DRAINS
The First 20 Years

1. In the Beginning

DRAINS started life in 1996 when Bob Stack (of Watercom) suggested to Geoff O’Loughlin that Watercom’s PIPES software could be adapted to provide a Windows interface for Geoff’s (DOS based) ILSAX software. The "look and feel" of today’s DRAINS comes directly from PIPES.

Geoff’s background was in hydrology. Bob’s was in hydraulics and computer programming specialising in unsteady flow.

Geoff had sold about 200 copies of ILSAX at $50 each. Bob thought it might take 4 to 6 months to convert to a Windows interface and hoped to sell enough copies to cover the cost of his time. He did not originally envisage any Engineering modifications to the ILSAX procedures. Geoff recognised the limitations of ILSAX (ref Appendix 1) and hoped to overcome them. Neither Bob nor Geoff saw this as an on-going project lasting more than 20 years.

2. Development

When he started work on DRAINS Bob realised the severe limitation imposed by the assumption of pipes flowing just full, but not under pressure. This is not how many drainage systems work. Watercom’s PIPES program could analyse pipes flowing full and could account for shock losses at pits. It could not account for pipes flowing part full. Drainage systems typically contain both pipes flowing full and part full. Bob thought a drainage system could be split into parts flowing full and parts flowing part full, with PIPES used to model the former and new procedures developed to model the latter. This led him to develop the basic hydraulic model (and to a much longer development time). The rudimentary hydraulic model in ILSAX was never used in DRAINS.

DRAINS was first released for sale in January 1998. Bob wrote all the code for DRAINS in C++. Bob and Geoff carried out testing of beta versions of DRAINS. Much of the code for interacting with the user (i.e. respond to mouse and keyboard input in real time – zooming, panning, drawing pipes and other shapes etc.) was available in PIPES. The major steps Bob faced in the development process (pre-release) were:

- Adapt the PIPES code to include new features such as pits, detention basins, overflow routes, channels.
- Develop dialog boxes for user input of data for the various components of a DRAINS model including physical components (pipes, pits etc.)
- Develop a design procedure based on pipes flowing full and using the QUDM concept of maximising surface flows subject to satisfying safe depth and safe depth x velocity requirements. Take account of minimum pipe slope and cover (allow for varying surface levels between pits). The procedure sets pit sizes and pipe diameters and levels. The rudimentary ILSAX design procedure was never used in DRAINS.
- Develop various graphs and reports for presentation of results.
• Develop the basic hydraulic model.
  o This required new procedures to deal with situations such as having no freeboard at pits which required modification of the pit inlet capacity equations to reduce the inlet capacity, or in extreme cases to reverse it to produce upwelling.
  o Sudden changes (such as when water first touches a pit grate) led to numerical instabilities and mathematical procedures were developed to overcome these instabilities.
  o It was necessary to define boundaries between pressure flow and non-pressure flow (i.e. which pipes were pressurised and which were not). These boundaries moved during the course of the storm. Even to locate the boundaries at one time step could be an iterative process.
  o Backwater calculations were developed for open channels. Initially flow in pipes was assumed to be uniform, but this was replaced with backwater calculations in a later version.

The first version of DRAINS contained only the ILSAX hydrological model (Horton loss equation followed by time-area routing). Over time Bob added more models including the Rational method, Extended Rational method (ERM), RORB, RAFTS and WBNM emulations, and Initial Loss/Continuing Loss (IL/CL) for a total of seven hydrological models. Geoff carried out testing of beta versions of the RORB, RAFTS and WBNM models. All of these models are simple compared to the hydraulic models in DRAINS. Three models (Rational, ERM and IL/CL) require no iterations. Horton’s equation would require an iterative solution, but Watson provided an alternative that does not require an iterative solution (used in the ILSAX model). The 3 emulation models involve a non-linear equation ($S = kQ^m$) which requires an iterative solution at each time step. Fortunately, this equation can be reliably solved using standard numerical techniques. In comparison, the unsteady hydraulic model can require the solution of thousands of simultaneous non-linear equations at each time step.

Following the commercial release of DRAINS Bob continued to develop new procedures. The equations used to describe pit inlet capacity (as used in ILSAX) were replaced with tables. This revision led to better treatment of blocking factors at pits (the old ILSAX procedure of simply reducing inflows by a fixed percentage gave false results at low approach flows to on-grade pits). Geoff provided pit data bases from published data for different states in Australia.

In 1999 Bob added a spreadsheet interface to DRAINS. This allowed data to be transferred between DRAINS and Excel. It allowed bulk changes to DRAINS data to be made quickly. It also allowed third parties (e.g. 12D) to prepare data for import to DRAINS and for results from DRAINS to be transferred back to such third party software. This was followed by adding read/write capabilities for other formats including DXF files, ESRI shapefiles, Mapinfo files and Microsoft Access mdb files.

The basic hydraulic model had limitations which occasionally caused problems. Many were overcome with ongoing refinement of the model, but there was one that could not be overcome due to the inherent splitting of the model into pressure/non pressure components. Something better was needed.

In 2006 Bob completed development of the unsteady flow model in DRAINS. This solved the full 1D St Venant unsteady flow equations in pipes, channels and overflow routes. This allowed accurate
modelling of non-uniform flow in overflow routes, including storage routing effects. This was a major advantage over the basic model which assumed uniform flow (i.e. Manning's equation) in overflow routes and took no account of storage in overflow routes or channels. The unsteady flow model allowed accurate modelling of complex surface flows.

The unsteady model proved even more reliable than the basic hydraulic model. The unsteady model was sold as an optional extra for DRAINS, primarily for those users who need more accurate modelling of surface flows. It now became apparent that those users who did not purchase this optional model would benefit from its advantages in modelling pipes and channels. This led Bob to develop the standard hydraulic model which solved the full unsteady flow equations in pipes and channels, but not in overflow routes. The unsteady model was rebranded as the "Premium hydraulic model" and the "Standard hydraulic model" was released as a replacement for the basic hydraulic model in 2010.

The DRAINS program, like nearly all Engineering programs of the time, was developed for sequential processing. For many years CPUs had been increasing in speed. This stopped when CPU speeds hit the heat wall. Computer manufacturers started producing multi-core processors to compensate. Engineering programs of the time were not ready for this development.

Bob undertook a major rework of the DRAINS code to take advantage of multi core processing. This feature was included in DRAINS in 2010.

In 2014 Bob made substantial improvements to the design procedure in DRAINS resulting in more economical designs.

In 2015 James Ball and Mark Babister gave an outline of what was to come in Australian Rainfall and Runoff 2016. Of particular relevance to DRAINS was that a single storm (for a given frequency and duration) would be replaced by an ensemble of ten storms. Practitioners were to rely on median or mean results rather than the worst of the ten storms. This meant that instead of analysing say 10 storms DRAINS would now need to analyse 100 storms. The old ways of presenting results needed to be changed to suit this requirement. It also meant that sequential processing would take too long. Fortunately multi-core processing in DRAINS had then been in use for 6 years and was now very reliable. Bob released the ARR2016 version of DRAINS in 2016.

Overview

It is now 20 years since DRAINS was first released in 1998. The major developments over that time are summarised above. In addition there have been very many smaller developments. The only remnant of ILSAX still remaining in DRAINS is the ILSAX hydrological model (Horton loss equation followed by time-area routing).

The source code for DRAINS is now estimated to be over 500,000 lines of code. Hydrology calculations account for a tiny fraction of DRAINS. Hydraulic calculations account for a much larger amount, but still a very small percentage of total code.

Development is on-going.
3. Documentation

Geoff wrote the user manual and on-line help system for DRAINS. He also prepared numerous examples to accompany the documentation. He also prepared several spreadsheets to assist DRAINS users in various tasks (e.g. rearrange DRAINS results to suit various Council requirements).

He continues to update the documentation as Bob further develops DRAINS.

4. Training

Geoff has run regular training courses on DRAINS for most of the last 20 years. These have been held at various locations around Australia. He has also run specialised in-house training courses for various organisations. In recent years Ben Kus has joined him in running these courses.

5. Maintenance

All software as complex as DRAINS requires on-going maintenance. Some is forced on developers by changes in the IT industry which they cannot control. Examples are:

- DRAINS started life as a Windows 16 bit application. When 32 bit Windows was released it had to be adapted. When 64 bit Windows was released it had to be adapted again.
- DRAINS used Microsoft Access files (.mdb) to transfer data to and from Advanced Road Design (now Civil Site Design). The format of these files is not published and Microsoft provided developers with a library of functions to read and write data from and to these files. When Microsoft withdrew support for .mdb files the Microsoft library used to access these files no longer worked and the link between DRAINS and ARD was broken. Bob and Peter Bloomfield (the author of ARD) agreed to switch to XML files.

DRAINS is considered to be very user friendly by its users. In software as complex as DRAINS this doesn’t happen by accident. It takes a lot of work. From the beginning Bob included extensive error checking both at the time of data entry (property sheets) and at the start of every design/analysis run. In recent years he has introduced checking of results with the aim of warning users of possibly bad results.
Appendix 1

ILSAX Capabilities

ILSAX, developed by Geoff O’Loughlin, was based on ILLUDAS-SA with something extra added (hence the X in ILSAX). It included a hydrological model and a hydraulic model.

The hydrological model converted a storm hyetograph into a runoff hydrograph for each sub-catchment. It used Horton’s equation (as modified by Watson) to calculate rainfall losses and the time-area method to convert rainfall excess into a runoff hydrograph. Today we refer to this combination as “ILSAX hydrology”.

The hydraulic model included design and analysis capabilities:

- Pits were classified as sag, on-grade or ILLUDAS (a simplistic pit no longer used in DRAINS). Inlet capacities were described by equations for which the user provided parameters. Flows from sub-catchments arrived at pits where they were split into “captured” flow which entered the underground pipe system and “bypass” flow which remained on the surface.
- The user was required to specify a slope for every pipe. The diameter was optional. If not provided, ILSAX would select a suitable diameter to carry the “captured” flow assuming the pipe was just full, but not under pressure. This was the rudimentary design capability provided in ILSAX.
- No level data (RLs) were considered in hydraulic calculations. Calculations assumed pipes flowing full, but not under pressure. No allowance was made for shock losses at pits. This was the rudimentary hydraulic analysis capability provided in ILSAX.

ILSAX also included other capabilities not relevant to DRAINS.