Model Verification
The Case Against

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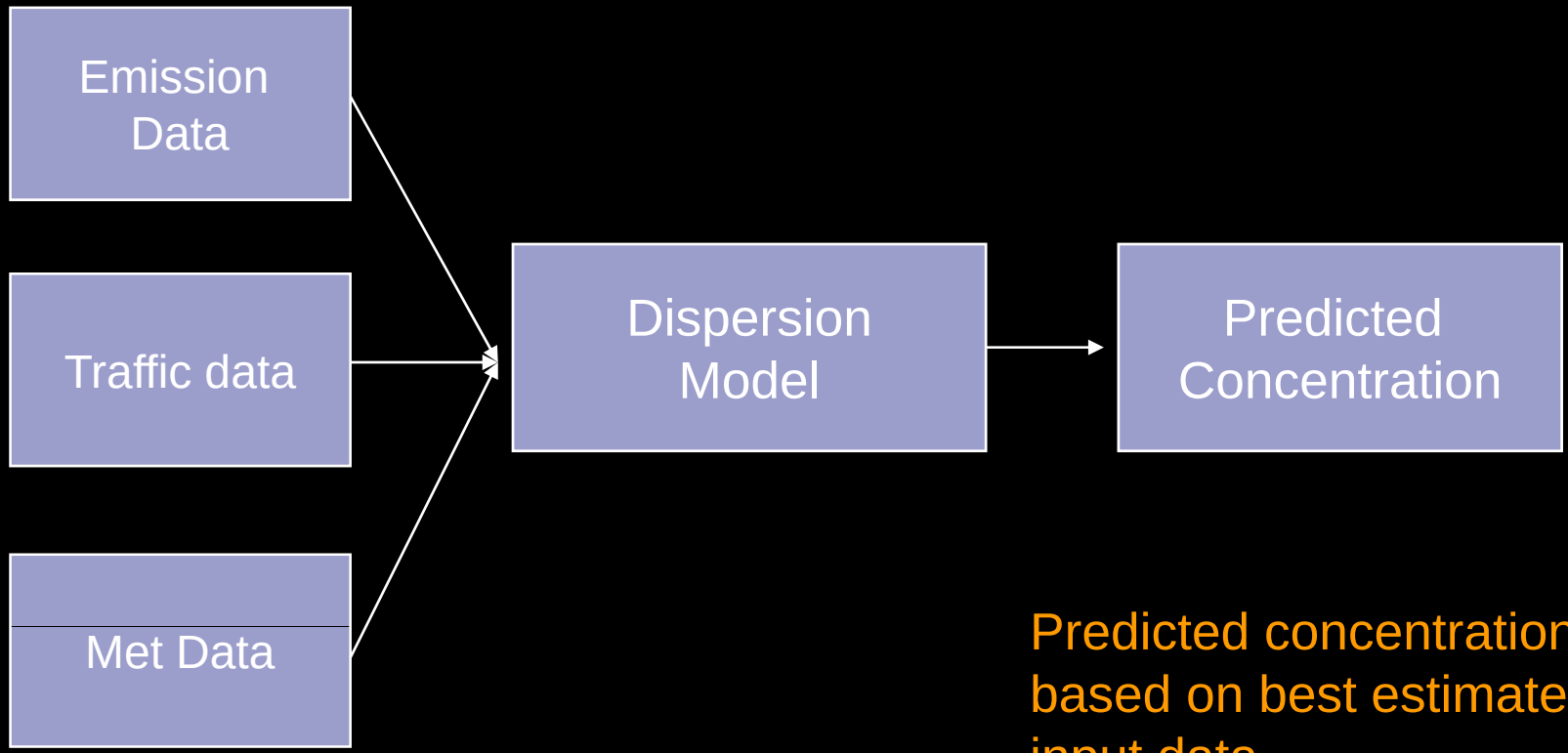
Accuracy in Dispersion Modelling

- Widely acknowledged that dispersion modelling is not a process that can be expected to be 100% accurate
- Inaccuracies arise from the model itself but also from the data used as model input
  - Emission data
  - Meteorological data
  - Traffic volume data
  - Traffic composition
  - Traffic speed
  - Pollution contributions from sources not included in the model including background concentrations

Current Approach to Dispersion Modelling



Predicted concentrations based on best estimate input data

Best Estimate Values

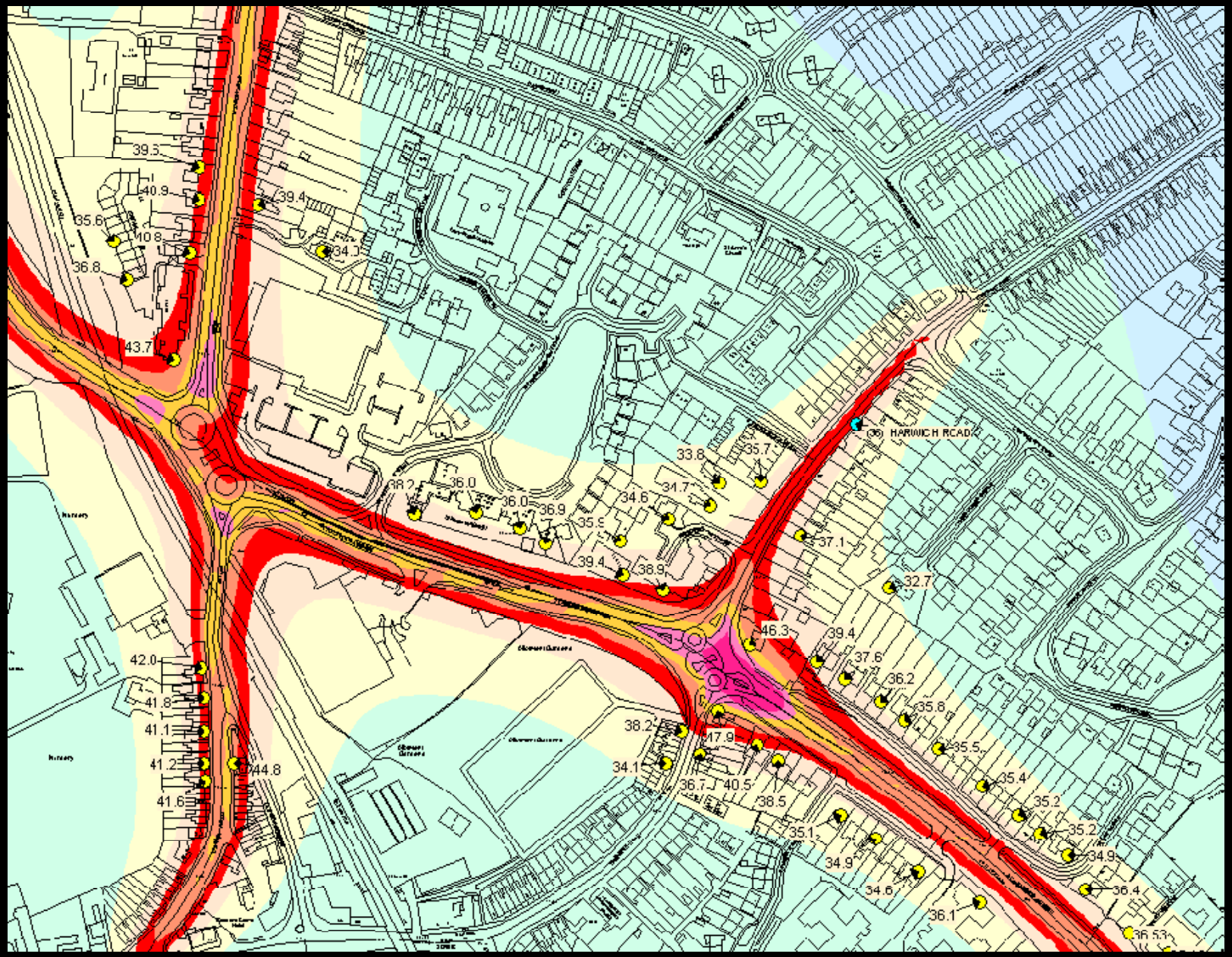
Model Verification - Summary

- Modelled results are compared with suitable monitoring data
- Where significant deviation from observed NO_2 values is noted, then model verification is recommended to adjust the modelled road NOx contribution
- Adjustment assumes a linear relationship between monitored and modelled concentrations and an intercept of zero

So What's Wrong With That?!

Approach assumes the existence of a systematic error

- The model verification process assumes that reasons for differences between modelled and monitored results are the same over the model domain
- Highly improbable this is the case for many of the factors that could give rise to differences
  - e.g. wind speed and direction, traffic speed, composition


HARWICH ROAD
39.5
40.9
39.4
35.6
40.8
34.5
36.8
43.7
33.8
35.7
34.7
34.6
37.1
32.7
46.3
39.4
37.6
36.2
35.8
35.5
35.4
35.2
35.2
34.9
36.4
36.1
42.0
41.8
41.1
41.2
41.6
44.8
38.2
17.9
34.1
36.7
40.5
38.5
35.1
34.9
34.6

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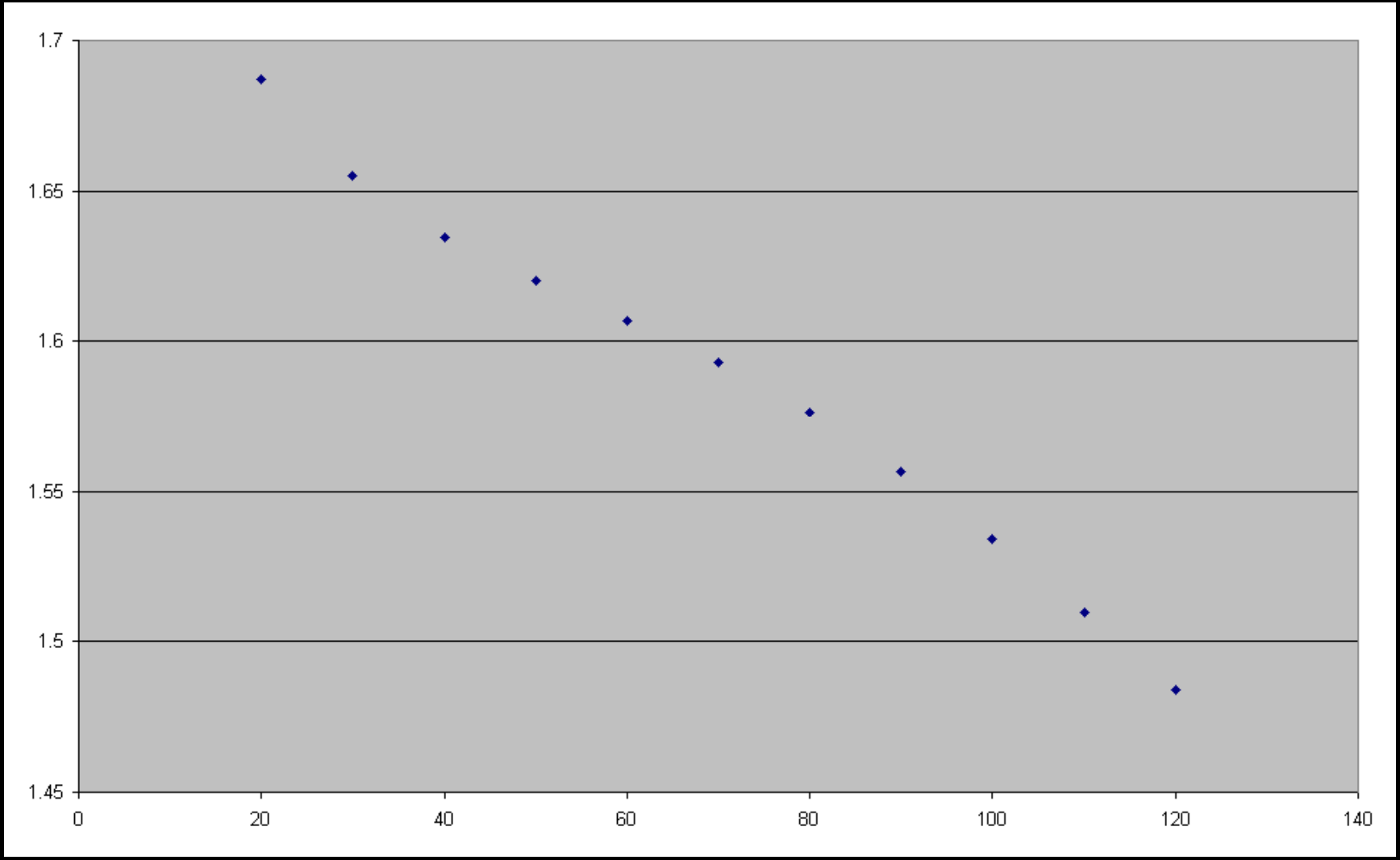
Approach assumes the existence of a systematic error

- The model verification process assumes that reasons for differences between modelled and monitored results are the same over the model domain
- Highly improbable this is the case for many of the factors that could give rise to differences
  - e.g. wind speed and direction, traffic speed, composition
- So many possible conflicting factors that could contribute to an error there can be little confidence these are “systematic” across the model domain

Approach assumes a linear relationship

- The TG(09) approach to model verification assumes that the correction factor is the same across the whole range of modelled concentrations
- No evidence to suggest that this is the case
- Many factors contributing to the observed differences could have different effects in different situations (e.g. vehicle speeds)
- Equally plausible another type of relationship would be more appropriate

Example – Change in relative emission rate with changing %HGV



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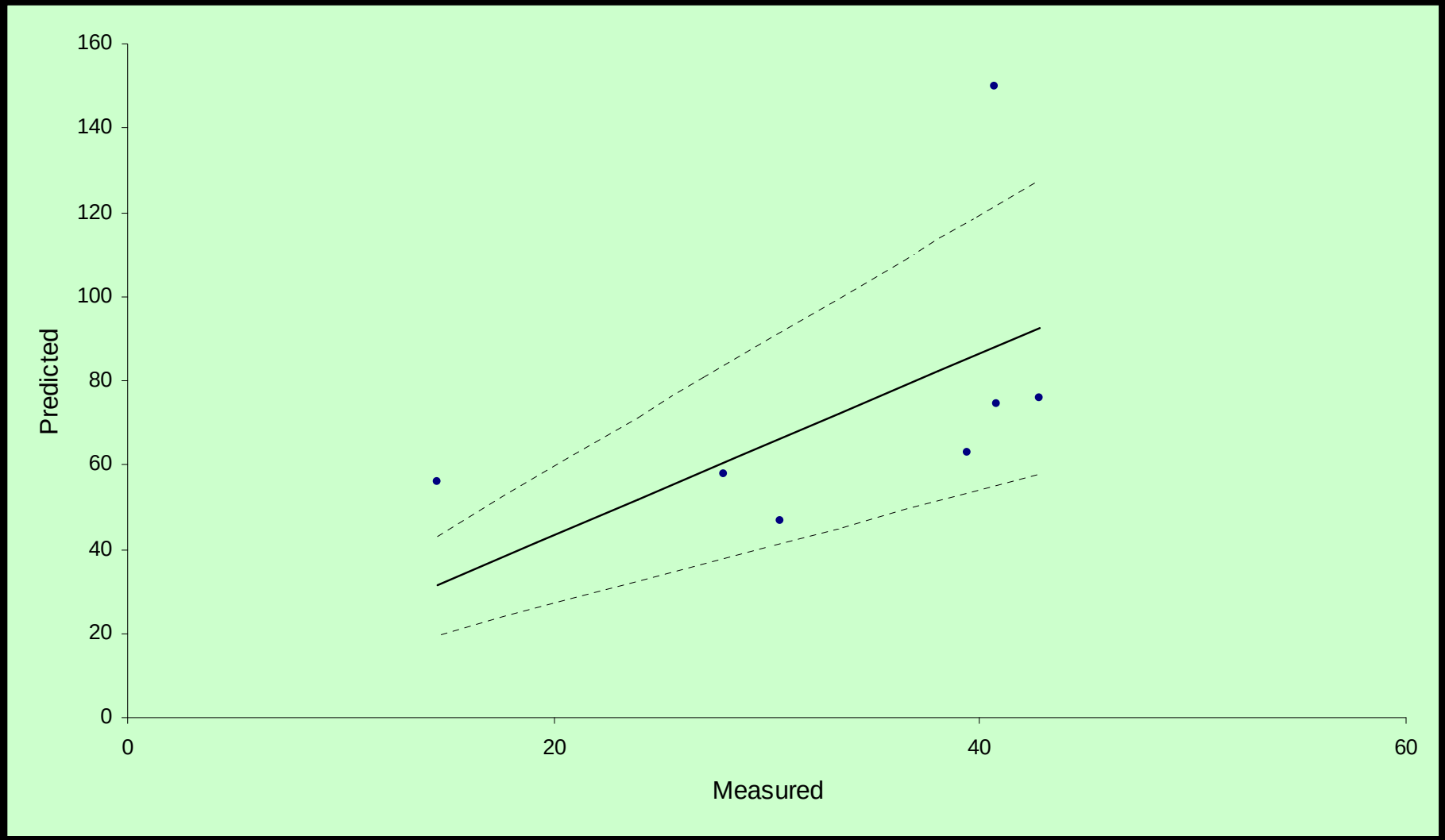
Only Likely Systematic Error is Excluded

- Forcing the regression line through zero assumes that there are no consistent residual errors
- Quite possible that background concentrations used in modelled are not correct
- If so, the intercept of the regression will not be zero

Inadequacy of available monitoring data

- Frequently very few monitoring sites available to use in model verification
- Unlikely to have more than one continuous site except in large city studies
- Commonplace to find verification undertaken using between 5 and 10 measurements
- Confidence intervals of resulting regression line can be large
- Is difficult to have confidence in the resulting regression line

95% Confidence Limits on Verification Regression



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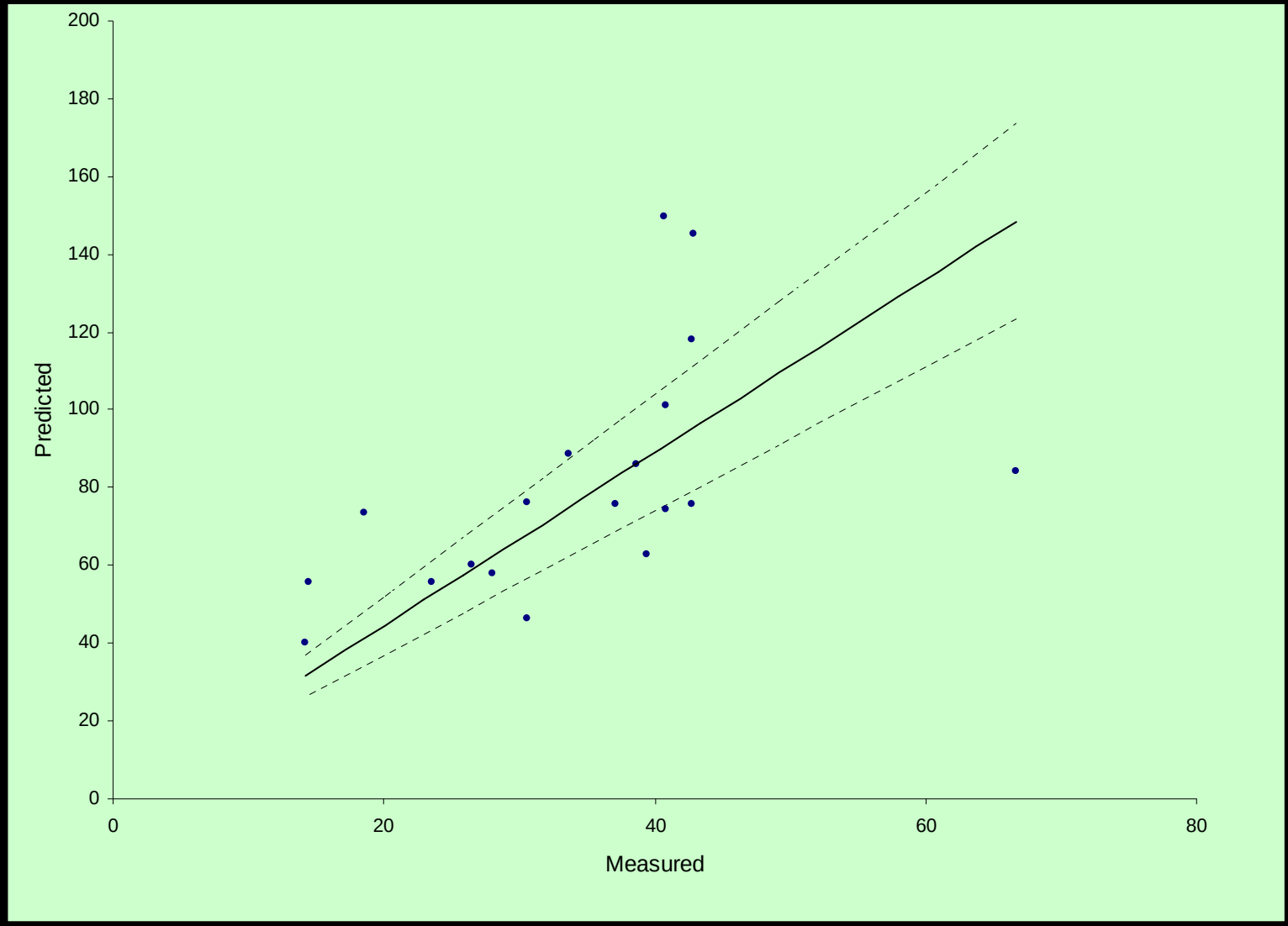
More data points



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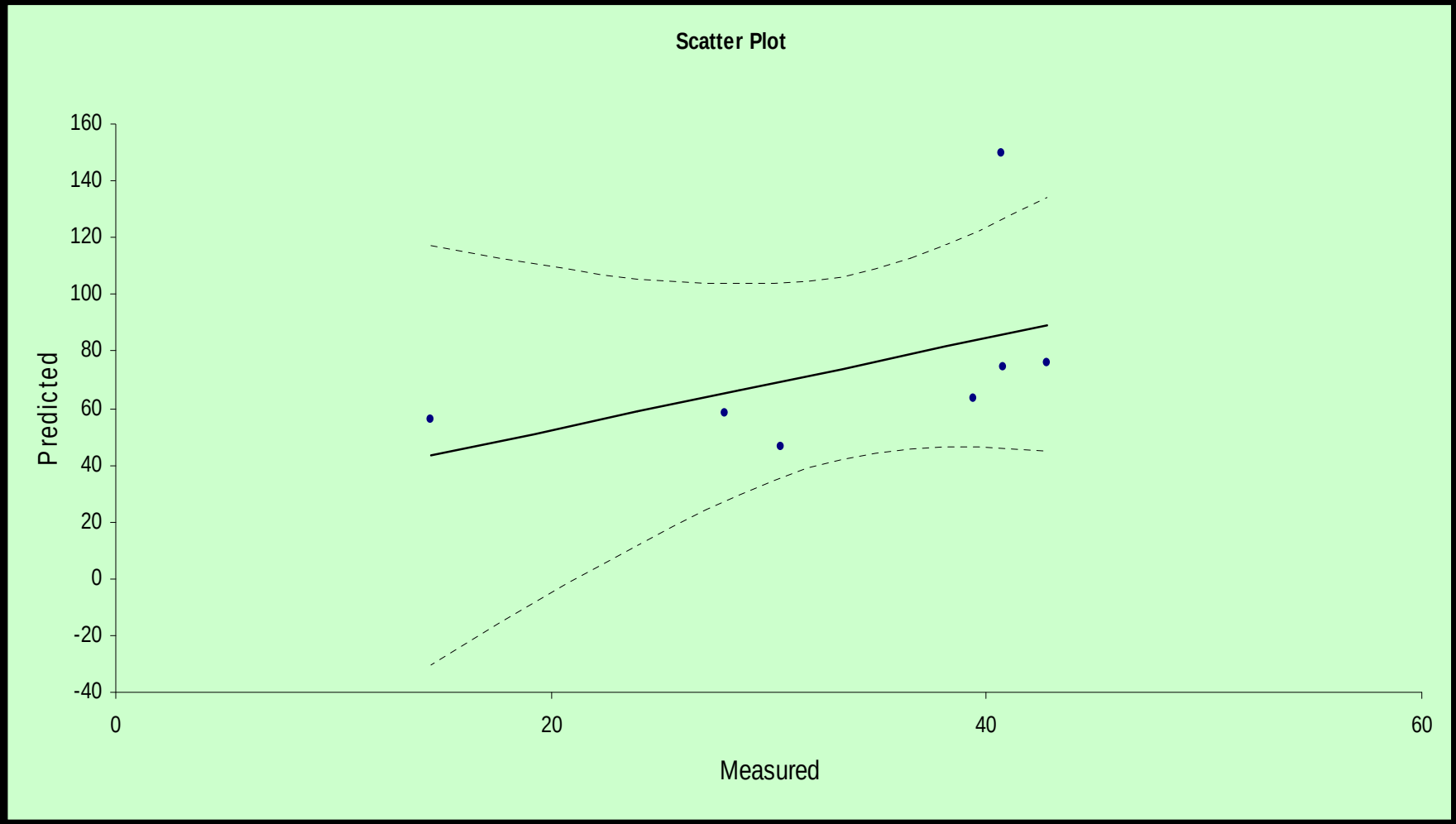
What if the intercept isn't set to equal zero?



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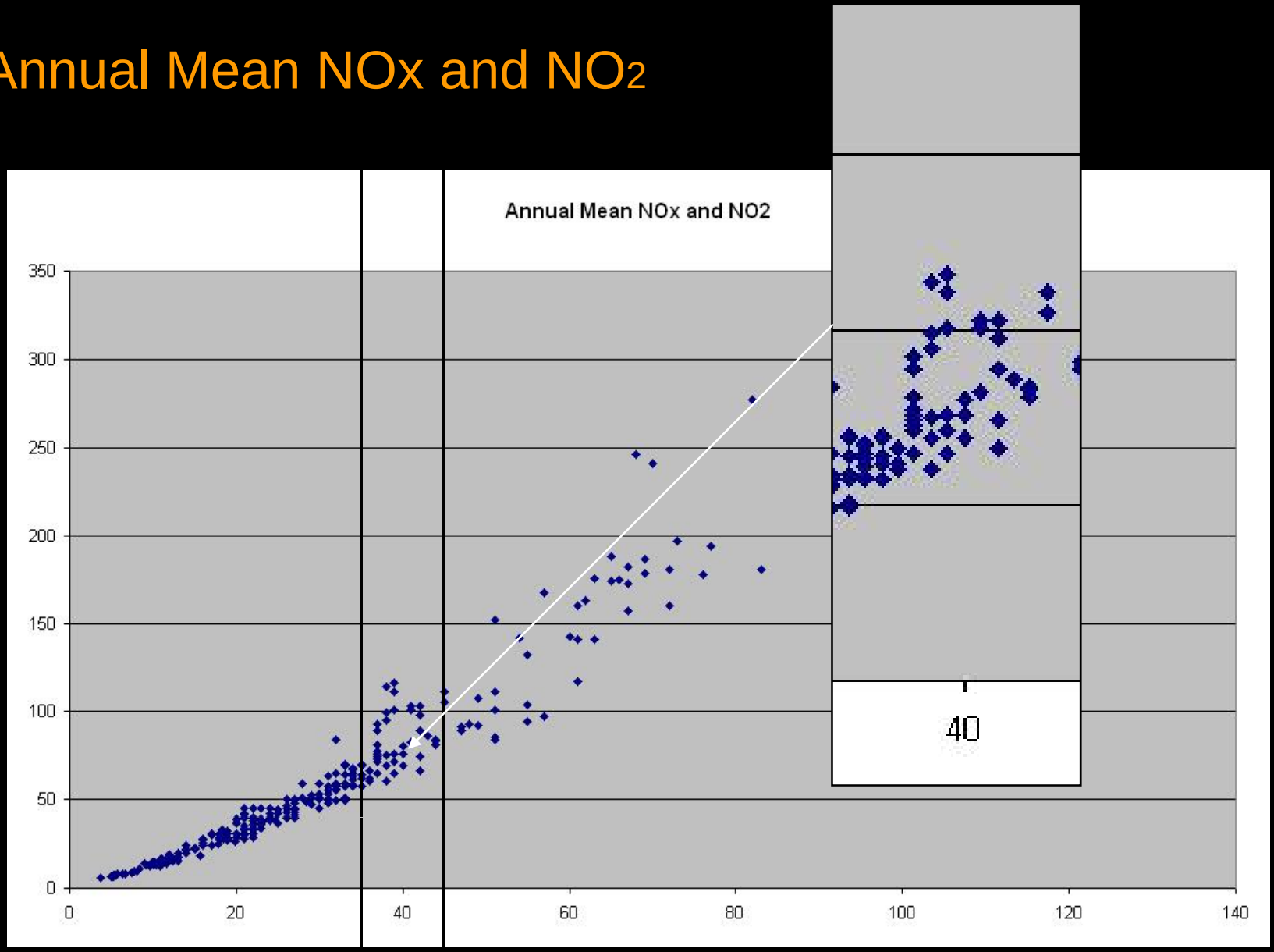
Use of NO_2 monitoring results to derive NOx concentrations

- Guidance recommends that verification is generally done with NOx rather than NO_2
- Diffusion tube measure NO_2 and hence NOx concentrations must be estimated
- Considerable potential range in estimated NOx concentrations

Annual Mean NOx and NO_2



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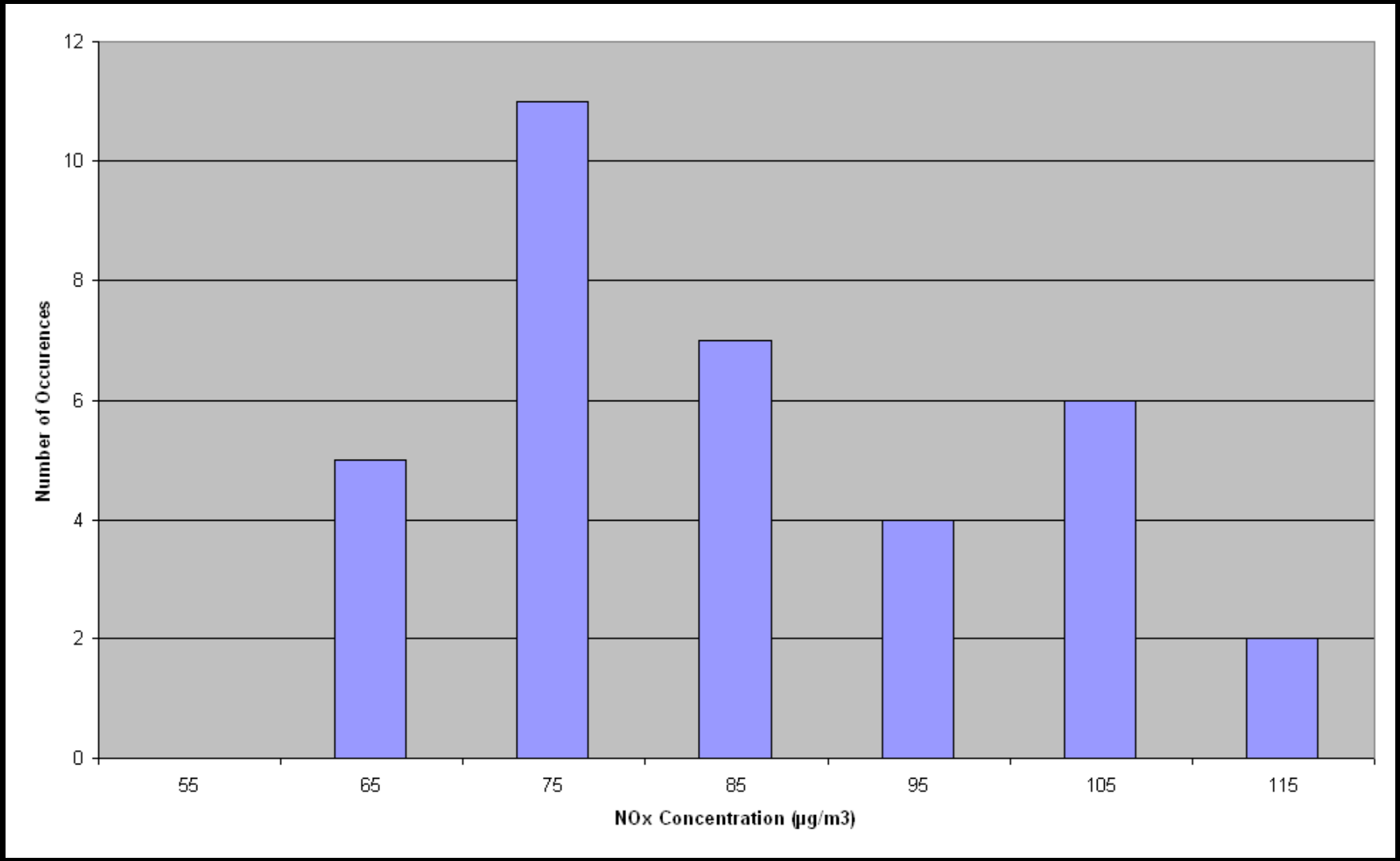
Frequency of observed NOx values: NO_2 36-42µg/m^3



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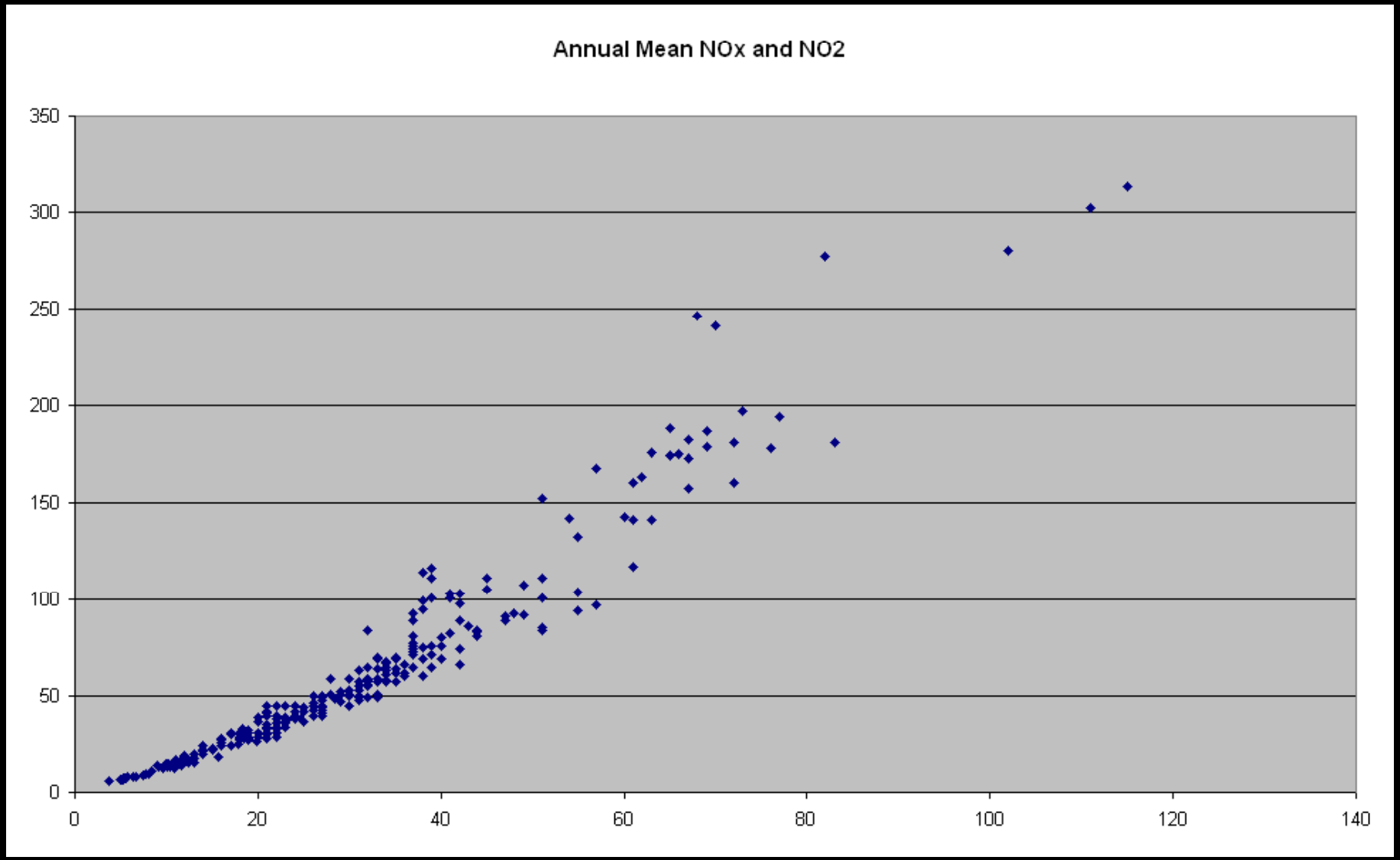
Example from Table 4 of TG09 – Site 8

	Monitored NO_2	Monitored NOx	Monitored Road NO_2 Contribution	Monitored Road NOx Contribution	Modelled Road NOx	Monitored /Modelled
TG09 Conversion	38.6	92.4	20.3	67.8	34.1	1.99
Lower extreme	38.6	60	20.3	35.4	34.1	1.04
Upper extreme	38.6	116	20.3	91.4	34.1	2.68

Approach assumes monitored values are correct

- Most model verification is done using diffusion tube data
- Diffusion tube data is not accurate –considered that it is ±20% of the true value
- Combine this level of uncertainty with potential conversion errors and the range in possible associated NOx values increases further


Annual Mean NOx and NO2
350
300
250
200
150
100
50
0
0
20
40
60
80
100
120
140

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Model verification attempts to impose certainty on an uncertain situation

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Model Verification Also Masks Poor Practice

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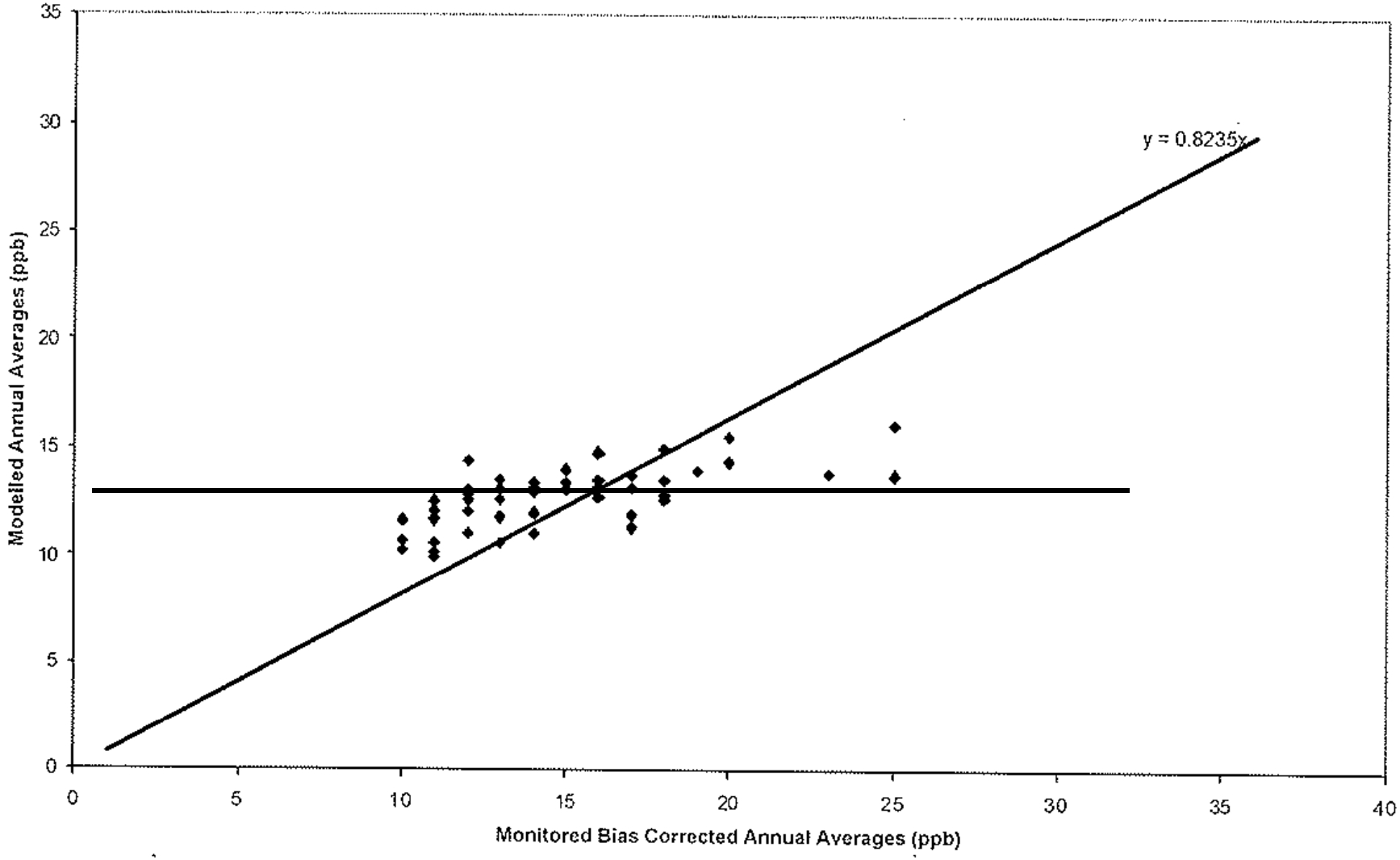
y = 0.8235x
Modelled Annual Averages (ppb)
Monitored Bias Corrected Annual Averages (ppb)
0
5
10
15
20
25
30
35
40

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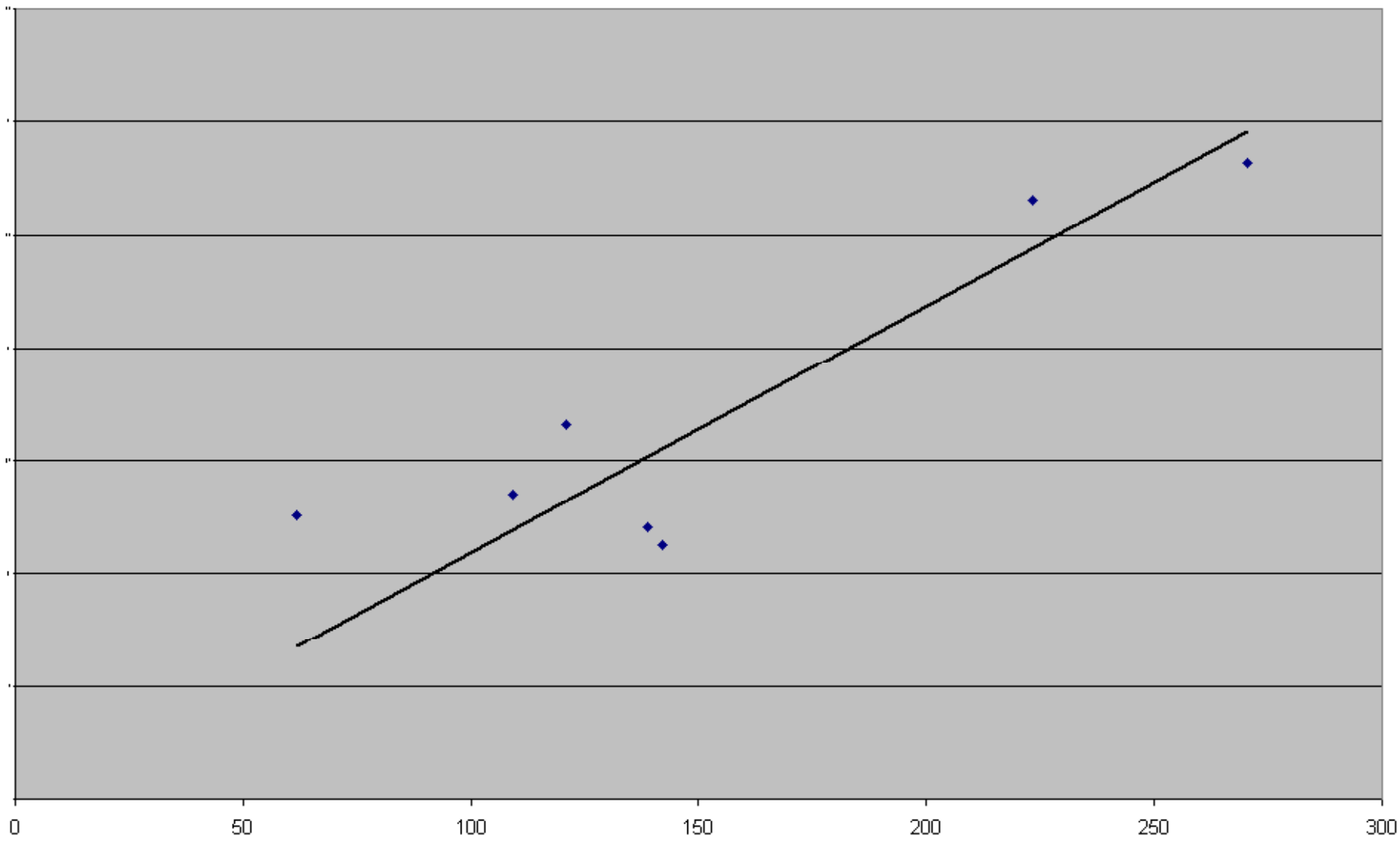

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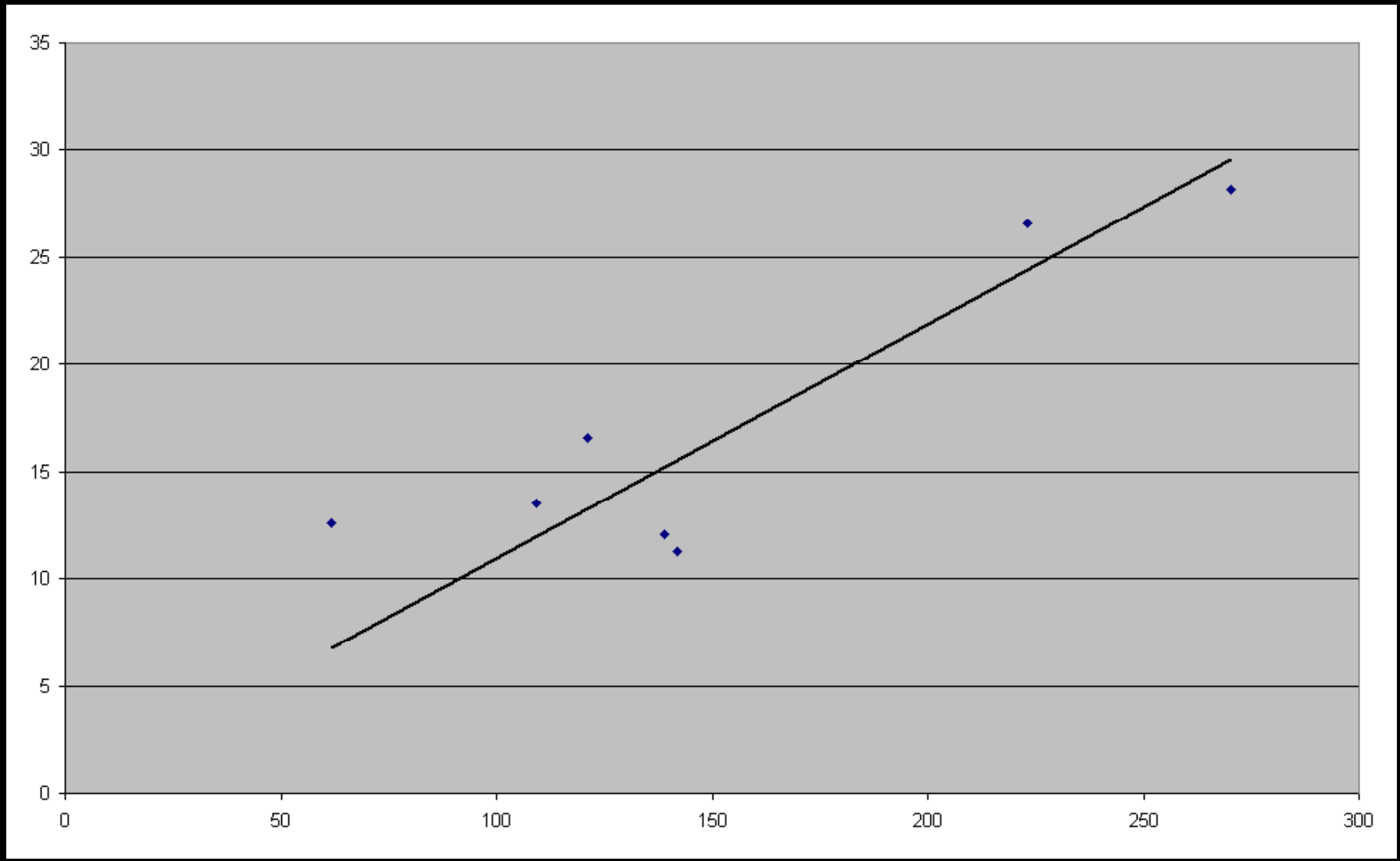

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The Process of Model Verification has …….

Taken these numbers

Monitored NOx	Modelled NOx
223.2	26.6
109.3	13.5
138.8	12.1
61.8	12.6
270.4	28.2
142.0	11.3
121.0	16.6

Monitored NO2	Modelled NO2
57.7	57.8
44.7	45.5
48.6	43.7
37.3	44.4
61.8	59.2
49	42.8
46.3	48.9

And given us these

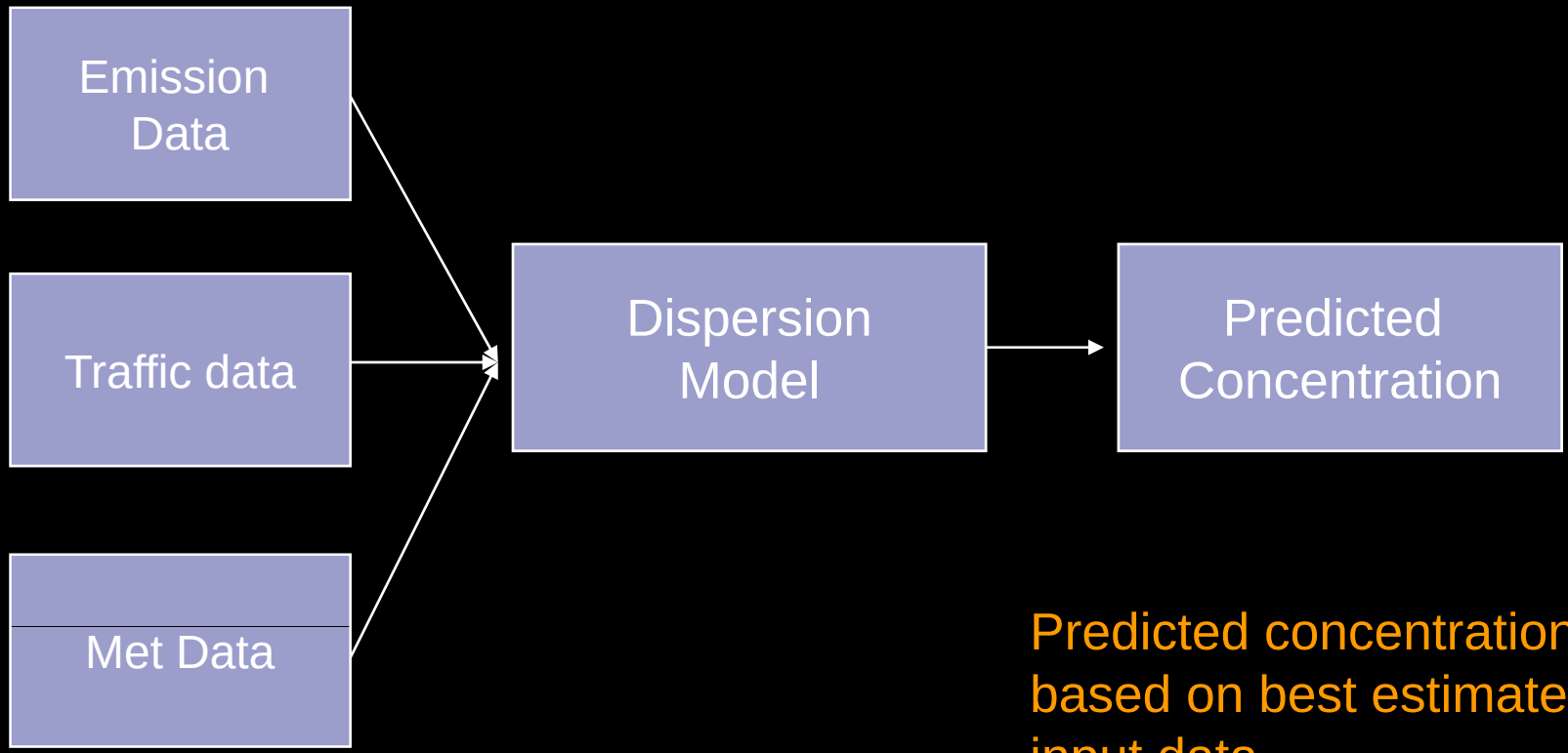
Changes an average over-prediction of 850% into an average under-prediction of 1%

The model verification process will inevitably give good average predictions whatever the input

Does Model Verification Sometimes Hide Poor Modelling?

- High correction factors suggest that either the model was unsuitable for the area or the model wasn't set up correctly
- Although the Technical Guidance suggests that the model inputs should be reviewed prior to model adjustment – there's little evidence this is done in a comprehensive manner
- Provided with an example where a 12 times underprediction was removed when a detailed investigation was made of the model inputs and set-up
- At present, high correction factors appear acceptable – factors above 10 are not uncommon

Current Approach to Dispersion Modelling



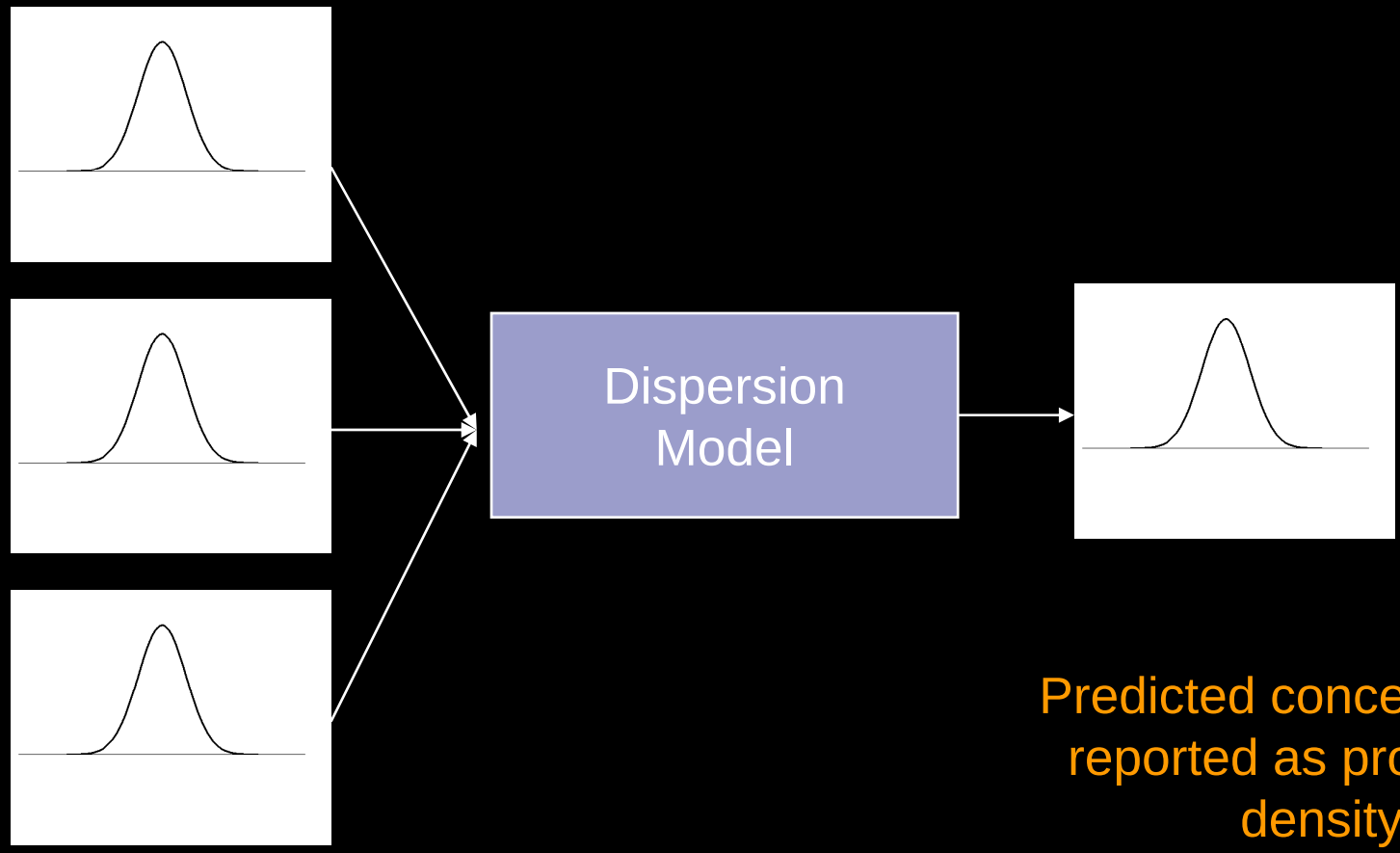
Predicted concentrations based on best estimate input data

Best Estimate Values

Input errors

- Modelling approach uses best estimate values for input data
- In reality many variable are uncertain and inputs could be better represented as probability distributions
- Probabilistic approach would actually give a better estimate of the most likely value

Probabilistic Approach to Dispersion Modelling



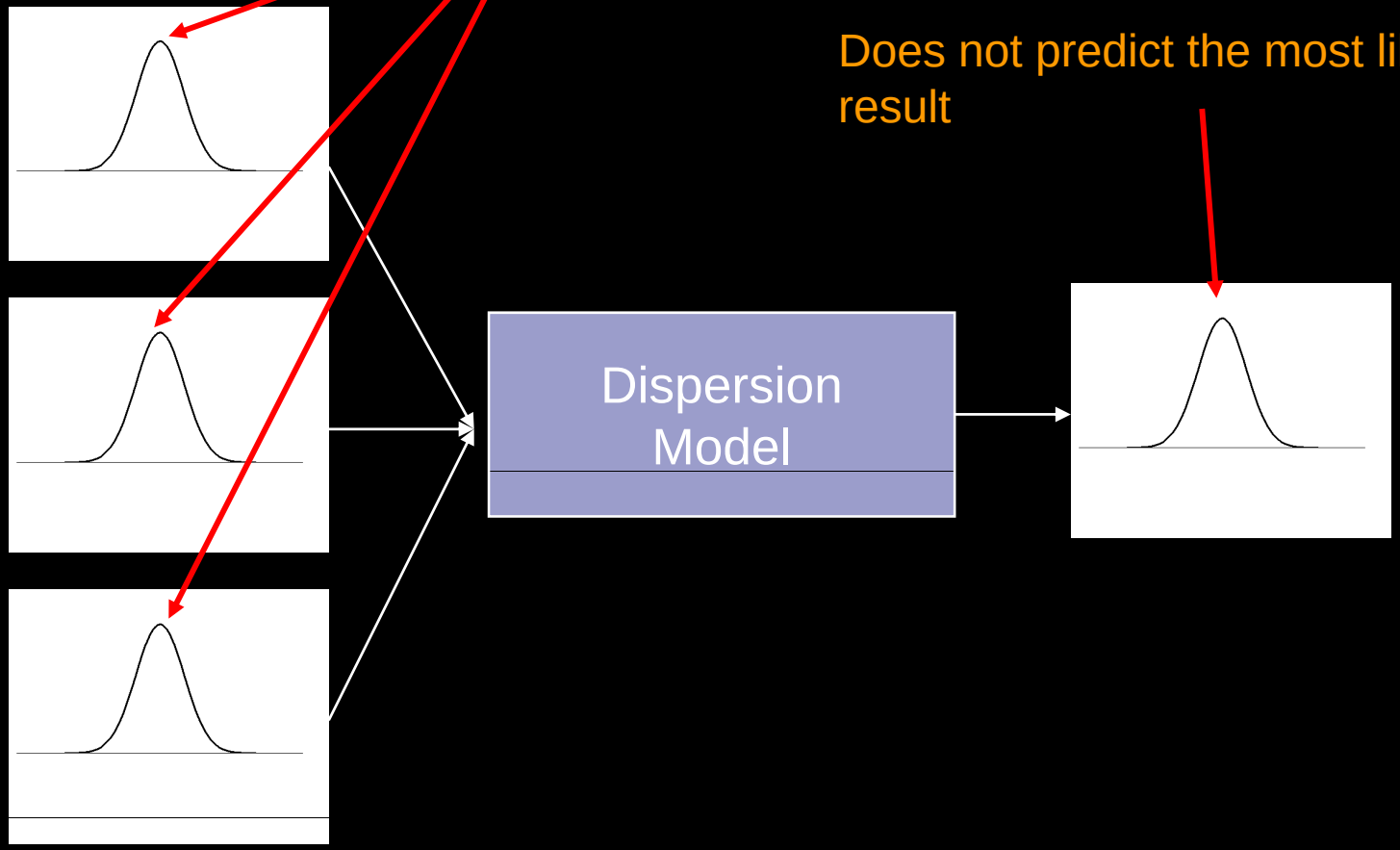
Inputs based on probability densities

Predicted concentrations reported as probability density

Probabilistic Approach to Dispersion Modelling

Using the most likely value as a single input to the dispersion model

Does not predict the most likely result



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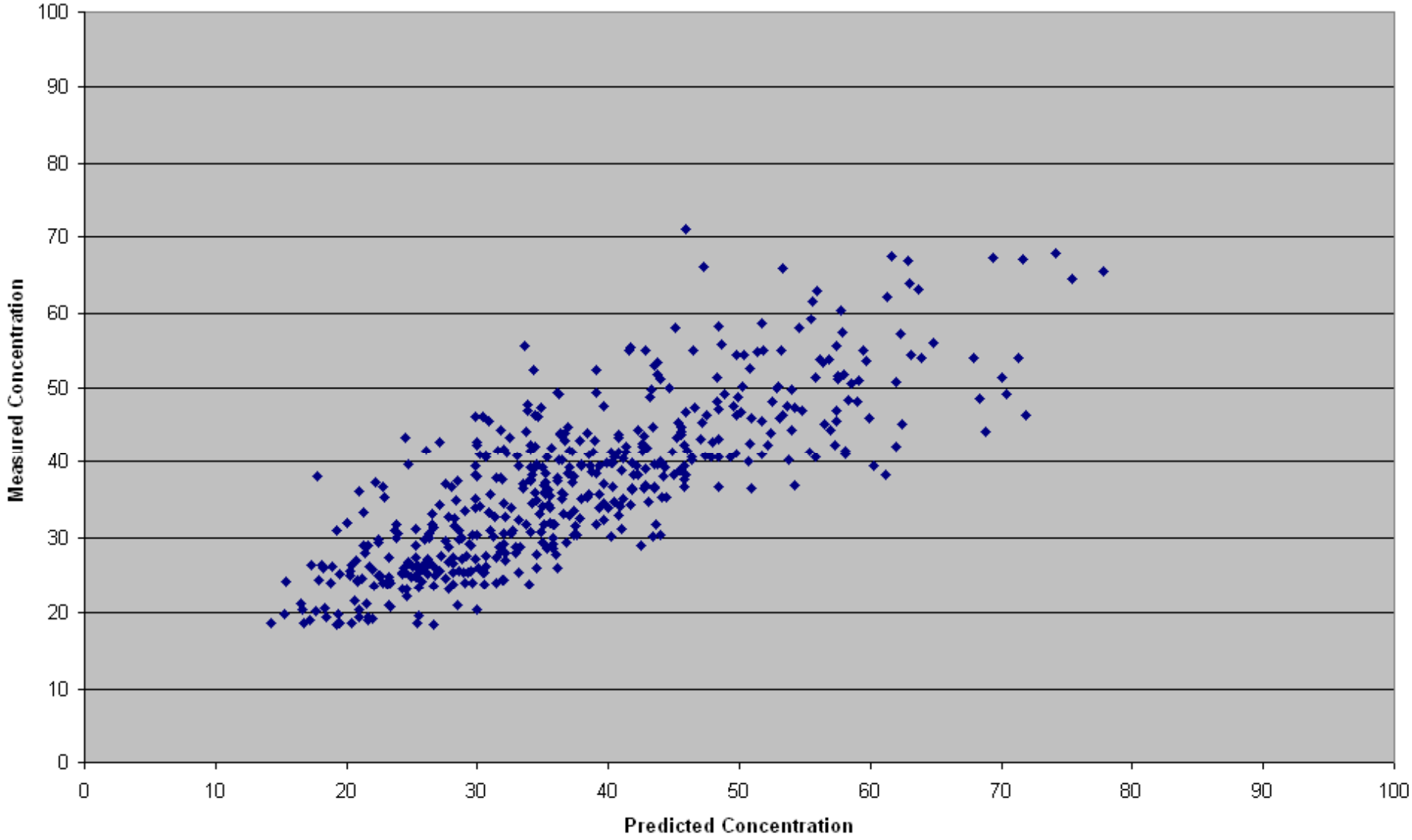
Should we be surprised with the situation?!

- Both modelling and monitored data will have inherent errors
- Monitored data ±20%
- Error in modelling results higher


Measured Concentration
Predicted Concentration
0
10
20
30
40
50
60
70
80
90
100

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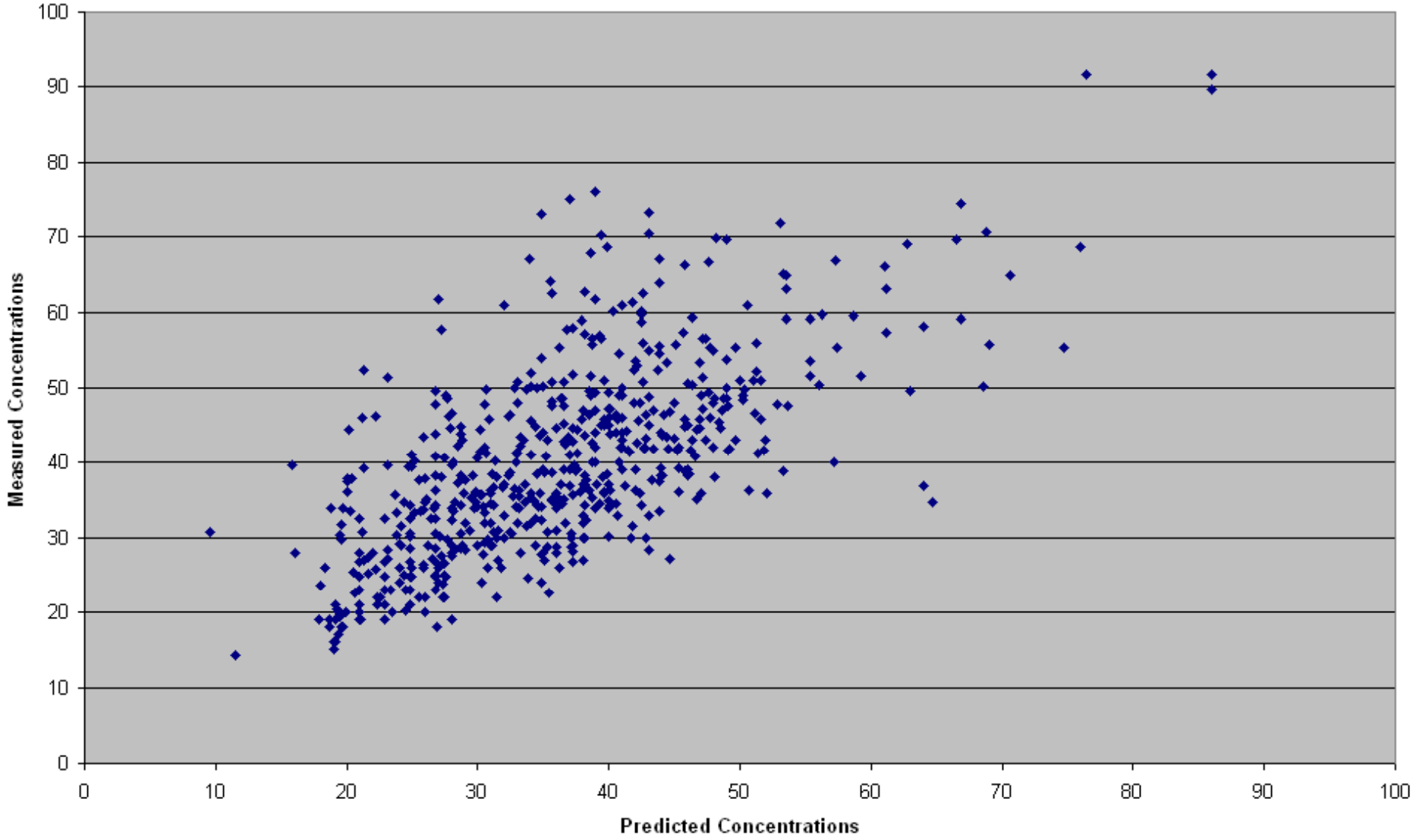
Measured Concentrations
Predicted Concentrations
0
10
20
30
40
50
60
70
80
90
100

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Summary

- Verification assumes an underlying systematic error
- Verification assumes an underlying linear relationship with an intercept of zero
- Rarely sufficient monitoring data points available to have confidence in the correction factors produced
- Process is generally reliant on monitoring data that itself is uncertain
- Process hides poor performance of modelling process and make acceptable results that may otherwise be discarded or investigated further
- Given known errors in modelling and monitoring data we should not be surprised with what we observe