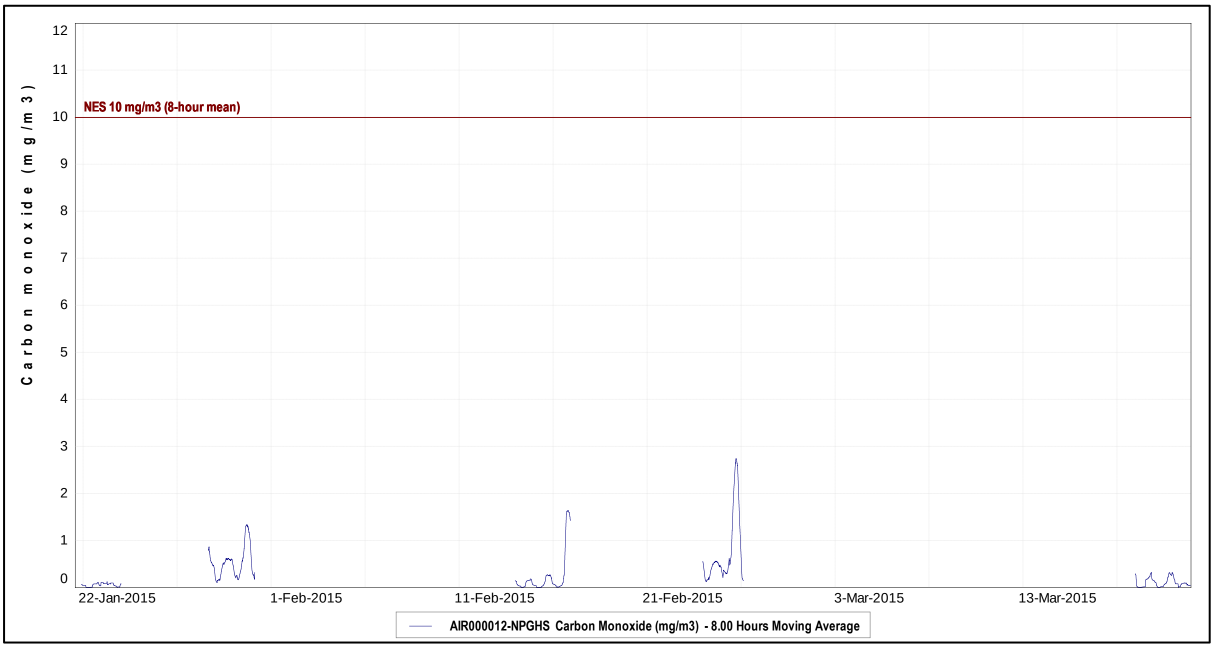
In any 8-hour period, the running average concentration of carbon monoxide in the air should not be more than 10 mg/m^3.

Before the introduction of the NES, air quality was measured against the national air quality guidelines. The national guidelines were developed in 1994 and revised in 2002 following a comprehensive review of international and national research and remain relevant. The national guideline for the carbon monoxide (CO) is set out below.

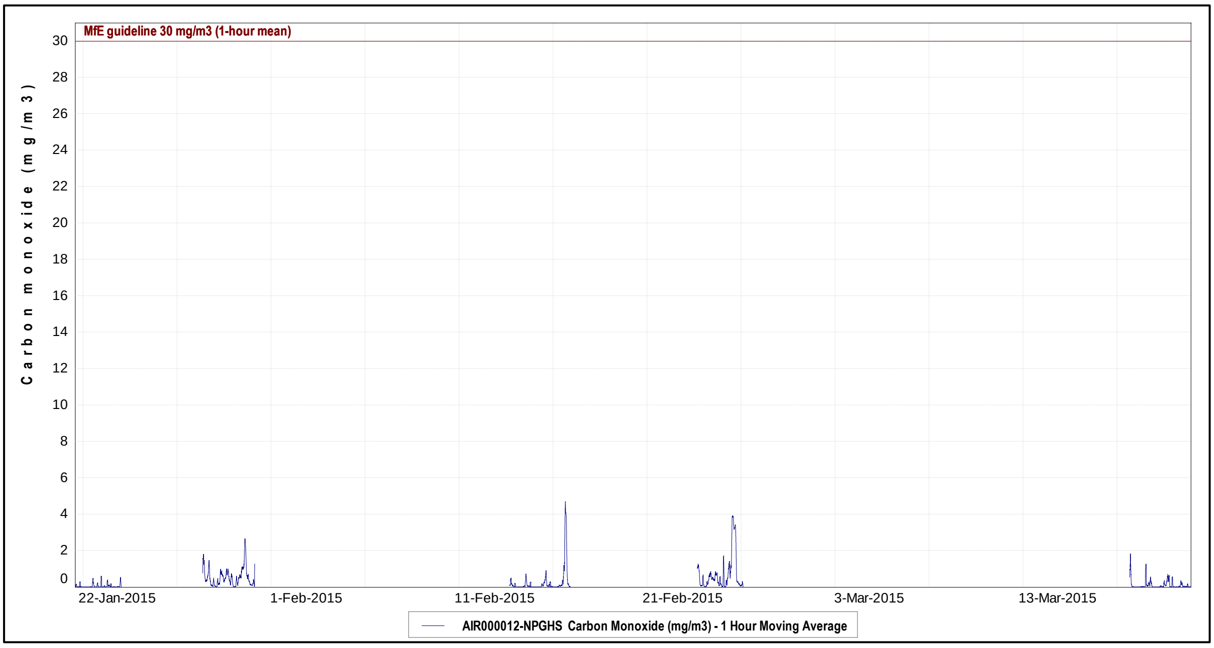
In any 1-hour period, the average concentration of carbon monoxide in the air should not be more than 30 mg/m^3.

3.2 Results

The details of the carbon monoxide monitoring with relative National Environmental Standard and Ministry for the Environment guideline are graphically presented on Graph 1 and Graph 2.



Graph 1 Carbon monoxide levels (8-hour mean) with NES at NPGHS



Graph 2 Carbon monoxide levels (1-hour mean) with MfE guideline at NPGHS.

3.3 Discussion and Environmental Performance Indicator

Analysis of the average carbon monoxide concentrations shows that the highest data point on the 1-hour average graph reached only 4.7 mg/m3 or 15.6% and on the 8-hours moving average graph reached only 2.7 mg/m3 or 27% of the Ministry's guidelines.
This continues the pattern found in previous years.

Based on the Ministry for the Environment's categories for air quality, the quality of air at New Plymouth Girls High School near the major road realignment works can be characterised as 'excellent' in respect to the levels of carbon monoxide.