FINAL REPORT ON IMPEL EXPERT TEAM / PROJECT(S)

1. Name of project/expert team

Safeguarding the Water Environment Throughout Europe (SWETE) 4

2. Reporting period

January 2018 to November 2018

3. Name project manager or expert team leader

Barrie Howe

4. Projects included in the expert team

5. Project approval

6. Project activities

a) Carried out to date since the start of the reporting period.

SWETE 4 focusses on a number of activities:

Establish Technical Working Groups

- Soil management and protection
- Agriculture and its impacts on the water environment
- Wastewater discharge regulation

Including workshops or study tours as appropriate.
eLearning on UK approaches to water discharge modelling to protect water quality and achieve Water Framework Directives.

Soil Management

As previously reported, this part of the project was put on hold as we were unable to get sufficient support from other member states. There are now two new soil protection project proposals for 2019/20 which may be part of SWETE. We are hopeful that these will have sufficient support if they are approved.

Agriculture and its impacts on the water environment

The workshop that was initially proposed has not been possible because of lack of resources. Our Danish project team ember has instead produced an eLearning 'good practice' package for assessing nutrient inputs to agricultural land. This was shown at the Zwolle conference and is being refined.

Water Discharge Modelling

We have recorded four eLearning lectures that explain the approach to water quality and discharge modelling in England, including explanations of the modelling packages that we use. These are being

reviewed and supporting information is being written. This should be complete by the end of November to mid-December. The project also includes undertaking a forward look exercise to develop proposals for future projects. These were discussed at the SWETE/Expert Team peer-meeting in Zwolle and the Expert Team meeting in Heraklion and are being progressed.
b) Expected before the end of the reporting period.
c) Planned after the reporting period.
Finalising the modelling eLearning.

7. Changes in the project

8. Human resources dedicated (person days)

From MS
27
From Commission

9. Products delivered

10. Expected final date for the project

15th December 2018

11. Date of this report

16th November 2018

12. Report prepared by:

Barrie Howe

Safeguarding the Water Environment Throughout Europe (SWETE)

Introduction to SWETE discharge regulation eLearning

SWETE is an IMPEL work programme that has been running since 2015. Its aims are:

1. Assist members to implement legislation
2. Build capacity in member organisations to help WFD implementation and improve aquatic environments and land quality.
3. Work on 'problem areas' of implementation identified by IMPEL, the European Commission and water management practitioners to share and/or develop good practice to help with these problem areas.

The project started with a focus on discharge regulation, with a survey of member organisations to get an understanding of regulatory approaches across Europe, problematic issues and to obtain examples of good practice. In 2016 the SWETE project team organized the IMPEL Land and Water conference which confirmed that wastewater discharge regulation was a subject area that members would like to continue to focus on. In 2017 the project hosted a workshop to discuss discharge regulation and obtain further examples of good practice and problematic areas, which were shared on IMPEL's website basecamp pages.

The workshop also identified areas for further work. One of these was Water Quality modelling - sharing tools and practices (via webinar) then create an on-line library for wider use. There was a particular interest in some of the approaches to modelling and water quality management used in England and it was agreed that this would be the subject of a future webinar.

The SWETE eLearning package provides this webinar, via four recorded presentations. Together these provide an excellent understanding of the approach to managing water quality and discharge regulation in England and the models and compliance tools that are used to support this. The package is accompanied by extensive notes and examples to help viewers understand the approaches and how to use the models.

The models include 'RQP' that can model the impact of single discharges and SIMCAT which is used multiple discharges across waterbodies and catchments. As well as modelling impacts of discharges, both can be used to calculate permit limits to protect and improve the aquatic environment. RQP also includes the mPER model which is used for permitting to achieve the new Water Framework Directive bioavailable metal environmental quality standards. The SWETE project team hope that members find the eLearning and models a useful resource. We would welcome feedback on any aspect of it to barrie.howe@environment-agency.gov.uk.

Protecting river quality – getting the sums right

1. I have worked with brilliant colleagues for more than 40 years on how to calculate and justify what must be done to protect or improve the quality of rivers. We have covered more than £30 billion of capital investment.

2. My software (RQP and SIMCAT) is still used for today's plans. It is enhanced whenever we face new types of pollution, if we learn of new ways of controlling threats, or if we have access to better data.

3. A sound calculation will always assess the confidence that its results are correct and not ruined by poor data. We can then choose the best balance between:

   - targeted actions for individual sites on a river;
   - national actions such as a ban on chemicals, imposing fixed standards on all discharges, or setting controls on the use of land.

4. How do we justify a need to persuade or insist that farmers, industry and others take action? How do we select the best mix of actions? My four presentations cover:

   - the type of standards and targets we must use (1);
   - how we identify the current or potential failures of standards (the red on a map) (2);
   - how pollution mixes into a river and can be controlled to meet standards for the downstream river (3);
   - doing this for the entire river and, as necessary, across all the rivers in our country, covering all of the many kinds of pollution (4).

5. The presentations stress the need to assess errors – the confidence that a standard is failed or that action is needed. We can then control the risk of bad decisions. We can also avoid over-elaborate calculations.

6. Good calculations make us effective when we:

   - examine the importance of issues and the need to act;
   - devise, influence and implement laws and policies;
   - set up and maintain helpful monitoring;
   - define standards for rivers and set up national targets of compliance;
   - choose actions that best meet local standards and national targets;
   - set up controls on pollution, and a fair basis for legal action if these are failed;
   - review progress over the years – and update our plans.

Standards

7. We may have monitored thousands of sites by taking regular samples. If we look, say, at three years of results for a pollutant in rivers, and plot a histogram for each site, we usually see that the shape of the histogram is similar across nearly all sites.

8. This means that if a site has a mean of X we have a good idea of the range of values that lie behind this. The range might, say, exceed 3X for 10-20 days in a year – days that might be more common in summer or winter, or more likely to occur in sequences than not.

9. This persistence in shapes and structure helps us work out:
   - what needs to be done;
   - the confidence that decisions are correct and will succeed;
   - sites or issues that require more elaborate monitoring or calculations.

10. We sometimes talk as if a standard is a concentration that must never be exceeded – an absolute limit. But standards deal not only with events, but with the risk they will happen. We must decide an acceptable risk that a level is exceeded.

11. It is easy to declare that a concentration should NEVER be exceeded. But there is a big difference between risks of 1 in a hundred, 1 in a thousand, or 1 in a million. With an absolute limit, each decision may sit at a different and unknown point on this range. This means that a different "standard" is used for every location. Bad decisions will result.

12. With absolute limits, assessments of failure will be biased by sampling rates – the more samples the tighter the standard. Action will be wasted on sites of low risk, and real problems will escape detection. We will get corrupt comparisons of nations and regions – penalising those that take more samples.

13. If we insist on absolute limits, we cannot work out correctly and honestly the conditions required to protect water quality using, say, legal permits for discharges to rivers. Polluters would be justified in objecting to such permits.

14. A minimum requirement is that a standard must be a summary statistic like an annual mean, or an annual percentile such as the 95 or 99-percentile. These embody setting particular risks that we see specified concentrations.

15. This use of a summary statistic is supported by the observation that a summary statistic for a site is linked to an underlying shape observed for that pollutant at nearly all sites. Achieving an annual mean gives a good idea of the range of values that contribute to it.

16. This standard is the simplest that allows a correct calculation of action to avoid failures. No hidden risks to rivers, nor unfair costs to industry, need stem from our calculations. And the impacts of limited data can be quantified correctly and used to help us take sensible decisions; and decide where more information is needed.

17. Where there is monitoring, we can assemble data on all sites of excellent quality and plot a histogram of, say, the annual means for a pollutant. The results might identify, say, an annual mean for which 90% of sites have excellent biology. This annual mean is a potential standard.

The data for these sites, and parallel data for sites with poorer biology, allows the calculation of the risk of not getting excellent biology, even if the standard is met.

18. This sort of standard is a summary statistic. It will embrace effects like toxicity but it may also be affected by other features. These may include a link to types of land use, or a correlation with other pollutants. There may also be supporting information from toxicology.

19. Some sites may face risks of rare events and huge concentrations. We use an annual mean standard to cover such risks by dragging the annual mean to a lower value where its shape suggests high values occur at an acceptably low frequency. (But we shall still need a background regime that deals with the risks of freak events or illegal activities).

20. An annual mean or percentile provides answers to:

a) what is the limit?
b) how often can it be exceeded?
c) over what period of time?
d) in how many of these periods of time?
e) what confidence of failure will lead to particular actions?

21. For item [e] the action might be legal. 95% confidence of failure accepts a risk of 5% that we take wrong action. Such a mistake is usually driven by the errors from monitoring.

22. For a failure that is merely noted, or which needs, say, action like increased monitoring, we might reduce the 95% to 50%. For a deadly threat to public health, we might demand less than 1% confidence of failure (and so respond dramatically to the first glimmer of a risk).

23. The level of sampling, and the resulting errors in estimates of things like the annual mean, dominates the risk of taking bad decisions. We must calculate these errors.

24. An annual mean from 36 samples may have errors of ±20%. For 12 samples this might be ±40%. Such errors can make it pointless to worry about other errors: we need not opt for elaborate calculations or more complex standards.

25. Continuous monitoring may be needed at sites that are precious or face abnormal risks. There may be cases where such monitoring is affordable everywhere. We need to take care in using short bits of such data to calculate things like an annual mean – how we merge 10,000 results from a cold wet day in January with the 11 samples taken during the rest of the year.

26. A standard once used for bathing waters was:

a) a level of 200 units
b) met for 95% of the time
c) over one summer
d) 50% confidence of failure leads to action
e) compliance is required for 19 summers in 20

27. Item (e), 19 summers in 20, means that (b) is actually tightened towards 99%, or that the level set by (a) is decreased from 200 to 100. The standard is also tightened by (d) – low confidence of failure for action.

28. The severity of the standard is dictated by the total effect of (a) to (e). If an item is not set, it will tend to vary from place to place or from time to time. This is the same as allowing variations to the standard's concentration.

29. For bathing waters, item (e) stems from the influence of weather, especially sunshine and storms. A better option is to average 3-5 summers – a line picked up in later years.

30. Work on toxicity may lead to a concentration that is declared "safe". If this is to be our standard, we must nail down how often the concentration can be exceeded. As a minimum we will have to set up something like an annual mean. In this, we take into account any degree of precaution that was built into the "safe" value – the "safety factors".

31. As mentioned above (15), we usually see that data used to set up an annual mean standard confirms an underlying shape to the data used to calculate the annual mean. This shape applies nearly everywhere. It is often a log-normal distribution.

32. This outcome simplifies the calculations of future action and helps assess compliance with a standard. Errors in assuming a log-normal distribution are nearly always trivial compared with those accepted with sampling rates.

33. Why choose an annual 90-percentile and not a mean? Probably because we feel a need to control variability, or that high values have toxic effects. But errors from sampling will be much bigger for things like a 90-percentile than for the corresponding annual mean.

34. You might prefer a more complex standard – one that specifies how many hours a high value may last and how often such events can be allowed to happen. You may want to simulate 50 years of minutes, hours and days in the life of a river. By all means include these details but retain the ability to calculate unbiased values of statistics such as the annual mean.

35. Computer simulations nearly always show that such embellishments are unnecessary and that a summary statistic works. This is reinforced by the errors we accept from sampling.

Confidence of failure

36. We might take 36 samples in 3 years and calculate the summary statistic. We then compare this with the standard. In doing this it is shameful not to calculate the "confidence of failure".

37. We might decide that 95% confidence is needed to justify action. We might show as RED on a map all the places which have 95% confidence of failure. We then give priority to designing action for these places.

38. It is sometimes unpopular to demand as much as 95% confidence before taking action. But the cost of extra monitoring is usually trivial compared with the wasted cost of action on failures that are not real – those that "fail" because of bad luck with monitoring.

39. We may be told to act wherever we cannot show "no risk of damage". Such a requirement still comes down to fixing the five numbers for the standard – (20).

40. We may face laws that require that waters are declared as High, Good, Moderate, Poor or Bad. We must estimate the confidence that a site has been put in the right class.

41. We might collect 36 samples over 3 years. Even for these the risk the class is wrong can be 25%. And the risk of declaring wrongly that class has changed is 30%. (Such calculations are easy to do).

42. Rivers have many standards. Some people might declare that a site fails if any one of its 20 standards is failed. For 20 different standards, the site "fails" if one of them fails.

43. This leads to a pessimistic bias in the number of sites reported as failed. Suppose a site is truly compliant but has six standards which risk being wrongly reported to fail one year in 10. This site will be will be "fail" in 5 years in 10. For 20 standards this rises to 9 in 10.

44. This is no basis for national targets. Reported trends will be bad even when, in truth, things are improving. We should plan and report separately for each pollutant.

Action

45. As noted above, we'll decide the balance between:

a) national action such as a ban on a chemical or imposing fixed standards on all polluters;
b) the use of special controls calculated separately for each site.

46. Option (a) reduces the effect of errors from sampling. These are averaged out when we adopt a target of reducing the number of failed sites. Our target is to reduce the number of bad lengths of rivers – without being worried about which ones actually get better.

47. For nitrate, failure leads to general constraints on all farmers in the entire catchment. It may be unclear that this will secure compliance. The constraints may be tightened in the future.

48. If a water is declared as "sensitive", all sewage works above a certain size must achieve specific standards. This leads to improvements, but perhaps not always to rivers in best need of them.

49. Option [b] attempts to get a good decision on the action at each site: action to meet a standard at that place. This usually gives us more improvements for our money.

Dilution and mixing

50. We'll focus on discharges such as wastewater treatment works. The same logic applies to things like urban runoff, agriculture, mines, and all kinds of uses of chemicals.

51. We might think we can use a selected value for low river flow to calculate the discharge quality needed to achieve a standard in the downstream river. This makes sense only if the discharged load is constant and the river has no pollution from upstream sources.

52. Such decisions must be based on the full range of the flow and quality of rivers and discharges, and how these are combined. This is also demanded by the need to calculate correctly the values of statistics like the annual mean or percentile. The calculations will then include all the variations in dilution, upstream pollution, and discharge load.

53. This calculation requires a technique like Monte Carlo Simulation, or a simulation of several years in the daily life of a river. The simulation of a month or a few days is misleading except where it is part of a simulation that covers several years.

54. Monte Carlo Simulation is sound in nearly all cases. The statistical errors linked to monthly or weekly sampling are larger than any extra precision that might be produced by more complicated models. And the saving in the time and cost of making decisions is enormous.

Monte Carlo Simulation

55. We'll look at mixing a single discharge with a river. We use the Mass Balance Equation:

$$\frac{\mathrm{FC} + \mathrm{fc}}{\mathrm{F} + \mathrm{f}} = \mathrm{T}$$

- F is the river flow upstream of the discharge
- C is the concentration in F
- f is the flow added by the discharge
- c is the concentration in f
- T is the concentration downstream of the discharge

56. A single application of the equation cannot calculate the mean or percentile of discharge quality, c, that is needed to achieve a mean or percentile for T.

57. In Monte-Carlo Simulation, a single value for each of F, C, f and c is extracted from the full spread and frequencies of their possible values. The above equation is then used to calculate a value for T from these values of F, C, f and c. This is repeated, say, 2000 times.

58. Usually, the thousands of sets of values of F, C, f and c are extracted from distributions that are assumed to be log-normal. But any forms of distribution can be used, as necessary.

59. The flows of rivers and from sewage works are affected by rainfall. To model this, we include, for example, the correlation between river flows and flows from sewage works. Correlation coefficients are easily calculated and can be used to tie together the 2000 pairs of values of F and f, and f and c etc.

60. We need data that characterise the distributions of F, C, f and c. In most cases, two summary items are enough. We use the most easily available:

river flow (F): mean and 95-percentile low flow
upstream river quality (C): mean and standard deviation
discharge flow (f): mean and standard deviation
discharge quality (c): mean and standard deviation

61. The results of the calculation provide the link between the distributions of c and T and how the mean and percentile values of T vary with the mean and percentile values of flow and quality for the discharge and the upstream river. (Monte Carlo Simulation for individual discharges is provided in "app" like RQP).

Modelling a catchment

62. SIMCAT does calculations for an entire catchment or the whole country. It looks at the things like diffuse pollution, plans for industry, economic growth, climate change, new standards, new policies and new laws.

63. SIMCAT works its way down a river, perhaps dealing with thousands of kilometres and hundreds of tributaries, abstractions, discharges and the sources of 20 types of diffuse pollution. Water quality is calculated down the whole length.

64. Increasingly, data for SIMCAT are produced by data bases and mapping systems such as SAGIS. SIMCAT then does its calculations and sends its results back to SAGIS.

65. At points where effluent or diffuse pollutions enter a river, SIMCAT uses Monte-Carlo Simulation to mix thousands of values of flow and quality for the pollution with the thousands of corresponding values of flow and quality for the upstream river.

66. At all points in the catchment, SIMCAT tells us the breakdown of pollution into contributions from any or all of the upstream discharges or zones of particular types of diffuse pollution. This shows where to act in order to protect water quality.

67. SIMCAT also calculates limits needed at individual discharges to meet local river quality targets. The resulting improvements proceed downstream.

68. As the river flows downstream, the thousands of values of river quality are adjusted to account for specified effects like natural decay and further diffuse inputs. The results will define the upstream quality for any subsequent inputs or places of interest.

69. At abstractions, the values of flow will be reduced according to the scale and type of abstraction.

Errors

70. SIMCAT calculates the confidence that any point in any river is worse than it standards.

71. The total effect of sampling is modelled. We include the effects of the sampling rates for all discharges and all rivers, and how these rates combine and affect the whole of the downstream river. We also add the errors linked to any equations used in some calculations (such for unionised ammonia).

72. The errors make us think about the effort we need to devote to details like the in-river processes that affect water quality, or how we define the input distributions. There is little point if the effect is much smaller than errors from sampling.

Calibration

73. When you assemble your data, you will be lucky if the results of your first run agree with the measurements of flow and quality recorded by monitoring. To secure a fit you will check for mistakes and for missing sources and sinks of flow or pollution. This is calibration.

74. SIMCAT can calibrate automatically by:

- adding extra river flows, or removing them, so that it reproduces what is measured at things like flow gauges;

- making adjustments that secure agreement with the distributions of quality recorded at the monitoring stations.

You can use such changes to help identify what caused them.

Examples from SIMCAT

75. 37% of 50,000 km fails phosphate standards. If all sewage works received a fixed level of treatment, failure would reduce to 31%. This would cost £3.6 billion.

76. We calculate the contribution from diffuse pollution. A 30% reduction would reduce failures from 31 to 27%. Removing phosphorus from certain types of detergents would bring only 0.4% into compliance, though even this has a calculated benefit of £130 million.

77. Lawyers set a definition of "no deterioration". SIMCAT calculated that it would cost £13 billion. A policy that avoided the wasted investment caused by sampling would cost only £2 billion. Early modelling can improve bad ideas.

78. Failures of a new standards for nutrients for special habitats were shown to be unachievable even if all discharges were improved by 90%. We would also need to curtail farming.

79. Climate change poses risks. Reduced flows and higher temperatures and population were shown to produce a downgrade of only 0.4% of kilometres for 2050. But the effects of bigger and more frequent storms are more difficult to predict.

Tony Warn MBE
13 December 2018

Calculations

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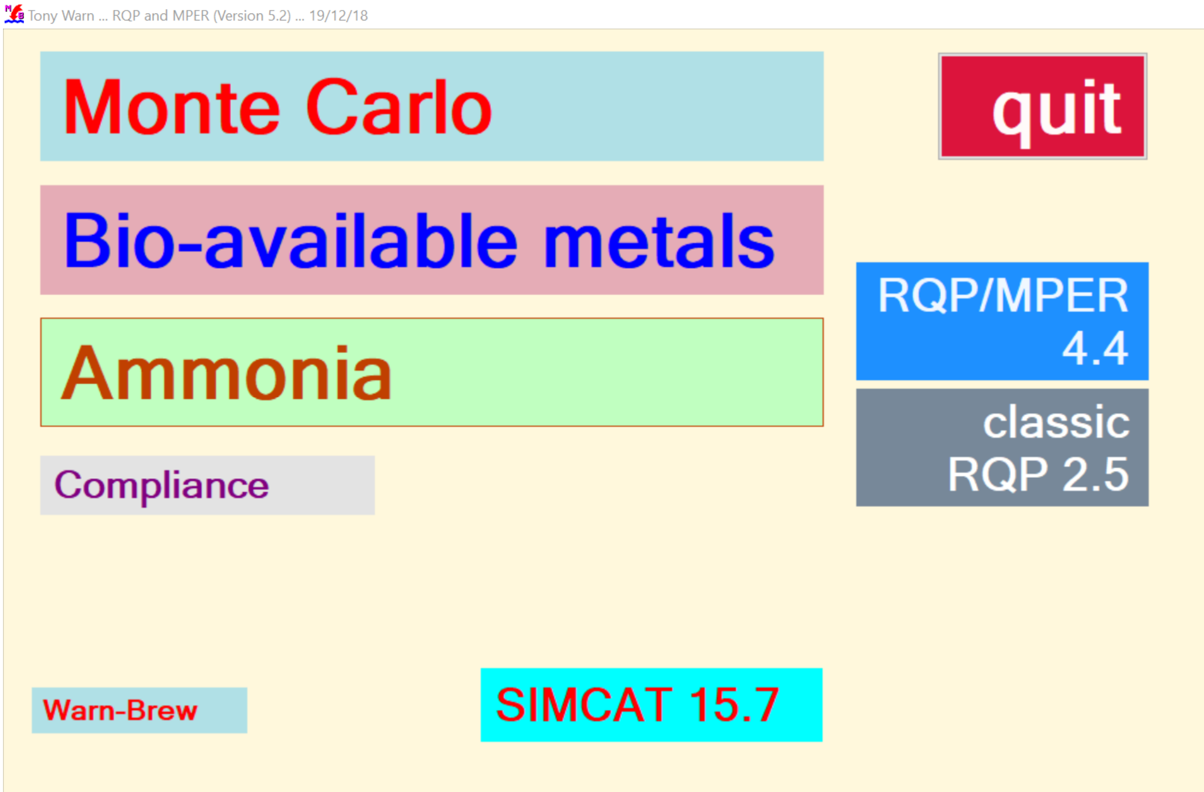
1 Apps

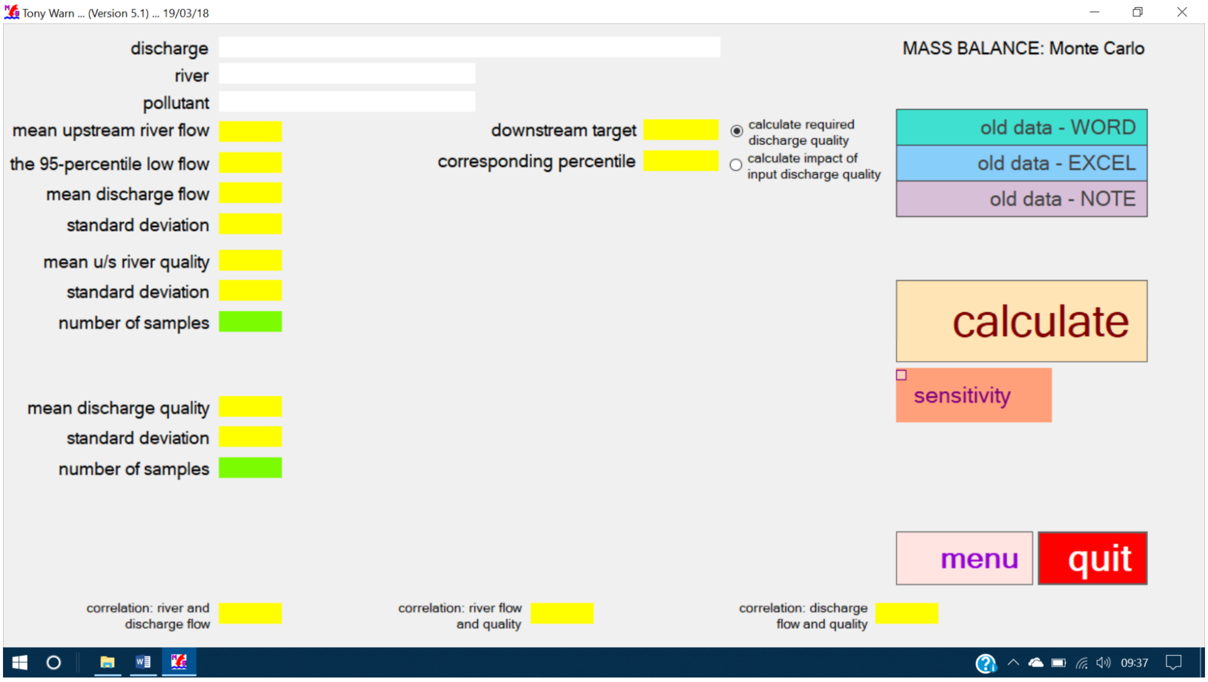
Copies of the computer screens are displayed below. You can play with the App to learn how to use the system.

2 Starting screen

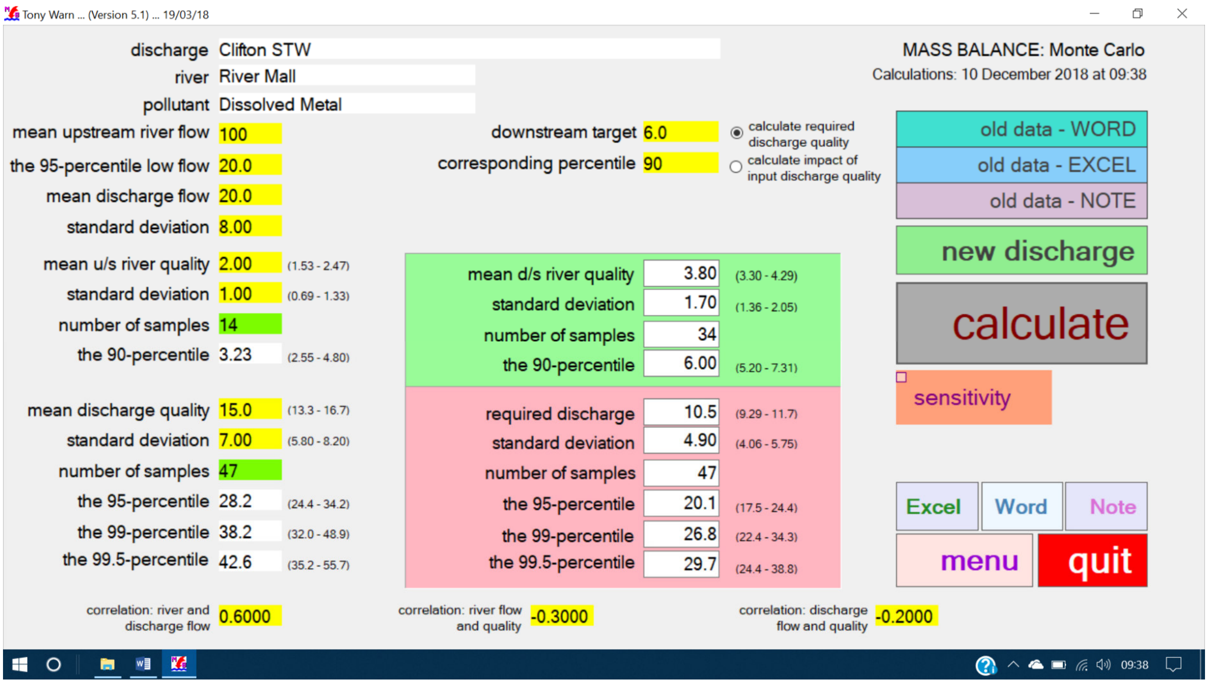


- Monte Carlo, Bio-available metals, Ammonia, Compliance and Warn-Brew are versions 5.2.
- The previous RQP/MPER is version 4.4. Classic RQP is version 2.5
- Click on a box to proceed.

3 Monte-Carlo (or Ammonia)



You can enter a set of test data by typing "156" in the discharge name box. Or you can fill all the little yellow and green boxes with your own numbers. Then press "calculate". This gives:



Input and output can be saved as a document in WORD or EXCEL. These documents can also be used as input. The following is a WORD document:

MASS BALANCE (MONTE CARLO): Version 4.4

Calculations: 10 December 2018 at 11:07

Discharge:	Clifton STW			
River:	River Mall			0
Pollutant:	Dissolved Metal	Target:	6.0	90-percentile

Mean u/s river flow	100		Mean discharge flow	20.0	
95-percentile low flow	20.0		Standard deviation	8.00	
		(confidence)			(confidence)
Mean u/s river quality	2.00	(1.53 - 2.47)	Mean d/s river quality	3.80	(3.30 - 4.29)
Standard deviation	1.00	(0.69 - 1.33)	Standard deviation	1.70	(1.36 - 2.05)
Number of samples	14		Number of samples	34	
90-percentile	3.23	(2.55 - 4.80)	90-percentile	6.00	(5.20 - 7.31)
CURRENT DISCHARGE		(confidence)	**REQUIRED DISCHARGE**		(confidence)
Mean discharge quality	15.0	(13.3 - 16.7)	Mean discharge quality	10.5	(9.29 - 11.7)
Standard deviation	7.00	(5.80 - 8.20)	Standard deviation	4.90	(4.06 - 5.75)
Number of samples	47		Number of samples	47	
95-percentile	28.2	(24.4 - 34.2)	95-percentile	28.2	(17.5 - 24.4)
99-percentile	38.2	(32.0 - 48.9)	99-percentile	38.2	(22.4 - 34.3)
99.5-percentile	42.6	(35.2 - 55.7)	99.5-percentile	42.6	(24.4 - 38.8)

CORRELATION COEFFICIENTS	
River and discharge flow	0.6000
River flow and quality	-0.3000
Discharge flow and quality	-0.2000

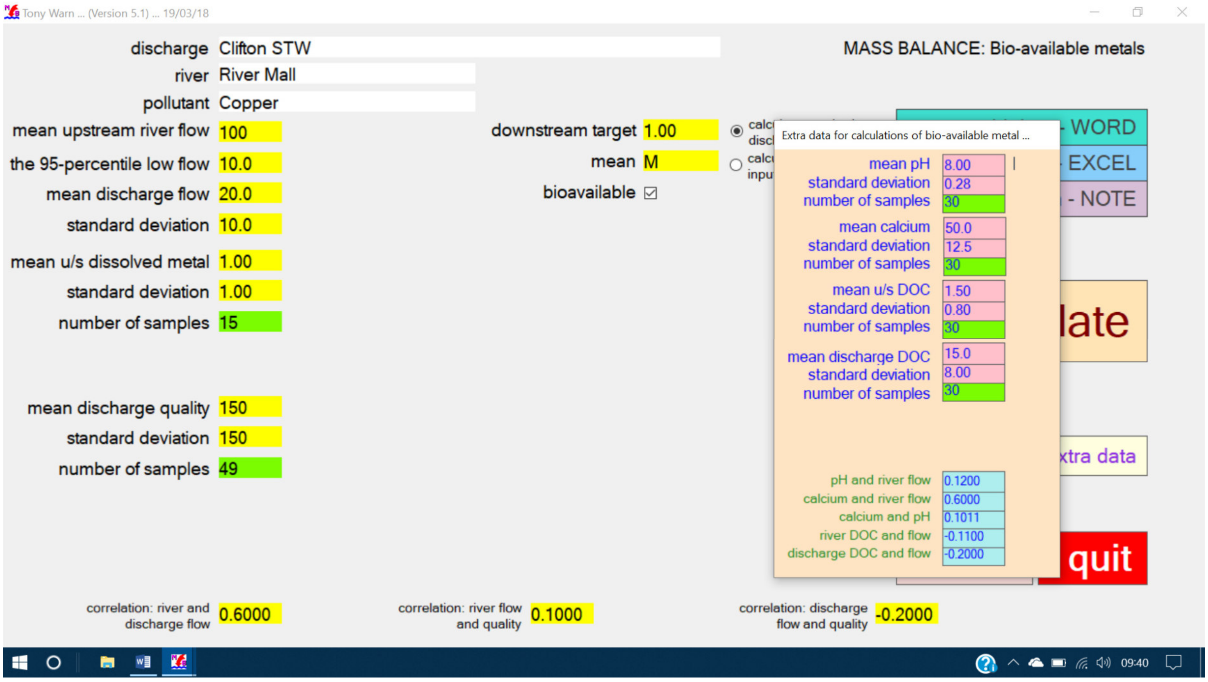
And you can add sensitivity tests by clicking on “sensitivity” and then “calculations”:

Effects of ...	... on the required discharge quality
10% change in: in mean u/s river flow	2.9 %
95-river flow	3.5 %
mean discharge flow	8.4 %
standard deviation	1.5 %
u/s river quality	3.4 %
standard deviation	1.2 %
variability of discharge quality	3.4 %
river target	16.2 %
0.1 change in correlation of river and discharge flow	1.7 %
0.1 change in correlation of river flow and quality	8.5 %
0.1 change for discharge flow and quality	8.5 %

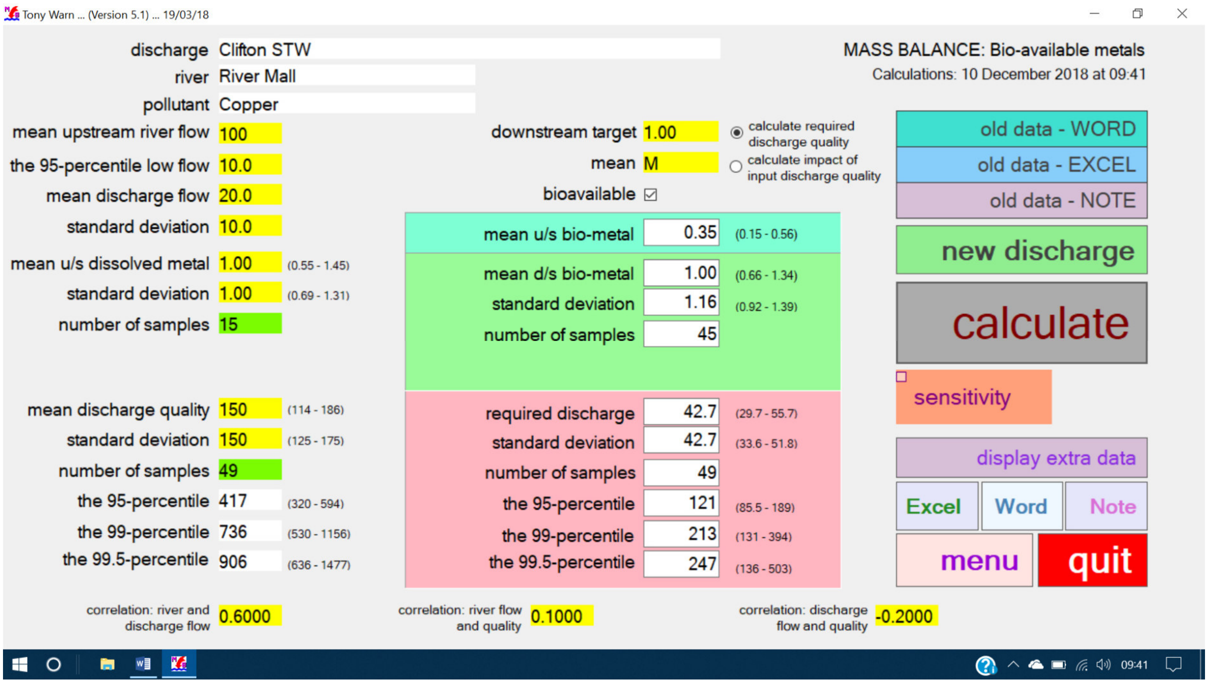
3 Bio-available

You can enter a set of test data for copper by typing “15c” in the discharge name box. Or you can enter “16n”, “15z”, “15m” or “15l” for other metals.

Or you can fill all the little yellow, green, pink and blue boxes with your own numbers.



Then press “calculate”. This gives:



As with Monte Carlo, you can then request a WORD document:

MASS BALANCE (BIO-AVAILABLE METALS): Version 4.4

Calculations: 10 December 2018 at 11:20

Discharge:	Clifton STW			
River:	River Mall		1	0
Pollutant:	Copper	Target:	1.00	(mean)

Mean u/s river flow	100		Mean discharge flow	20.0	
95-percentile low flow	10.0		Standard deviation	10.0	
		(confidence)			(confidence)
Mean u/s diss. metal	1.00	(0.55 - 1.45)	Mean d/s diss. metal	12.4	(8.76 - 16.1)
Standard deviation	1.00	(0.69 - 1.31)	Standard deviation	14.5	(12.0 - 17.1)
Number of samples	15		Number of samples	45	
Mean u/s bio-metal	0.35	(0.15 - 0.56)	Mean d/s bio-metal	1.00	(0.66 - 1.34)
Standard deviation	0.42	(0.28 - 0.56)	Standard deviation	1.16	(0.92 - 1.39)
Number of samples	15		Number of samples	45	
CURRENT DISCHARGE		(confidence)	**REQUIRED DISCHARGE**		(confidence)
Mean discharge quality	150	(114 - 186)	Mean discharge quality	42.7	(29.7 - 55.7)
Standard deviation	150	(125 - 175)	Standard deviation	42.7	(33.6 - 51.8)
Number of samples	49		Number of samples	49	
95-percentile	417	(320 - 594)	95-percentile	121	(85.5 - 189)
99-percentile	736	(530 - 1156)	99-percentile	213	(131 - 394)
99.5-percentile	906	(636 - 1477)	99.5-percentile	247	(136 - 503)

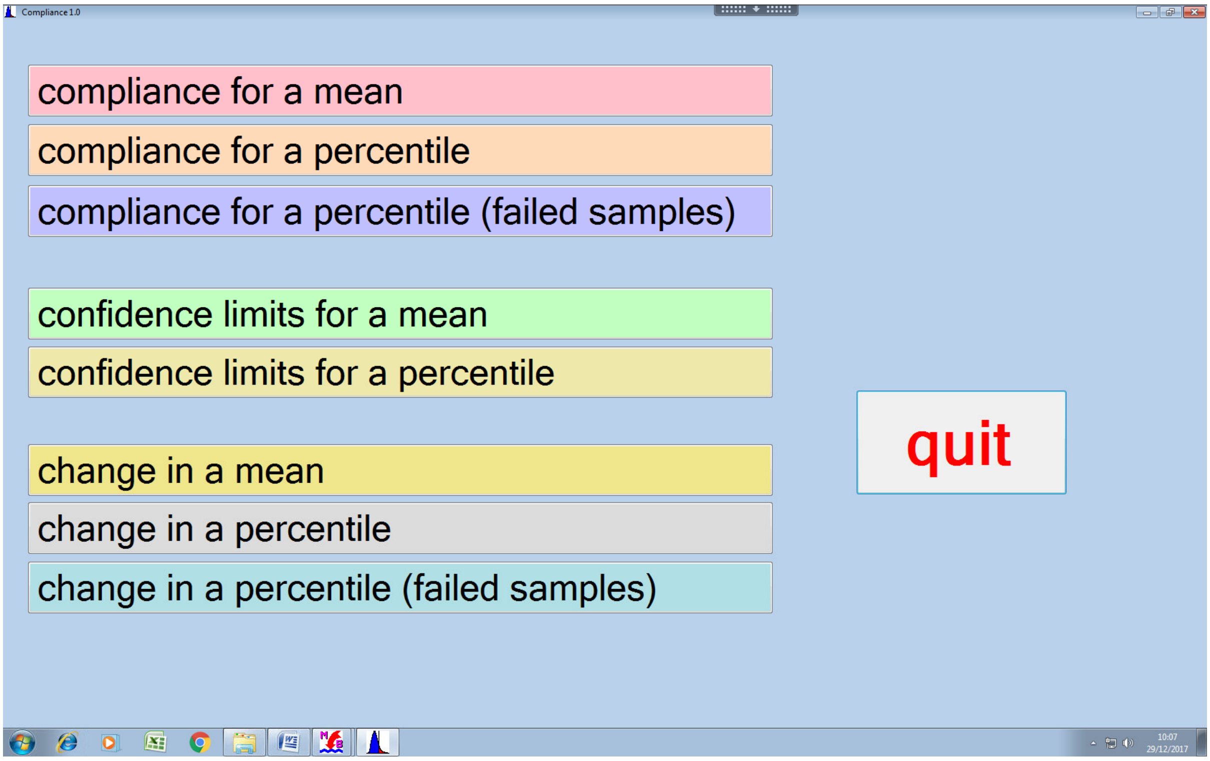
CORRELATION COEFFICIENTS	
River and discharge flow	0.6000
River flow and quality	0.1000
Discharge flow and quality	-0.2000

Mean pH (u/s & d/s)	8.00	(7.91 - 8.09)	Mean calcium (u/s & d/s)	50.0	(46.1 - 53.9)
Standard deviation	0.28	(0.22 - 0.34)	Standard deviation	12.5	(9.80 - 15.2)
Number of samples	30		Number of samples	30	
Mean DOC in u/s river	1.50	(1.25 - 1.75)	Mean DOC in discharge	15.0	(12.5 - 17.5)
Standard deviation	0.80	(0.63 - 0.97)	Standard deviation	8.00	(6.27 - 9.73)
Number of samples	30		Number of samples	30	

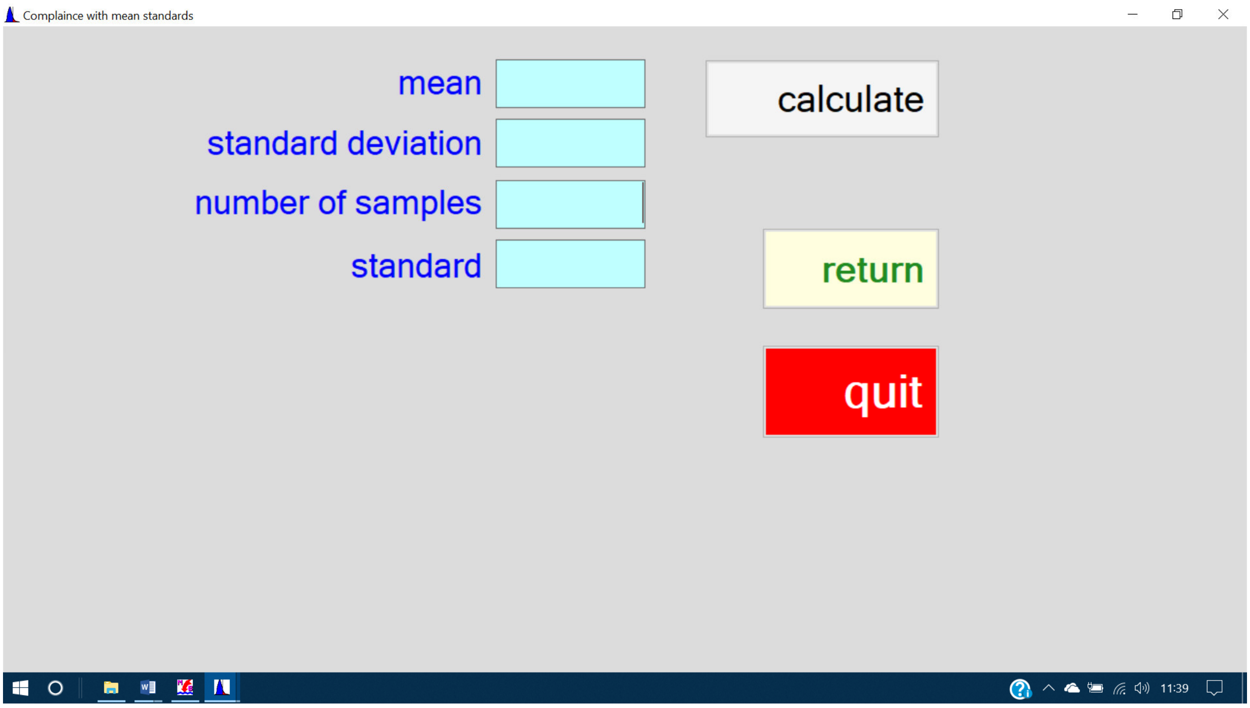
MORE CORRELATION COEFFICIENTS	
pH and river flow	0.1200
Calcium and river flow	0.6000
Calcium and pH	0.1011
Upstream DOC and river flow	-0.1100
Discharge DOC and flow	-0.2000

6 Compliance

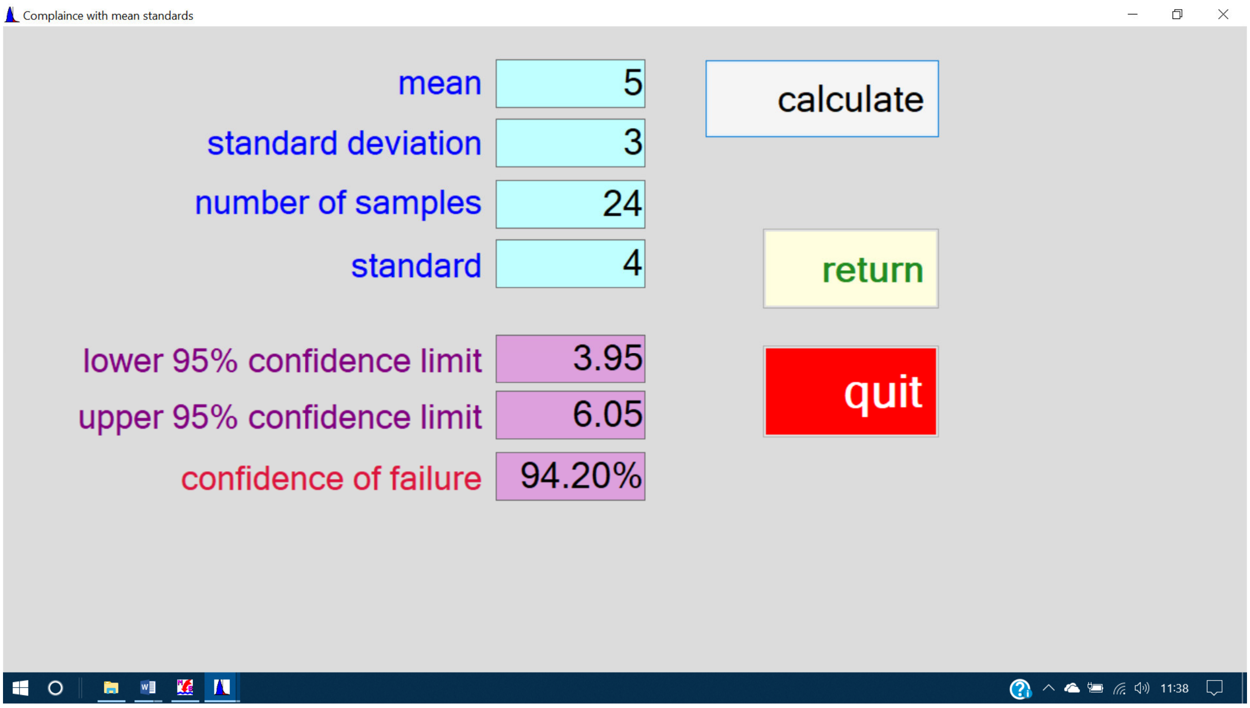
Click the box marked "Compliance":



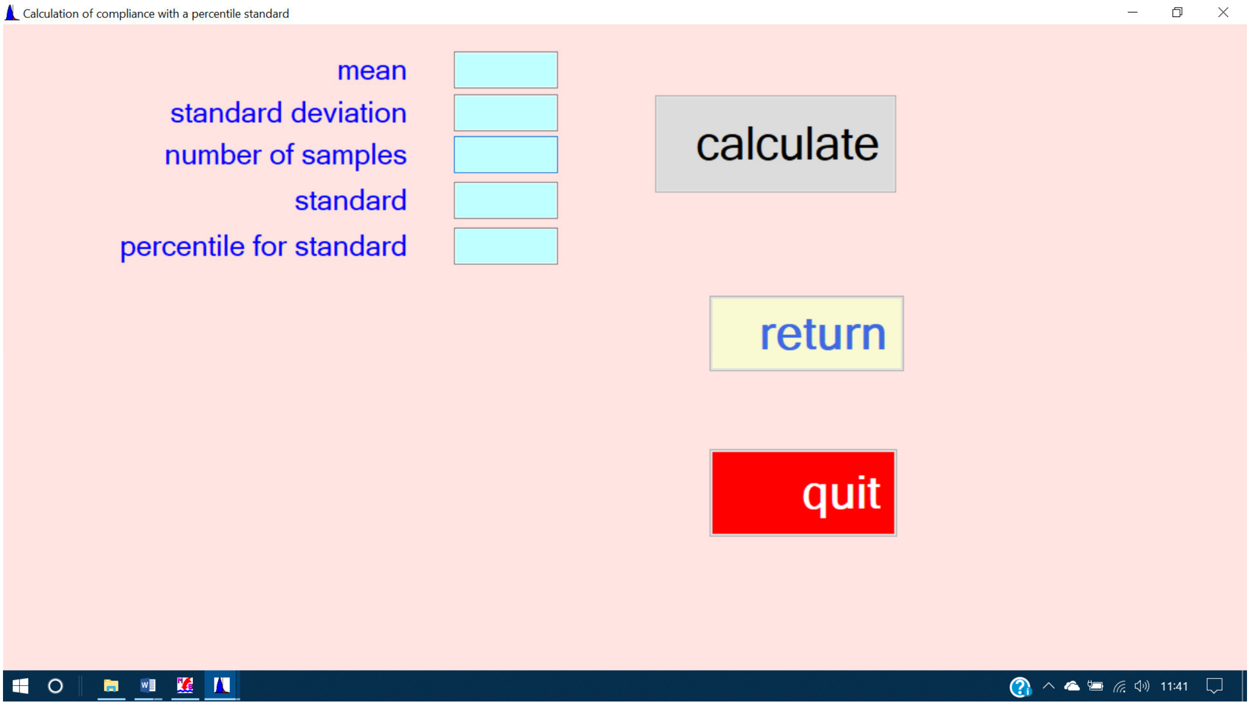
Then "compliance for a mean" and enter numbers in the blue boxes:

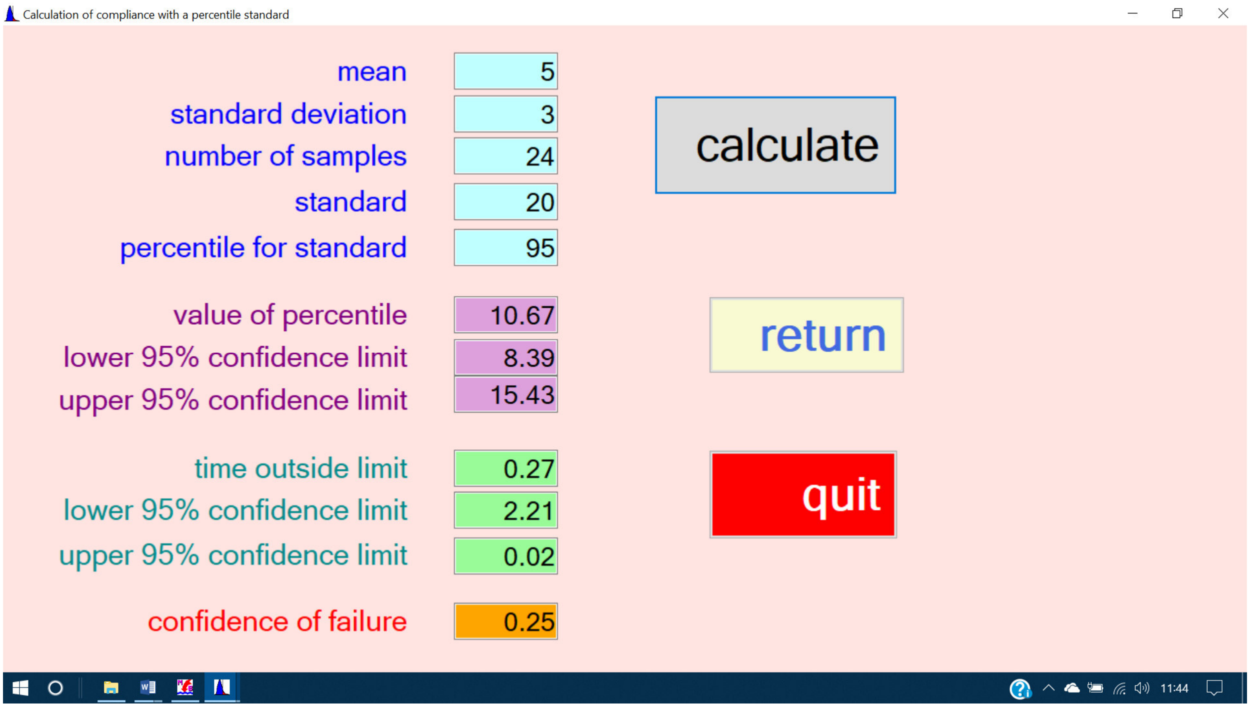


An example of results is:

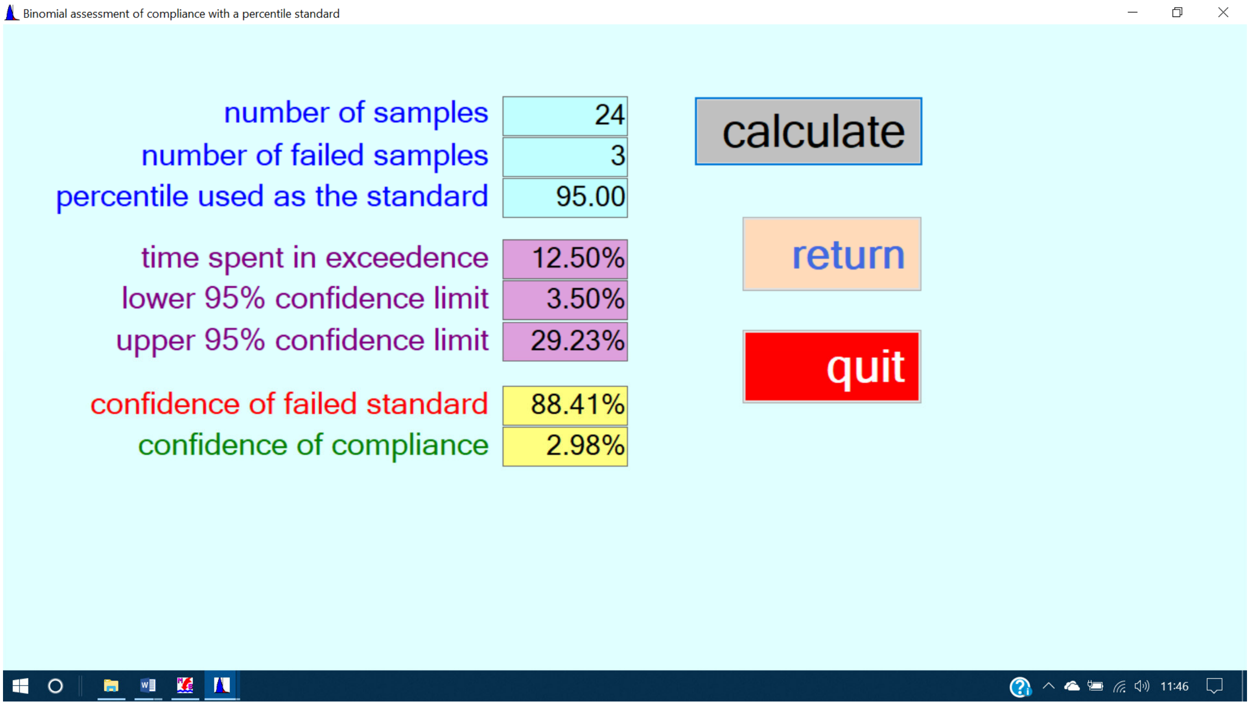

Complaince with mean standards
mean
5
standard deviation
3
number of samples
24
standard
4
lower 95% confidence limit
3.95
upper 95% confidence limit
6.05
confidence of failure
94.20%
calculate
return
quit
11:38

Do the same for “compliance for a percentile”

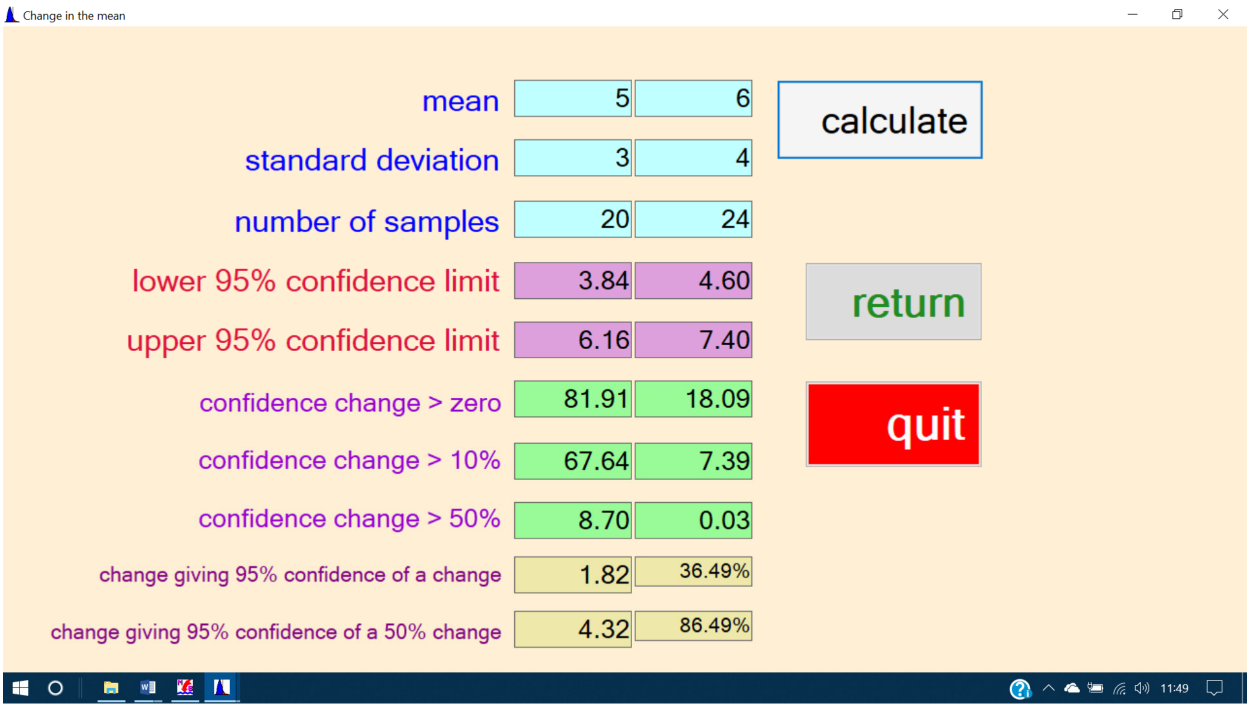




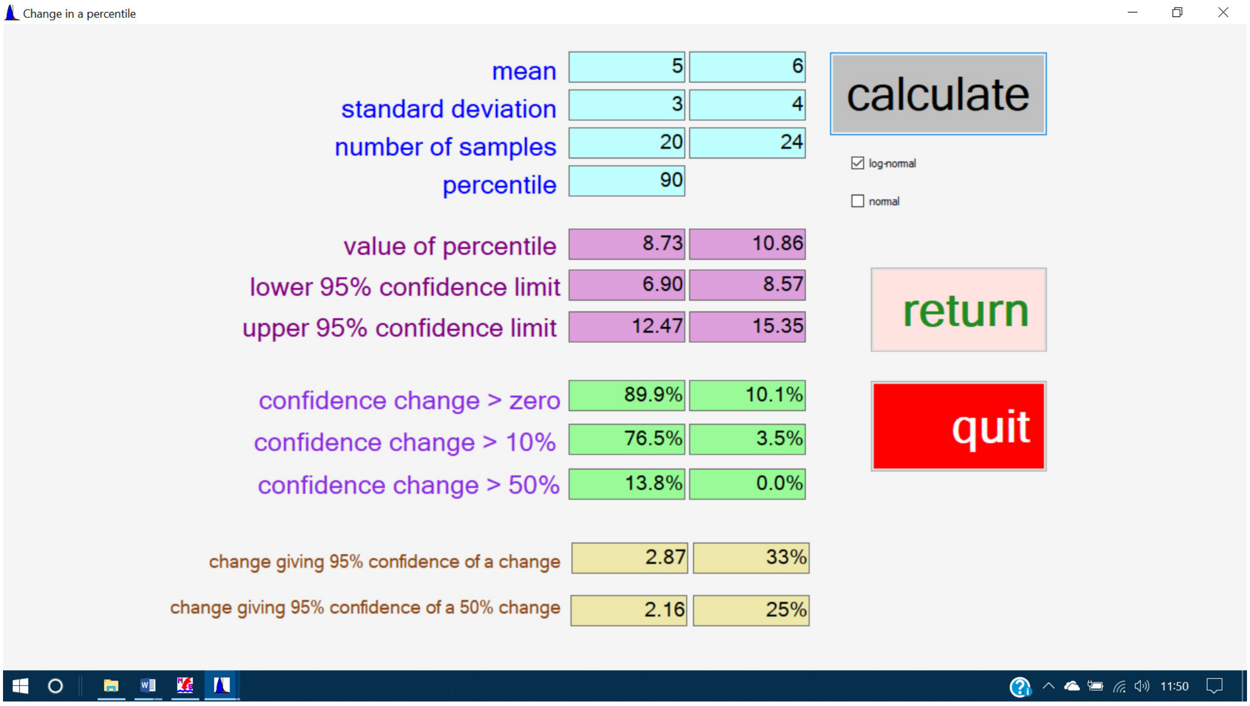
Do the same for “compliance for a percentile (failed samples)” – fill the blue boxes and click “calculate”.



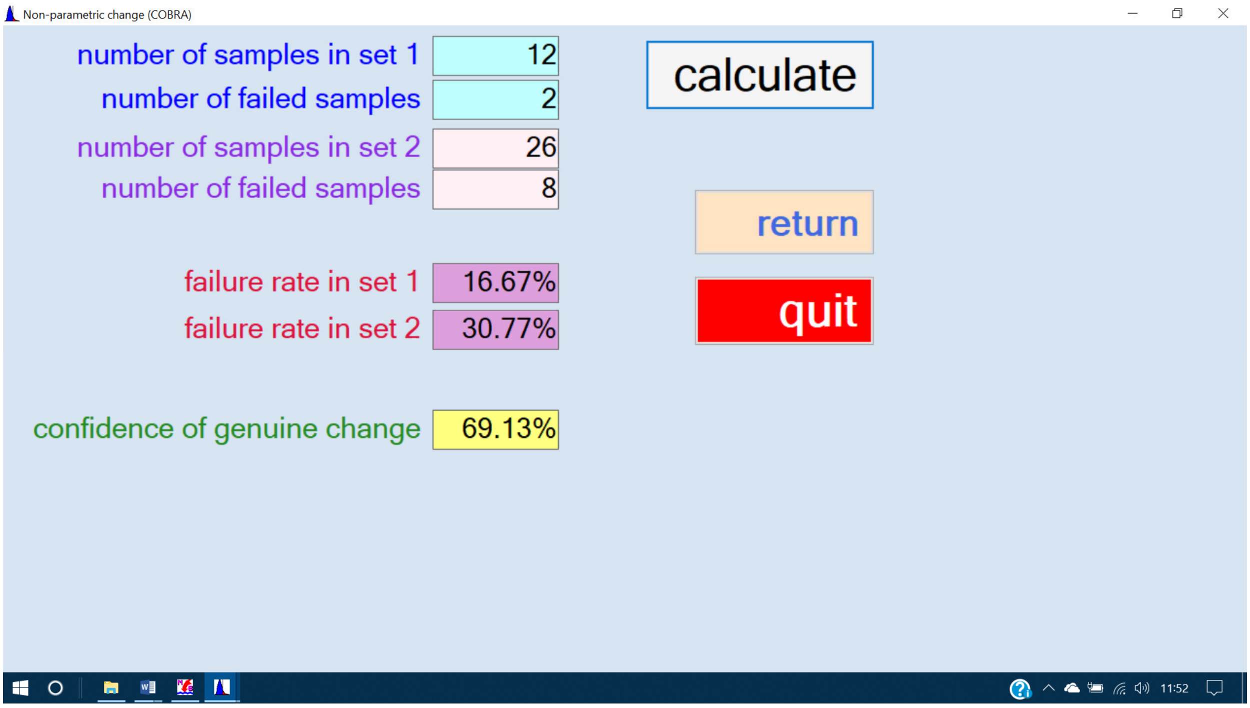
Change in mean



Change in Percentile



Change – percentile – failed samples



Tony Warn MBE
10 December 2018