1. WRA

China – UK, WRDMAP
Integrated Water Resources Management Document Series

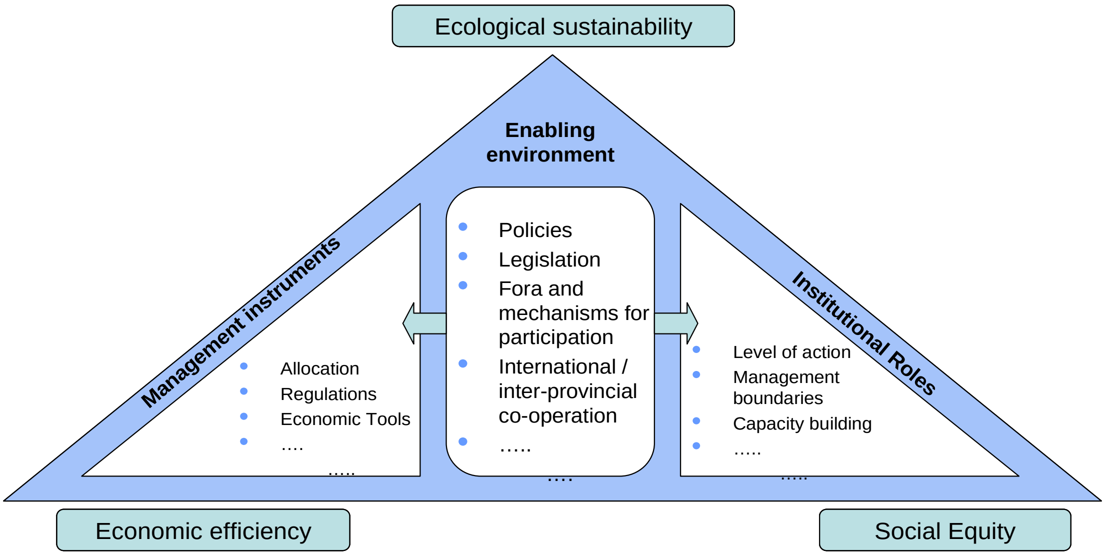
Thematic Paper 1.5: Use of Water Quality Modelling for Water Protection

May 2010

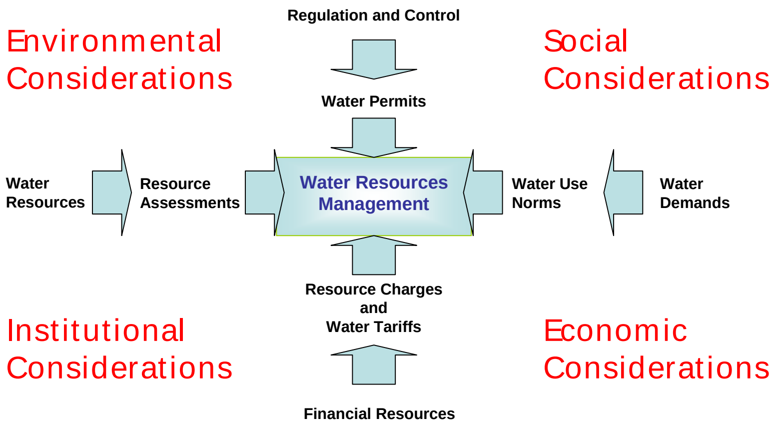
中国水利 CHINA WATER
DFID Department For International Development
Mott MacDonald

Integrated Water Resources Management (IWRM)

(Basics after Global Water Partnership)



Driving Elements of Integrated Water Resources Management



(Second figure after WRDMAP)

Summary: Water pollution is a health hazard to people, and can be damaging to the environment. Water quality modelling can be used to better understand sources of pollution and how the quality of the receiving waters can be improved.

This guideline document describes water quality modelling approaches and discusses options for use at provincial level in China. The aim is to provide an overview for leaders in an Environmental Protection Bureau or Water Affairs Bureau who are contemplating water quality modelling. It should be read in conjunction with Advisory Note 1.5 and Example 1.5.

This document covers the following topics:

- Existing Water Quality Modelling in China
  - Provincial level modelling
  - Chinese universities' and institutes' models
  - Donor funded projects
- Available Modelling Tools
  - Types of Surface Water Models
  - Widely used modelling software
  - Limitations of water quality modelling
- Implementing a water quality model
  - Choosing modelling software
  - Constructing a model
  - Data requirements
  - Running the model
  - Interpreting the results
  - Water quality responsibilities
  - Training and staff requirements

The Ministry of Water Resources have supported the Water Resources Demand Management Assistance Project (WRDMAP) to develop this series to support WRD/WAB at provincial, municipal and county levels in their efforts to achieve sustainable water use.

1 Introduction

This guideline document describes water quality modelling approaches and discusses options for use at provincial level in China.

This document covers model selection (primarily focussing on one-dimensional modelling), associated data requirements, normal model usage, and options for use by a provincial level Environmental Protection Bureau (EPB) or Water Affairs Bureau (WAB).

The aim of this document is to provide an overview of the subject for leaders in EPB or WAB who are contemplating water quality modelling.

Accompanying documents include Advisory Note 1.5 'Use of QUAL2K Water Quality Model in IWRM Planning', which provides more detailed guidance for implementing the Qual2K model, and Example 1.5 'Water Quality Modelling in Chaoyang, Liaoning Province', which gives an overview of the experience and lessons learnt during a water quality modelling study in Chaoyang, Liaoning Province. All references are listed in the bibliography at the rear of the document.

2 Water Protection

Water pollution is a health hazard to people, and can be damaging to the environment. Protection of water is therefore important for protection of the population and the environment that rely on water use.

Water quality modelling can be used to better understand sources of pollution and to understand how the quality of the receiving waters can be improved.

Daling River near Chaoyang, Liaoning

Practitioners of integrated water resources management (IWRM) may find water quality modelling useful for informing decisions about pollution control (such as discharge permitting) or demand management (such as abstraction permitting).

A model can be used to test “what if?” scenarios which can demonstrate the effect on the water quality in the river due to changes in abstractions and discharges, or changes in flow volumes (e.g. drought conditions). Conversely, appropriate discharge and abstraction limits to achieve specific river water quality targets can be investigated using a water quality model.

Water quality models can be used for a variety of different purposes including analysing pollutant spills and predicting long-term water quality in rivers. The various options for water quality modelling are discussed in this document.

3 Existing Water Quality Modelling in China

Water quality modelling is already undertaken in China; however it is typically as short-term studies by universities and research institutes.

This section gives an overview of the types of water quality modelling already being undertaken in China.

3.1 Provincial level modelling

Investigations into existing modelling at provincial level in China have concluded the following points:

- The EPB and WAB organisations at provincial level do not typically undertake modelling studies themselves, but outsource these to institutes or universities.
- The majority of water quality models in China are part of short-term studies or research projects, rather than involving the creation of a tool that is to be used over the long-term.

There are however some exceptions to the above, including:

The Songliao River

The Water Resources Protection Bureau of the Songua River Commission (an organisation which is part of the Ministry of Water Resources) has a water quality model that is used for the management of the water quality in water functional zones and of wastewater discharges along the river.

This model is a MIKE 11 ECOLAB model from DHI and its development was funded as part of a project with the Asian Development Bank. Data is collected by the Bureau’s own water quality monitoring centre and is augmented with data from the Hydrology Bureau. The model is calibrated using this data.

This model has also been used successfully in emergency modelling of pollution spills. The model was used to simulate a spill of nitro-benzene resulting following an explosion at a petrochemical plant in the upper reaches of the Songliao River Basin on 13 November 2005. The modelling results were in good agreement with real data taken during the incident.

The Daling River at Chaoyang

This case study was undertaken as part of the WRDMAP project and is described in Box 1, and further information on this study can be found in the example document EG1.5 in this series (see bibliography).

Gross volume control management model of water pollutant (translation from Chinese)

This model was developed in 1997 by Dr Li Chong of IWHR. It was designed for use by EPB municipal level staff and is a simple "black-box" model capable of zero to three dimensional analyses. A free copy of the model can be acquired from Dr Li Chong.

The model can be used to assess the Total Maximum Daily Load (this is the maximum amount of pollution that a waterbody can take on without exceeding water quality standards).

No information is available to show how much use this model has received in EPB, or whether it is still in use at the present time.

Box 1: Example of water quality modelling in Liaoning province

Chaoyang city is located in the province of Liaoning in north east China, approximately 390 km from Beijing. The city has a population of approximately 300,000 people, and this is expected to increase in the future.

In Chaoyang, a steady state water quality model called Qual2K has been employed to predict the long term response of a river system's water quality to changes in conditions; for example, changes in the water quality of discharges to the river system.

In predicting changes to the water quality of a river system, the aim is to use the water quality model to assist with permitting for abstractions and discharges.

In Chaoyang, data is now shared between the WAB and EPB agencies. This has allowed the setting up of a simple water quality model for a pilot reach of the Daling River. This cooperation has been essential in obtaining the required data for the creation of such a model.

3.2 Chinese universities' and institutes' models

Water quality modelling expertise in China is typically confined to universities and institutes. Contact was made with some experts at universities and institutes to explain the kind of work that they undertake.

1. Dr. Liu Xiang, Professor of Environmental Engineering and the Department of Environmental Science & Engineering, Tsinghua University, Beijing (x.liu@tsinghua.edu.cn)

Dr Liu indicated that in his experience, common water quality models used in China included SWAT, and the AGNPS. These are both basin scale models, and SWAT includes some groundwater components. (See

Section 4.3 for more information on these models.)

2. Dr Zeng Siyu, Associate Professor at the Department of Environmental Science & Engineering, Tsinghua University, Beijing (szeng@tsinghua.edu.cn)

Dr Zeng explained that her team at Tsinghua University typically undertake water quality modelling on behalf of Ministry of Environmental Protection at various levels (national, provincial or municipal). Work is often undertaken to inform strategic pollution control plans (such as a five year plan for several provinces, or a 1 year city plan).

Tsinghua University typically uses in-house models because of the particular demands of the projects. For example, looped rivers with tidal influences are common place in the south of China and these require special models. In addition, the water quality objectives are given for particular parameters, and these are not the same as the parameters used in international models. If international models are adopted, they are typically the freely available ones from the USEPA or US Department of Agriculture.

Data is provided by the client, and if there is insufficient data, students may undertake monitoring.

3. Dr. Li Chong, Section-in-Chief, Department of Water Environment, Institute of Water Resources and Hydropower Research (IWHR), http://www.iwhr.com/english/News_View_en.asp?NewsID=16687

A variety of water quality modelling is undertaken by IWHR. Dr Li said that IWHR use analytical models, as well as numerical models. Their numerical models include in-house (self-developed) models in one, two and three-dimensions, and commercial models such as MIKE, SMS and Qual2K.

The IWHR in-house models have been used in Tai Lake, Dian Lake, Three Gorges and Badakou station of Zhu River.

Typically, they use data on topography, hydrology and pollution load. This data is obtained from field monitoring, co-operative partners or from statistical data from government agencies. The data obtained from third-parties is purchased.

3.3 Donor funded projects

International funding agencies have sponsored numerous modelling studies in China. In these studies, an international modelling consultant is typically brought in to set up and develop the model with the answers being given to the Chinese. There are also many examples of studies funded by the World Bank.

Many large donor projects use commercially available software (such as MIKE11). The project is typically designed to solve a particular problem and the model is not designed to be used for the long term.

There are some exceptions to this however which are “enablement” projects, including the DFID funded WRDMAP. The Chaoyang case study outlined in Box 1 is from that project.

4 Available Modelling Tools

4.1 Types of surface water models

Hydraulic & water quality models

Hydraulic models calculate the motion of water. This type of model can usually calculate flow rates, water levels and velocities. It usually requires flow data for the upstream boundaries, and some bathymetry or cross-sectional profile data. Flow data for at least one other location on the model will be required for calibration.

Water quality models calculate the concentrations or loads of water quality parameters (typically chemical concentrations). Water quality models are usually linked to hydraulic models because the hydraulic conditions also affect the water quality. There are some exceptions, which just use a travel time between the model nodes.

Many water quality models predict river water quality based on specified sources of pollution; however, some water quality models focus on the effect of different land management practices on water quality. These models are typically known as non-point or diffuse pollution models.

Steady-state and Unsteady Models

Steady-state models cannot simulate changes over time, so the flow/water quality conditions cannot evolve. This type of model is used for a single condition – usually a long-term response or an average condition.

Unsteady models simulate changes over time. This type of model can tell you how water levels might change with time during a flood, or how a pollution spill might travel downstream.

Model dimensions: 1D, 2D, 3D

A 1D model uses data averaged at a cross-section. This means that the model can calculate average velocity, flow rate and water level at a river cross-section, and/or average water quality at a cross-section.

A 2D model uses depth-averaged data. This means that the model can tell you how conditions change horizontally; for example it could calculate depth-averaged velocities on a floodplain, or depth-averaged water quality conditions for a shallow lake.

2D models are only suitable for "shallow water", which is defined as being when the horizontal length scales are much greater than the vertical length scales (e.g. coastal waters, but not the open ocean). Reservoirs can fall into this category, but deep reservoirs have 3D hydrodynamics so 2D models may not be appropriate.

2D models are more complicated to set up than 1D models as they require more data, more development time, and more computational time; therefore they are more expensive.

A 3D model calculates hydraulic, and possibly water quality, conditions at different depths and horizontal locations in a water body. Usually effects such as buoyancy are included, so warmer water can be shown rising to the surface.

3D models are more complicated to set up than 1D and 2D models as they require much more data, development time, and computational time; therefore they are more expensive.

4.2 I want to investigate X… What kind of model do I need?

To determine the most appropriate model, careful consideration is needed to decide precisely what information is required from the model, i.e. what you are trying to find out. Defining the problem thoroughly at the start is the best approach to ensuring use of the most appropriate model and data collection. This will save time, money and frustration in the long term.

The following are some examples of situations in which modelling is often used, and the kind of model that is usually appropriate.

A change to the water quality conditions in a river due to a change in the discharges to that river:

(a) What will happen in the long term?

For this kind of study, long term average data with a 1D steady-state water quality model can be used. The model can be calibrated using historic data, then making a change to the model inputs (to simulate the change to the discharges) allows the model to calculate the long-term effect of that change.

(b) How long will it take for the water quality to change?

To find out how long it will take for a water quality change to occur, a 1D unsteady water quality model is likely to be most appropriate. If this is first calibrated to historic data, then the model inputs are changed (to simulate your change to the discharges), the model can simulate the resulting changes to the water quality and how they evolve over time.

(c) How will the discharges and resultant water quality be affected by changes in land management?

To find out how changes in land management will affect the river water quality a non-point (or diffuse) pollution model is likely to be most appropriate. This type of model can be used to investigate changes in fertiliser and pesticide use, or changes in land use. This type of model is typically steady-state and will therefore calculate the long-term effect of the change in land management.

A pollutant spill

If you want to investigate the fate of a pollutant spill, an unsteady water quality model which can simulate the spread of pollutant throughout the water body will be appropriate.

(a) In a shallow lake

For a shallow lake, a 2D water quality model may be sufficient. It would need to be a reasonable assumption that the pollutant was thoroughly mixed in the vertical direction, so this would not be appropriate if there are any buoyancy effects (e.g. the spill is warmer than the ambient water, or the spill is oil, which sits on the water surface). If thorough vertical mixing cannot be assumed, then a 3D model is needed.

(b) In a tidal estuary

In a tidal estuary, there are buoyancy complications arising from the different densities of the fresh river water and the saline seawater. To understand accurately how a pollutant plume or cloud disperses in these conditions, a 3D model is necessary.

4.3 Widely used modelling software

There are many different water quality models available. This is not intended as an exhaustive list, merely an overview of those most commonly used internationally in river water quality modelling.

SIMCAT is a 1D, steady state model used in catchment water quality management and planning in the UK. It uses statistics from long term water quality data to predict the behaviour of river water quality using a mass-balance approach. Point sources and diffuse inputs can be included in the model. Hydraulics are not simulated in this model. SIMCAT has been created by the UK Environment Agency. It is freely available on CD in the UK upon request from the Environment Agency; all documentation is in English.

Qual2K is a steady state, 1D hydraulic and water quality model available as a free download from the United States Environmental Protection Agency (USEPA). The model can be used to simulate daily variations in water quality due to differences in temperature and light. The model is supported by a users manual (Chapra *et al*, 2006). Development is ongoing and updates are on the website. http://www.epa.gov/athens/wwqtsc/html/qual2k.html.

The ISIS model is a 1D hydraulic and water quality model produced by Halcrow in the UK. It is capable of steady and unsteady flow calculations. (For information visit: http://www.halcrow.com/isis/wq.asp) This software must be purchased. This model is typically used in the UK for flood modelling, however water quality and sediment transport modules are available.

MIKE11 is a competitor of ISIS and has similar capabilities. It is produced by (and can be purchased from) DHI (http://www.dhigroup.com/Software/WaterResources/MIKE11.aspx). The ECOLAB module can be added on to allow simulation of ecological parameters.

The Surface Water Modelling System (SMS) by Environmental Monitoring Systems Inc. is a modelling pre- and post-processing tool for models that can be embedded within it (and are purchased with it). The suite of embedded models includes one-, two- and three-dimensional hydraulic and water quality models. It can be purchased on-line (http://www.ems-i.com/SMS/SMS_Overview/sms_overview.html#WATERQUALITY).

The following models are typically used at a basin scale to evaluate water resources and water quality:

The SWAT (Soil & Water Assessment Tool) model is available as a free download from the Blackland Research & Extension Centre (part of the US *Texas Agricultural and Mechanical System* – a Texas State network of universities and state agencies). SWAT is typically used at a river basin scale to predict the effect of management decisions on water, sediment, nutrient and pesticide. It includes groundwater and soil types. http://www.brc.tamus.edu/swat/factsheet.html.

The AGricultural Non-Point Source Pollution Model (AGNPS) is a freely available tool for use in evaluating the effect of land management decisions impacting a watershed system. http://www.wsi.nrcs.usda.gov/products/w2q/h&h/tools_models/agnps/index.html.

MIKE Basin is a GIS-based water resources model created and sold by DHI. The model deals with hydraulics; for water quality to be included, an additional module must be purchased. (http://www.dhigroup.com/Software/WaterResources/MIKEBASIN.aspx).

4.4 Limitations of water quality modelling

Different types of water quality models have different limitations, depending on the model type.

A steady model cannot:

- predict the spread of a pollutant spill in a river system;
- give an indication of the timescales necessary to reach the predicted water quality.

A one-dimensional model cannot:

- show the spreading of a plume of pollutant from a point discharge;
- indicate the lateral or vertical spreading of a pollutant, only the average concentration at a cross-section.

None of these water quality models are able to back-calculate the water quality permits from the desired river water quality.

There are also limitations relating to data availability; if there is a lot of uncertainty in the input data, there will be a lot of uncertainty in the model result. While estimations and approximations concerning data are often necessary, it should be understood that these will impact on the accuracy of the model result.

4.5 An overview of data requirements

The modelling adage “rubbish in, rubbish out” is an important message to keep in mind when planning the data required for your model. The quality and amount of information that you give the model will definitely affect its accuracy. Focus on the points that you are particularly interested in – for example, if you particularly want to know about dissolved oxygen, you should have good dissolved oxygen data, and good data for anything that affects dissolved oxygen (e.g. ammonia concentration).

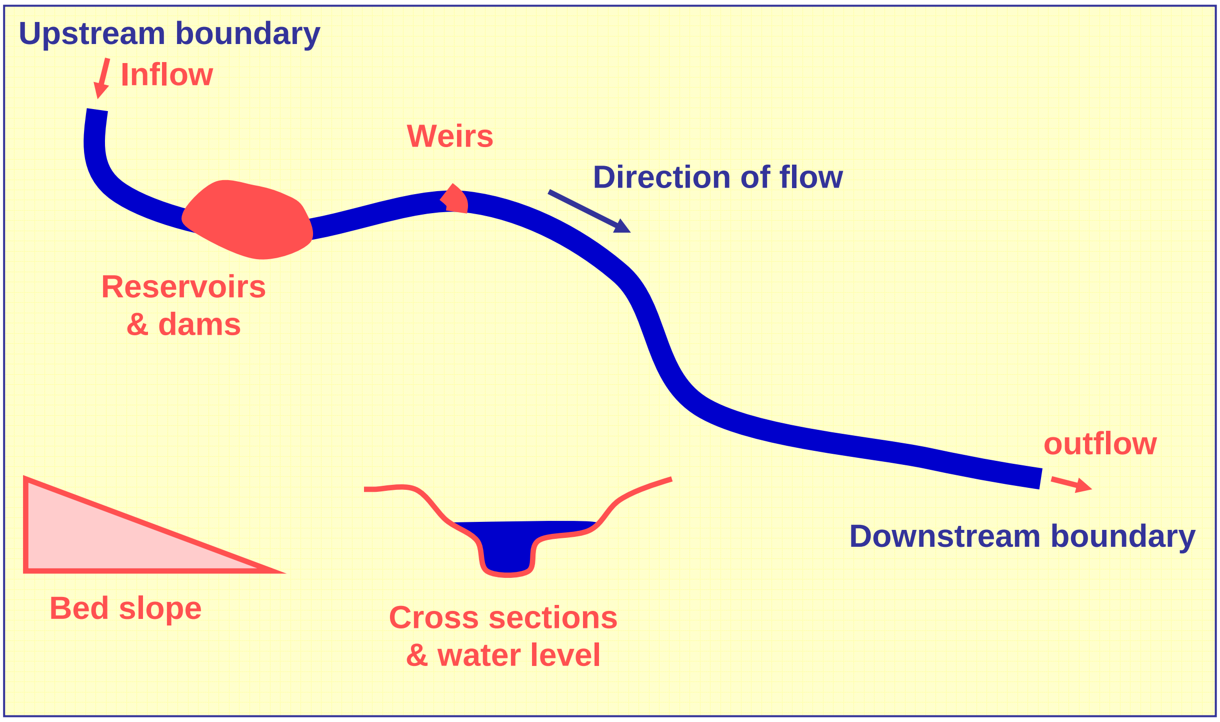
The following is intended as an overview of the types of data required.

Hydraulic models in general

Abstractions / discharges – you will need data on the flow rates for any abstractions/discharges to your water body. (If creating a water quality model, you will need water quality data for any discharges).

Rainfall runoff – you may need to include rainfall runoff as a significant contribution to your water body. This can be calculated using a hydrological model. The hydrological model can be very simple, just using a runoff coefficient to estimate the percentage of rainfall that runs off, and multiplying by the area of the catchment to calculate a volume. (If creating a water quality model, you will need this to estimate the pollution load from diffuse sources such as agriculture.)

Figure 1 Hydraulic data required for a one-dimensional model



1D hydraulic models

Figure 1 illustrates the typical data required for a one-dimensional hydraulic model.

Cross-section profiles – these should be taken from surveys at regular intervals along the river sections.

Structure information – physical dimensions are needed of any structures on the river which could influence the flow. If the model is unsteady then operating instructions for any mechanical structures will be necessary.

Flow data – you will at least require flow rates for any upstream boundaries for a 1D model. Depending on the purpose of the model, these might be estimated from hydrological modelling, or measured flows. You will also require flow data at other locations in the model (such as gauging stations) for calibration purposes.

Chaoyang gauging station, Daling River

2D & 3D hydraulic models

Bathymetry – This is best measured by survey, though it may be possible to take data from marine charts or similar. It will be needed throughout the modelling area.

Flow data – All boundaries should be defined by flow data – depth-averaged for 2D models, but at various depths for 3D models. The data may be from measurements, or for coastal/estuarine models, you could use tide data (water elevations and flow rates).

Water quality models in general

Figure 2 illustrates the typical data required for a one-dimensional water quality model.

Different water quality models include different water quality parameters. Always check for a good correlation between the data you have and the data required by the model.

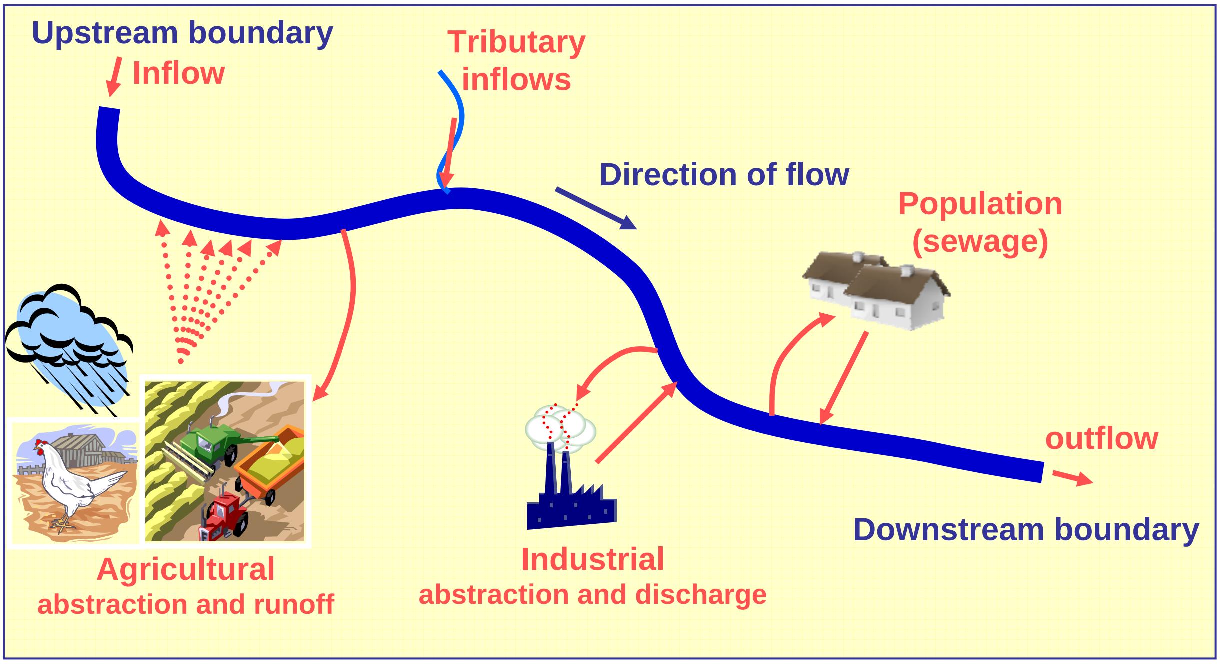
Boundary data – You will need water quality and flow data for any upstream boundaries.

Runoff – The contribution to pollutant loadings in a water body that comes from rainfall runoff carrying fertilisers etc. can be large. This should be estimated, usually from land use data.

Discharges – You will need water quality and flow data for discharges into your modelled water body.

Climatic data – the wind speed and air temperature can affect water quality and so typical values should be included in a model where possible.

Figure 2 Typical inflows and outflows required for a river water quality model



5 Implementing a Water Quality Model

5.1 Choosing the modelling software

As described in Section 4, a large number of modelling options are available. It is important when choosing the kind of model that is required, to first carefully define the question that you wish to answer.

At a provincial level in China, the most useful types of models for the local WAB and EPB staff to make use of are likely to be one-dimensional steady state models. These are useful for determining the future water quality of a river, based on changes to the abstractions and discharges.

Having determined that a one-dimensional, steady-state water quality model is what is required, it is then necessary to choose a software package. The following things should be considered at this stage:

- Data availability and comparison of this with the determinands available/required in the model;
- Cost of purchasing and licensing the software (some software require an annual fee);
- Ease of use and training support availability (e.g. are manuals available? Are there experts in this model in China?).

Expert advice may be highly beneficial at this stage of the project. This could be sought from Chinese universities or institutes, who may act as consultants to the project. If the local WAB and EPB staff are to be responsible for running the model in the future, they should also be involved at this stage so that they have a full understanding of the modelling process. There is an Advisory Note 1.1 'Models for Water Resources Planning and Management: Selection Procedures' that may well be instructive.

5.2 Constructing a model

Expert input will be required for constructing a model. This could be provided by Chinese universities or institutes, who may act as local consultants to the project. If staff from the local WAB and EPB are to be responsible for running the model in the future, they should also be involved throughout the model construction so that they have a full understanding of the modelling process.

The model should be constructed and calibrated for the "baseline case", which represents the current conditions in the river. This is the initial state of the model in which it is calibrated. The data collected should be representative of the current situation, and therefore any data which is no longer representative (e.g. data that was collected before the completion of a new sewage treatment works) should not be used.

Calibration is the most difficult part of modelling and expert knowledge is needed for this step. When additional data is available for the model, calibration will need to be repeated. In the long term it may be possible for local staff to be trained to complete the calibration, however if it is something that they undertake infrequently, relying on external expert help may be more appropriate.

Future predictions using the model are referred to as "scenarios". These represent future possibilities of water quality – a "what if?" situation. For example, a model scenario may be used to investigate the effect of reducing the discharge from a particular factory.

5.3 Data considerations and requirements

Data requirements

This section gives an overview of the data requirements for a typical one-dimensional water quality model.

A one-dimensional water quality model typically requires a combination of water quality, hydraulic and climatic data and parameters for its calculations. It is possible to estimate many of the required values if measured values are not available, though the effect of this is to reduce the accuracy of the model output.

A hydraulic model is usually the basis of a one-dimensional water quality model; however it is worth noting that some models (e.g. SIMCAT) are not based on a hydraulic model and instead use a statistical technique. The following hydraulic data is typical of the input to a one-dimensional hydrodynamic or hydraulic model:

- Flow rates (m^3/s) at all headwaters, point discharges/abstractions, and diffuse discharges/abstractions;
- Dimensions for each river reach (reach length and cross-sections*);
- Locations for model nodes or the upstream and downstream ends of each reach (i.e. latitude & longitude, distance from downstream end of river, elevation);
- For any weirs, dams and waterfalls: height, width and shape;
- Rating curve parameters where available (e.g. at gauging stations);
- Estimates of Manning's *n* for river reaches.

* Note that some models (e.g. ISIS) require a cross-section profile at the upstream and downstream ends of each reach (so these are typically located at the model nodes). Other models (e.g. Qual2K) require only a simplified cross-section that is representative of each reach; this type of cross-section requires only a bed width, bank slopes and bed slope.

Water quality data is required for all headwaters (upstream ends of the model), all point sources, and all diffuse sources. Water quality models typically include the following water quality parameters:

- Temperature (^{O}C)
- Nitrate, NO_3 (µg/l of N)
- Conductivity (µmhos or µsiemens)
- Organic Phosphorus (µg/l of P)
- Inorganic Solids (mg/l, dry weight)
- Inorganic Phosphorus (µg/l of P)
- Dissolved Oxygen (mg/l of O_2)
- Phytoplankton (µg/l)
- BOD (mg/l of O_2)
- Detritus (POM) (mg/l, dry weight)
- COD (mg/l of O_2)
- Pathogens (cfu/100 ml)
- Organic Nitrogen (µg/l of N)
- Alkalinity (mg/l of $CaCO_3$)
- Ammonia, NH_4 (µg/l of N)
- pH

Field water quality sampling

Baishi Reservoir on the Daling River (at the time this photograph was taken this new reservoir had not reached capacity)

In addition, water quality measurements are required at other locations in the model to allow the user to calibrate the model.

The reaction rates and settling velocities for the water quality parameters are typically user defined parameters. Default values for the reaction rates and settling velocities are usually provided but should be adjusted during calibration.

Water quality models also often use climatic data such as: air temperature, wind speed, dew point temperature, percentage cloud cover, and percentage shade.

Data collection considerations

The availability of data for water quality modelling is an important consideration for any study. If no data is available, it is not possible to calibrate or verify a model. Similarly, the modelling adage, “rubbish in, rubbish out” is worth keeping in mind through out any data processing and quality checking.

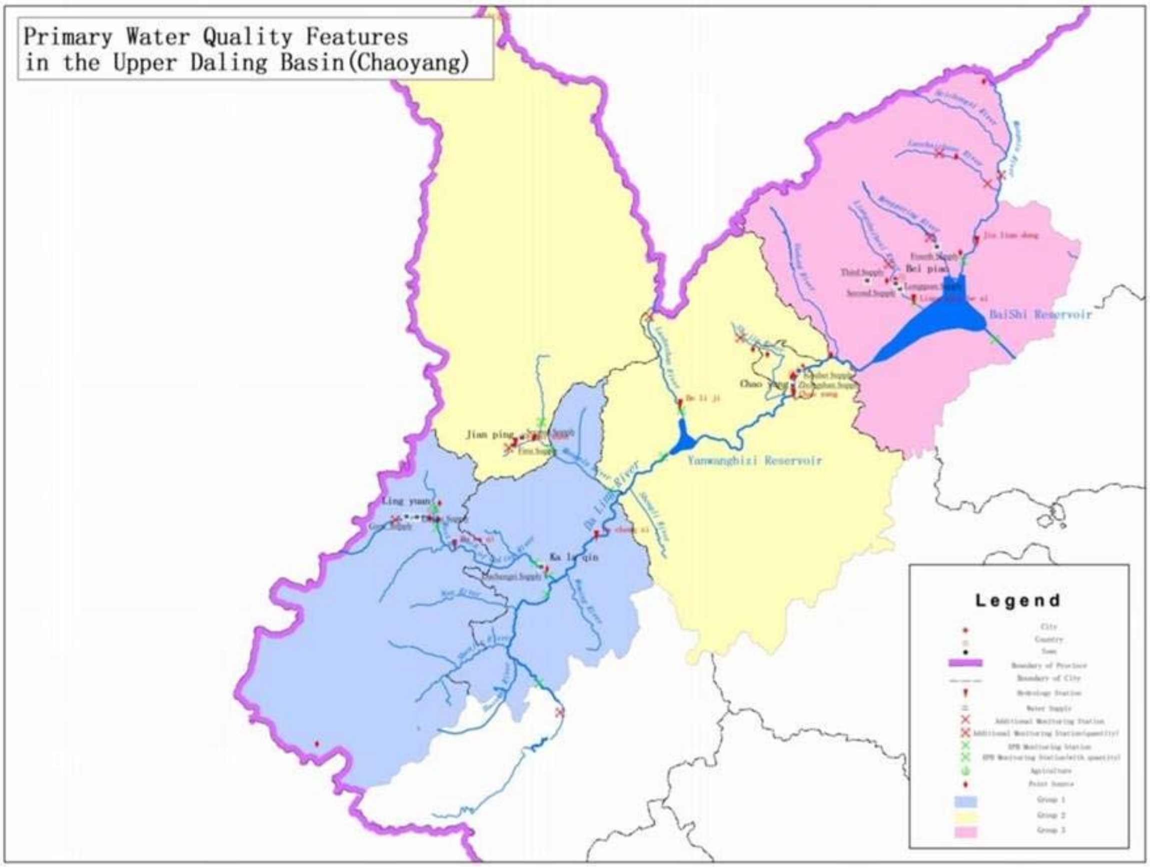
While the physical characteristics of a river are possible to measure during a relatively short field campaign, water quality, rainfall and flow measurements must take place over a timescale of months or years to provide meaningful data. There may be dramatic annual variation in these parameters which necessitate frequent measurement (perhaps daily, weekly or monthly). Typical data sets from the UK might be as follows: daily rainfall data, daily flow rates at gauging stations, fortnightly water quality and spot-flow data at other locations.

If water quality conditions are undergoing a period of change (e.g. growth of local industry) then it may only be appropriate to use water quality (and hence, flow) data from recent years. For example, if a water treatment plant was constructed three years ago, only data for water quality since the construction should be used to calibrate the model.

For a model such as Qual2K, which is based on a hydraulic model, it is particularly helpful to have adequate flow data for the study reach so that the hydraulic part of the model may be calibrated. The Chaoyang model was able to use data from a gauging station just upstream of the city, and this allowed calibration of the flow at that location. Ideally for a hydraulic model, one would have a gauging station at the upstream headwater and at the downstream end of the model. This allows the flow entering the system to be entered into the model accurately, and then runoff throughout the model can be calibrated to the known flow at the downstream end of the model. Any additional gauging stations or spot flows throughout the study reach are also useful for calibration purposes.

The available water quality data for any particular region may not exactly match the suite of water quality determinands in any particular model; some compromise will always be required. Specialist literature or expert advice should always be consulted to ensure that these compromises are appropriate.

Figure 3 Map showing proposed water quality model extent and data locations, Daling River Basin, Liaoning Province



Data sharing

In China, different elements of the required data for water quality modelling are held by different agencies. The WAB holds water quality and flow data for rivers, data on abstractions, rainfall data. The EPB holds data on discharges to the river, some river water quality data, meteorological data, land use data.

A water quality model requires all this data, and its creation is arguably to the benefit of both agencies in assisting with suitable abstraction and discharge permit setting. Therefore it is recommended that the data is shared freely between the two agencies.

In Chaoyang, data is now shared between the WAB and EPB agencies at municipal level. This was achieved through a Memorandum of Understanding. This cooperation has been essential in obtaining the required data for the creation of the water quality model.

Further information on setting up such inter-agency agreements, and examples of suitable text related to data sharing for improved water quality management, can be found in Advisory Note 8.4 ‘Inter-agency Agreements for Collaborative Water Quality Management’.

It should be noted that some data is held by municipal level WABs/EPBs, whereas other data is held by provincial level, or county level WABs/EPBs. Again it is recommended that data and model results should be shared freely between these agencies, however in Chaoyang, the agreement existed solely between the municipal level organisations. This required the purchase of further information from outside the Chaoyang Municipality when the team decided to expand the model coverage.

Box 2: Benefits of data sharing between EPB and WAB

Both EPB and WAB have responsibility for water quality management. Water quality managers will make better decisions if they have all the available data – this includes both EPB and WAB data.

There is some overlap in the data measured by EPB and WAB. There are some efficiencies to be gained by reducing this overlap and making more effective use of resources.

A water quality model is a useful decision making tool for water quality managers from both EPB and WAB. The more data available for a model, the more accurate and useful it will be. Therefore it is more effective to produce a shared model using data from both EPB and WAB.

It is worth bearing in mind the differences between the two datasets when combining the data. For example, water quality data may be measured at the same location by the two agencies on different days. This should be taken into account when finding the seasonal median values of the data sets.

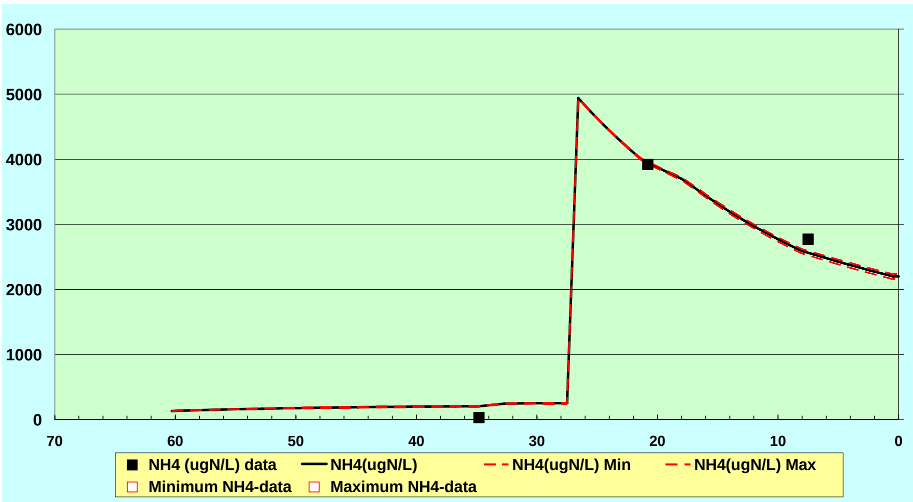
5.4 Running the model

Once the water quality has been set up and calibrated, the local EPB and WAB staff who have been involved in the model set up will be able to run the model independently.

Setting up new scenarios for testing changes in permitting is straight-forward; local staff can be involved in this and take on the responsibility of running new scenarios.

5.5 Interpreting the results

Interpreting model results requires a good understanding of the model, the characteristics of the river, and water quality processes. Care should always be taken with the interpretation to ensure that realistic inferences are made. The model results should be interpreted by someone with suitable experience. Local staff should be able to do this after training.



Qual2K simulation result for Ammonia concentration (ug/l of Nitrogen)

The first step with result interpretation should always be a “reality check”, i.e. does the model give the expected results? While the user may not be able to predict the percentage change in water quality due to some future scenario, they should still have an expectation of whether the concentration of pollution is likely to increase or decrease, and perhaps some appreciation of the order of magnitude of that change. Any result going against this reality check should be investigated to determine whether there is a good explanation, or if there are some errors in the model or inputs.

The results can then be interrogated to answer the question posed when creating the model or scenario. Discussion of the results amongst a knowledgeable team is always to be encouraged to gain as much insight as possible into the results.

5.6 Water quality responsibilities

In China, the Water Affairs Bureaus (WABs) are responsible for the water quality in the river systems. However, it is the responsibility of the Environmental Protection Bureaus (EPBs) to monitor and permit discharges to rivers. Both organisations would benefit from sharing information to inform both the permitting (which should be closely related to the desired river water quality) and to influence the river water quality.

In addition, the WABs issue permits for abstracting data from both surface and groundwater sources; these can also have significant impact on the water quality of a river system.

It should be noted that the water quality targets are related to loadings to the river (i.e. discharges), rather than the water quality in rivers. Therefore EPBs are responsible for reducing (or maintaining) the loads to rivers, but it is not always clear what difference this will make to the water quality.

The most effective use of a river water quality model is likely to be a shared-use model which is informed by the discharge and abstraction data of both EPB and WAB:

- EPBs should make use of a water quality model to inform the permitted limits that they issue to industries.
- WABs should use water quality modelling to anticipate changes to water quality in the river system.
- Joint targets in river water quality for EPB and WAB, in association with the modelling, could indicate suitable permitting limits for both abstractions and discharges to river systems.

5.7 Training and staff requirements

Local staff in the provincial WABs and EPBs may have no prior experience of water quality modelling. The staff are likely to be knowledgeable in a variety of subjects in the area of water and environmental management. They are likely to be university educated in relevant subjects such as Environmental Science, and Water Resources, but detailed knowledge of water chemistry, hydrology and hydraulics can not be assumed.

Training of staff needs to focus on water quality modelling, with other subjects being explained as and when necessary. Training could be provided by local consultants such as staff from universities or institutes where modelling is undertaken. Staff should be trained and involved throughout the project so that they get a full understanding of all the processes.

One area of training required will be in estimating and approximating values where no exact, measured value was available. Estimation and approximation can make the staff uncomfortable and doubt the model's relevance. This could be addressed using demonstration sensitivity tests in which the estimated values are adjusted slightly to see what difference is made in the model results.

Modelling work should always be undertaken in blocks of activity. The staff undertaking the modelling should be allowed to focus on the model and spend almost all their time on it during the initial project or subsequent updates. This is the best way to ensure good understanding, the best quality of work possible, and minimise errors.

Poor quality water in Daling River, Liaoning Province

Appendix A

Glossary of Modelling Terms

Analytical	An analytical model uses equations that have an exact solution. No numerical methods are required.
Bathymetry	Elevation measurements of the bed and banks. Can be spot measurements or cross-sections. This term is used predominantly for 2D and 3D modelling, whereas “cross-sections” are used in 1D modelling.
Boundaries	The edges of a model – for a 1D model, upstream and downstream boundaries are required. Data is required to establish conditions at the boundaries – typically flow, water level, and water quality conditions
Calibration	Calibration is the process whereby estimated model parameters (e.g. reaction rates) are adjusted so that the result agrees with the available data.
Cross-section	Profile of the river bed and banks, perpendicular to flow direction.
Node	Many models use point locations, “nodes”, at which the hydraulic and/or water quality calculations are made. Some models are cell based instead, and calculate values at cell centres.
Numerical	Numerical models use equations without an exact solution. Numerical (typically computational) methods are used to solve the equations.
Reach	A length of river, usually between two nodes.

Appendix B

Listing of Water Quality Modelling Software used Internationally

Package	Developer	Proprietary/ Free/ Bespoke	Used in China
AGNPS	US Department of Agriculture http://www.wsi.nrcs.usda.gov/products/w2q/h&h/tools_models/agnps/index.html	Free	Yes
ISIS	Halcrow http://www.halcrow.com/isis/wq.asp	Proprietary	
MIKE BASIN	Danish Hydraulics Institute http://www.dhigroup.com/Software/WaterResources/MIKEBASIN.aspx	Proprietary	Yes
MIKE11 with ECOLAB	Danish Hydraulics Institute http://www.dhigroup.com/Software/WaterResources/MIKE11.aspx	Proprietary	Yes
Qual2K	US Environmental Protection Agency http://www.epa.gov/athens/wwqtsc/html/qual2k.html	Free	Yes
SIMCAT	Environment Agency for England and Wales http://www.environment-agency.gov.uk freely available on CD in the UK upon request	Free	
SMS	Environmental Monitoring Systems Inc. http://www.ems-i.com/SMS/SMS_Overview/sms_overview.html#WATERQUALITY	Proprietary	Yes
SWAT	Blackland Research & Extension Centre (Texas university collaboration) http://www.brc.tamus.edu/swat/factsheet.html	Free	Yes

Notes: Software is continuously being updated and improved, hence the Listing above was valid only at the time of preparing this document.

Document Reference Sheet

Glossary:

EPB	Environmental Protection Bureau
MEP	Ministry of Environmental Protection
MWR	Ministry of Water Resources
WAB	Water Affairs Bureau

Bibliography:

Chapra, S.C. (1997), *Surface Water Quality Modelling*, McGraw-Hill。

Chapra, S.C., Pelletier, G.J. and Tao, H. (2006). *QUAL2K Documentation and Users Manual*. Civil and Environmental Engineering Dept., Tufts University, Medford, MA. Free download: http://www.epa.gov/athens/wwqtsc/html/qual2k.html

Related materials from the MWR IWRM Document Series:

Advisory Note 1.5	Use of QUAL2K Water Quality Model in IWRM Planning
Example 1.5	Water Quality Modelling in Chaoyang, Liaoning Province
Advisory Note 1.7	Designing a Monitoring Programme for Water Quality Modelling
Advisory Note 1.1	Models for Water Resources Planning and Management: Selection Procedures
Thematic Paper 8.4	Inter-agency Collaboration for Improve Water Quality Management
Advisory Note 8.4	Inter-agency Agreements for Collaborative Water Quality Management

Where to find more information on IWRM – recommended websites:

Ministry of Water Resources: www.mwr.gov.cn

Global Water Partnership: www.gwpforum.org

WRDMAP Project Website: www.wrdmap.com

China – UK, WRDMAP

1. WRA

Integrated Water Resource Management Documents
Produced under the Central Case Study Documentation Programme of the GoC, DFID funded, Water Resources Demand Management Assistance Project, 2005-2010.

Documents will comprise of:

Thematic Papers

Advisory Notes

Manuals

Examples

Training Materials

IWRM Document Series materials, English and Chinese versions, are available on the following project website

WRDMAP Project Website: www.wrdmap.com

Advisory Services by : Mott MacDonald (UK) leading a consultancy team comprising DHI (Water and Environment), HTSPE (UK), IWHR, IECCO (Comprehensive Bureau), CIAD (China Agricultural University), Tsinghua University, CAAS-IEDA, CAS-CWRR, Gansu WRHB and Liaoning WRHB.