CAPABILITY STATEMENT

1. QUALIFICATIONS AND EXPERIENCE

J. Malcolm Ashworth was educated in Britain and has a B.Sc. (2:1 Hons) in Environmental Science and an M.SC in Hydrogeology.

Over the period 1982 to 1991 he worked in Britain, Nigeria, Pakistan and the Sultanate of Oman for several different Engineering Consulting firms. Projects he participated on included catchment studies, the dewatering requirements of a nuclear power station, rural and town water supplies, assessment of recharge and impoundment dams, water requirements for irrigation, and environmental liability assessments.

Over the period 1991 to 1999 he worked for the Ministry of Water Resources in the Sultanate of Oman as a Hydrogeological Expert. Over this period he worked on a series of regional reports detailing the water resources for each basin in Oman, helped prepare 5-year Master Plans, developed water resources assessment methodologies, evaluated internal and external reports and provided advice to the Directorate of Water Resources Assessment (Technical Secretariat). He also set up a GIS system for managing groundwater data in the Nejd and provided team management to regional projects in the Nejd and Wahaybah Sands.

Since 1999 he has worked largely as a Freelance Consultant in Afghanistan, Albania, Botswana, Burkina Faso, Cambodia, Canada (Alberta), Kenya, India, Kosovo, Laos, Nigeria, Oman, Pakistan, Sudan, Thailand, UK, USA (California) and Vietnam. During this period the projects he has worked on included groundwater contamination assessments, production wellfields for rural and town water supplies, water source supplies for desalination plants, groundwater exploration, provision of training, large scale irrigation projects, implementation of new technologies for topographic surveys (UAV's), and the development of conceptual and numerical groundwater models.

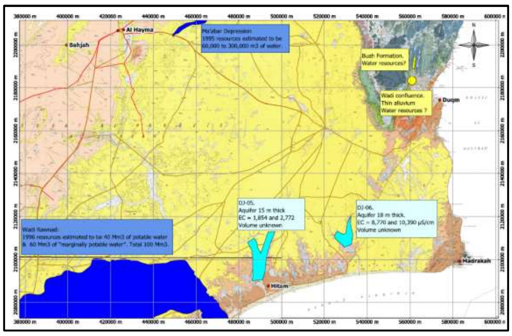
J. Malcolm Ashworth has excellent computer skills. He is an expert in collating and processing satellite, DEM, base data and water resources information into databases then utilising these data to create GIS maps for assessment, management, reporting and presentation purposes.

2. WATER RESOURCE CAPABILITIES

2.1. Water Resources

River Basin Assessment and Management:

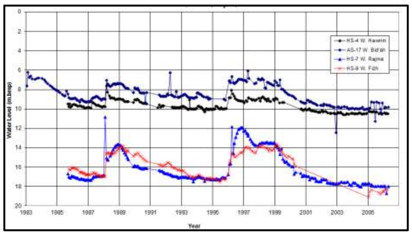
Water resource management plans start with a comprehensive assessment of the components of a river basin's water balance, available resources and the appreciation of how changes to one or more components of this balance affect other components and the environment in terms of quantity, quality and location.



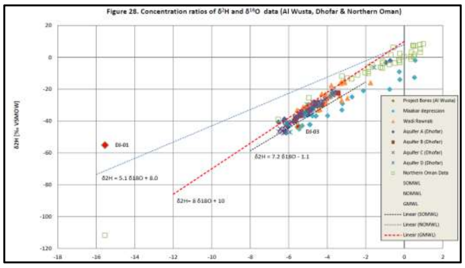
Information collated into databases and presented on maps, using ArcGIS, are key to a regional perspective for the management of water resource components.

In general, four general categories of data are required for such assessments.

- **Water resource development and use**: These items create significant “pressures” on available water resources and include the demographic distribution, agricultural development, significant domestic water supplies, livestock demand, municipal, industrial and commercial use, waste water treatment facilities and other significant sources of pollution.



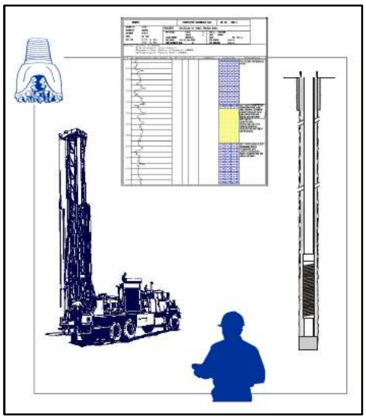
- **Water resources monitoring**. Monitoring data enable water resources and the chemical status of water bodies to be qualified, and trends to be assessed. Main data sets include meteorological information, surface water flows, spring flows, river ecology, ground and surface water quality, and groundwater level data.



- **Water resources assessment information**. These are interpreted and analysed data and include rainfall patterns, surface flows, evapotranspiration and recharge estimates, distribution of aquifer systems, groundwater levels and flow directions, groundwater storage, quality distribution and potability, isotope data, suitability of water for irrigated agriculture and ecological status.

- **Water management**. These are data and maps showing key water resources issues and include mean annual water balances, the general water resource situation, water resource and environmental protection areas, areas at risk of flooding, dams, conservation and development schemes, resource development constraints and potential.

Expert services can be provided to collate and process water resources information from stakeholders, field inventories, pilot projects and the internet, onto ArcGIS maps, for assessment, management, reporting and presentation purposes.



Exploration:
Key sets of data required for groundwater resource assessments are often missing or inadequate. Drilling exploration boreholes, conducting aquifer tests, and initiating appropriate monitoring programs are then needed. Associated services that can be provided include facilitating remote sensing investigations (airborne, satellite and geophysical investigations), borehole designs, preparation of tender documents and specifications, supervision of drilling and borehole construction, aquifer and borehole testing, and analyses of data.

Development:
Effective groundwater management may require a range of different development options. The three most common requirements are:

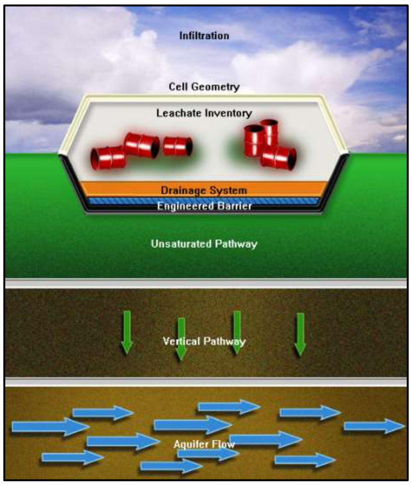
- Production Boreholes to provide potable drinking water for rural or urban water supplies.
- Production wells to provide water for irrigated agriculture and livestock.
- Managed Aquifer Recharge (MAR) is the process of adding a water source under controlled conditions for withdrawal at a later date, or used as a barrier to prevent saltwater or other contaminants from entering the aquifer. Water can be recharged by a number of methods including infiltration via reservoirs, galleries or injection wells (Aquifer Storage & Recovery (ASR)).

Consulting services can be provided for the design, tendering, supervision (testing and construction) and management of these groundwater development options, or other schemes as required.

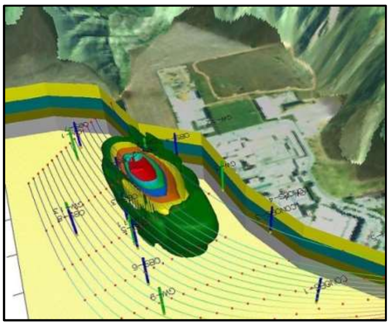
Evaluations:
Technical advice can be provided to determine the effectiveness of groundwater assessment, water management and development programs, and solutions to water conflicts.

2.2. Groundwater Models

Groundwater models are useful tools for solving and predicting groundwater flow and transport problems in aquifers. Typically these problems might involve: calculating the radius of influence of a well or wellfield; modelling the movement of leachate, leachate production, transportation and attenuation; and, calculating the impact of large scale groundwater abstractions on other users and on available resources. Analytical or numerical models can be deployed for solving these issues. The selection of the most appropriate model depends on the complexity of the problem at hand.



- **Analytic models**, such as LANDSIM, CONSIM, GFLOW or BLUEBIRD, allow steady-state 2-D groundwater flow systems to be simulated using analytic functions. In these programs, a library of specialized “analytic elements” are superimposed to model a variety of features such as head of leachate, flow rates, engineered barriers, advective transport, contaminant concentration, drains, slurry walls, wells and reservoirs. The functions associated with these elements meet Darcy’s law and Mass Continuity equations everywhere in the domain. Some of these models such as LANDSIM and CONSIM are specially designed to produce estimates of possible contaminant concentrations using probabilistic assessment techniques, e.g. Monte Carlo Method or Bootstrap Sampling.



- **Numerical groundwater models** such as the U.S. Geological Survey's (USGS) developed Modular Finite-Difference Flow Model (MODFLOW) provide the code for solving groundwater flow and contaminant transport in 3-D. Since its development in 1983, numerous codes or packages have been developed for MODFLOW. Packages can be stand-alone codes or can be integrated with MODFLOW. These packages include advective transport model (PMPATH), the solute transport model (MT3D), parameter estimation programs (PEST), solute transport model (MOC3D), inverse models (MODFLOWP) and seawater intrusion (SEAWAT).

Commercial software, such as *GMS (Groundwater Modelling System),* can be deployed that integrates these packages with analysis and calibration tools and 3D visualization capabilities into a single software environment.

2.3. Surface Water Models

Hydrological models provide conceptual representations of the hydrologic cycle. For civil engineering projects, they are particularly useful in solving and predicting return periods, flood discharges, flood volumes, the impact of floods and the design of engineering solutions to mitigate these risks.

The Annual Exceedance Probability (AEP) describes the likelihood or chance a specific event will be exceeded in a given year. There are several ways to express AEP as shown in the table below.

Probabilities of Exceedance

AEP as %	AEP as probability	Annual return period (ARP)
50%	0.5	2-year
20%	0.2	5-year
10%	0.1	10-year
5%	0.05	20-year
2%	0.02	50-year
1%	0.01	100-year

A Peak Flood having a 1 in 100-year (Q_{100}) chance of occurring in any single year is a 1% AEP event. Bigger rainfall and storm events occur (are exceeded) less often than small events, and therefore have a smaller annual probability of occurring. This is also equated to risk of an event occurring: the smaller the event the bigger its risk of recurrence[1] (e.g. "High Risk" can be equated to a Q_5 event, a "Medium Risk" to a Q_{20} event and "Low Risk" to a Q_{100} event).

Typical techniques for predicting Design Flood Discharges are:

- Flood Frequency Curves (e.g. Creager (1945))
- Frequency Analyses (e.g. Peak Over Threshold (POT)).
- Empirical Methods based on a catchment's geometry (e.g. Mean Annual Flood (MAF)).
- Rainfall intensity and area relationships (e.g. the "Rational Method").

Design Flood Volumes can be calculated by creating a Unit Hydrograph (UH) for a particular storm event. A UH is the hypothetical unit response of a watershed (in terms of runoff volumes and

[1] Not to be confused with damage that might result from a "low risk" event: if infrastructure is located in their path, small AEP flow events have the ability to cause significant damage.

timings) to a unit input of rainfall, which enables the time to peak-flood and time to flood-dissipation to be estimated for other storm events.

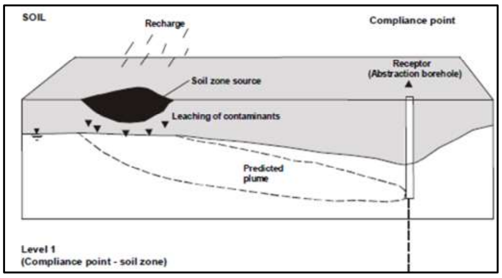
3D-Visualisation of flood inundation can be provided using HEC-RAS to see how these will impact a Project Site. HEC-RAS, developed by the US Army Corps of Engineers (USACE), is capable of modelling flow regimes (e.g. a network of channels, a dendritic system or a single wadi/river reach) along with the effects of bridges, culverts, weirs, and structures.

Flood Damage Predictions are made by modelling a flood's over-topping height, velocity and force when this strikes people or objects. Engineering solutions to mitigate these risks can then be advised as appropriate.

2.4. Environmental Assessment and Climate Change

Expert services can be provided to assist with Environmental Assessments, Compliance with Remedial Targets, and Climate Change. This includes:

- **Field Investigations, Laboratory Analyses and Monitoring**: Sampling to identify and delimitate sources of contamination, field investigations to characterise the extent of soil and groundwater contamination, laboratory tests to determine the properties of the soil, aquifer and contaminant, and monitoring to ensure contaminants concentrations meet acceptable levels.
- **Soil and Groundwater Risk and Vulnerability Assessments**: Risk and vulnerability analyses of soil and groundwater, to ensure compliance with Environment Agency standards, can be assessed using a variety of techniques including using; the UK's Level 1 to 4 procedures; numerical and analytic groundwater models; and, ArcGIS Overlay and Index methods. The latter includes a whole raft of different models, all founded on the US Environment Protection Agency's (EPA) DRASTIC Model (1987). This model comprises the superposition of maps detailing the depth to water table, net recharge, aquifer media, soil media, topography, impact of the vadose zone and hydraulic conductivity of the aquifer (the acronym DRASTIC). These hydrogeologic factors are used to infer the potential for contaminants to enter ground water. The relative ranking scheme uses a combination of weights and ratings to produce a numerical value, called the DRASTIC INDEX, which helps prioritize areas with respect to ground water contamination vulnerability.



  Newer Overlay and Index models tweak, remove or add DRASTIC parameters to investigate contamination, seawater intrusion, drought and climate change. These models include SINTACS (new EPA method), GOD (groundwater occurrence, overlaying lithology, depth to water), PRAST (protective effectiveness, net recharge, aquifer media, soil media and topography), GALDIC (used in coastal aquifers) and GRiMMS (drought assessment).

- **Climate Change**: Analysing the possible effects of climate change on groundwater on a country or region is challenging. A typically methodology involves: examining climatic trends; selecting appropriate climate change models that predicts future risks (e.g. changes in precipitation and temperature); modelling the groundwater vulnerability of the area to these risks; and, assessing the potential groundwater impact. In more detail this involves:
  - <u>Climatic Trends</u>: Historic variations and trends in temperature and precipitation can be assessed using Log transformations, descriptive statistics and the Mann-Kendall Trend Test (M-K test). The latter is a non-parametric test (distribution free).

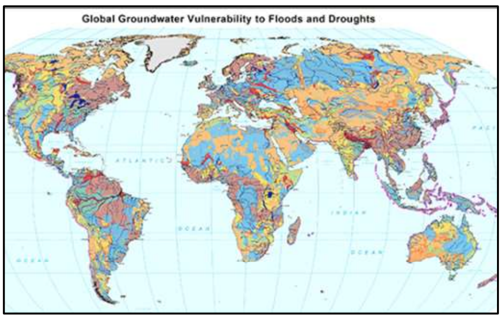
- Assessment of Risk. Historic data analysis may throw light on future trends. These can then be compared with Global Climate Models (GCMs), created by different agencies sponsored by the Intergovernmental Panel on Climate Change (IPCC), using inferential statistics. Over the last 30-years these data have been summarised and discussed in six assessment reports, referenced by the IPCC as FAR (1990), SAR (1995), TAR (2001), AR4 (2005), AR5 (2013) and AR6 (2021).

  Prior to year-2016 the most commonly used Climate Model Inter-comparison Projects (CMIPS) were CMIP3, released in year-2010, and CMIP5 released in year-2013. The CMIP3 and CMIP5 datasets contain output from a large number of different GCMs based on different emission scenarios. The 20 different models created under CMIP3 are collection of story-lines that describes different scenarios for the development of the human population, energy consumption and the proportion of renewable energy to fossil fuels. The 57 CMIP5 models are based on a simpler set of scenarios that use varying paths to reach different levels of greenhouse gas concentrations - or Representative Concentration Pathways (RCPs). Both collections of GCMs have scenarios that range from low to high degrees of climate change. The Fifth Assessment Report (AR5) produced by the IPCC drew heavily on CMIP5.

  Work on CMIP6 started in year-2016 and is a work in progress. Its main aims included provision of common standards, documentation and guidelines. By year-2021, AR6 had endorsed 23 CMIP6 models with "common data set forcing's".

With so many models, to choose from, CMIP advises that:

- *There is no perfect model, always use a selection of at least 4 different GCMs, the more GCMs included, the better. Do not attempt to select a best model for the region of interest.*
- *If using multiple climate model simulations for an analysis, always average across climate models as the very last step in the analysis.*
- *Do not average across multiple emission scenarios. In this case, averaging will NOT improve the quality of the output because scenarios are entirely different possibilities of future development.*
- *There is no one most likely emissions scenario. A good practice is to include a low and high scenario in the analysis to encompass the highest range in uncertainty.*
- *Inappropriate applications: Selecting one single model and/or one single future scenario for analysis.*
- *Do not expect a downscaled climate simulation to match day-to-day observations. Climate projections are intended to match observations over climate time scales of decades, not days.*



- Vulnerability Assessment. This assessment can be achieved using a Numerical Groundwater Model or an Overlay and Index Model and, as appropriate, may need to include for anticipated changes in precipitation, infiltration, recharge, runoff and water demand.
- Potential Groundwater Impact: In the case of depleted precipitation this will impact recharge and groundwater in storage, which could lead to falling groundwater levels, reduced base-flow in streams and flow in springs, and increased saline intrusion. Indirect impacts might include increased water demands for humans,

animals and agriculture due to a warmer climate and increased evapotranspiration, and deteriorating groundwater quality.

2.5. Project Management

Project Management services are also available to assist with:

- **Project implementation**: Provide Team Leadership, responsible for personnel, logistics, procurement and disbursement of equipment, project accounting and billing, project implementation and operations.
- **Liaison**: Provide expertise to liaise with parties concerned with project objectives and performance, from the perspective of either the Client or Consultant.
- **Proposals**: Develop scopes, plans, schedules and budgets and the integration of ideas into project proposals.
- **Training**: Provide training to improve the skills of junior and counterpart staff.