THE ON-SITE SEWAGE RISK ASSESSMENT SYSTEM

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ABSTRACT

There are over 280 000 on-site sewage facilities in use in NSW. Demand for decentralised sewage management options is growing. Septic systems which fail to adequately treat or contain effluent are a pollution hazard with potential to contaminate drinking water sources, aquatic food production areas and recreational waterways and to contribute to loss of amenity and environmental harm. This paper summarises the On-site Sewage Risk Assessment System (OSRAS) developed by Brown & Root Services for the NSW Department of Local Government (DLG) *Septic Safe* Program. OSRAS aims to help local government councils develop an evidence-based, risk management approach to regulating decentralised sewage management facilities.

OSRAS uses available natural resource information such as soils, slope and climate to classify the natural hazard of sewage facility failure. Attributes of the built environment such as lot size; water supply and sewerage reticulation contribute to the failure of on-site sewage facilities and to pollution hazards. These data are analysed within *OSRAS* using logic matrixes applied through a geographic information system (GIS). Environmental sensitivity data on drinking water catchment zones, shellfish production areas and other key receptors are incorporated to reflect sensitivity to sewage pollution. Effluent flows are tracked using a digital elevation model enabling cumulative impact assessment at downstream receptors.

OSRAS provides a means of assessing current risks, evaluating development scenarios and developing sustainable decentralised sewage management strategies. OSRAS can help guide the development of performance supervision and inspection programs. The visual outputs are excellent for communicating risk and for canvassing community expectations. OSRAS gives performance guidance for facilities in varying environmental circumstances and indicates standard data sets for failure risk analysis.

OSRAS is a software-independent tool for identifying sewage pollution hazards and analysing receptor risk for decentralised sewage facilities and diffuse source pollution. OSRAS supports catchment management, monitoring and capability planning and better local government management of the environmental health of catchments.

Keywords

decentralised, geographic information systems, management, on-site, risk assessment, septic tanks, sewage, strategic planning

Introduction

OSRAS provides an objective and accountable process for the identification and analysis of waterborne sewage pollution risks associated with the operation of decentralised sewage management facilities. OSRAS is a qualitative risk assessment tool for improved management of on-site facilities. It is not an automated model however the process can be quickly implemented, adapted and improved utilising readily available GIS technology. OSRAS is not a substitute for sanitation surveys and site-inspections but it can help maximise environmental and public health outcomes from limited management resources. *OSRAS* is not a guideline, plan or standard; rather it draws on available evidence, guidelines and knowledge to generate pollution risk maps for local government and the community.

Why is On-Site Sewage Pollution an Issue?

Better management of on-site facilities and other diffuse sources of pollution is increasingly important as discharge water quality from point sources is improved. On-site sewage facilities that are appropriately sited, designed and managed can provide satisfactory and sustainable sanitation services. However, lack of attention in any of these key areas can lead to failure and the release of hazardous levels of pathogens and other contaminants as shown in Figure 1. A facility is considered to have failed when an unacceptable level of contaminants is released from the facility to either the groundwater or surface water pathways to the environment. Discharge points include house drains, septic tanks, sewage treatment devices and land application areas that leak (eg. through structural damage, under-sizing, surcharge or runoff caused by hydraulic overloading). Intentional or accidental release of contaminated effluent presents a variable hazard to downstream receptors (Figure 1).

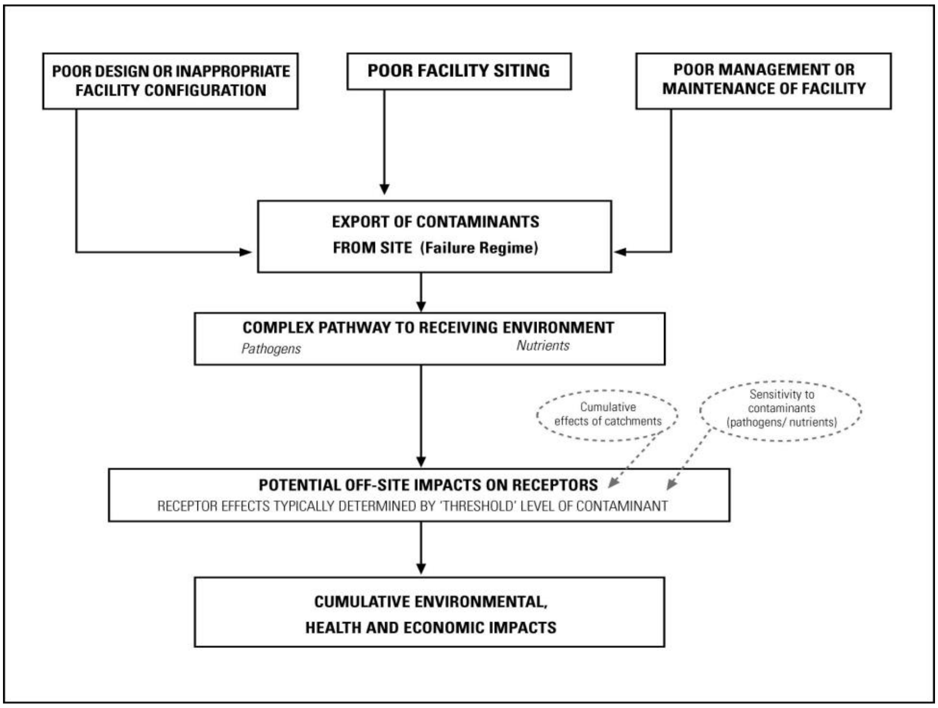

Figure. 1 - On-Site Failure and Risks

Overview of OSRAS

- Risk analysis requires identification of potential hazards and assessment of the consequence of those hazards (AS 4360). OSRAS provides a framework for classification and analysis of data relevant to on-site sewage pollution hazards and the subsequent downstream consequences. OSRAS is a "risk mapping" system and consequently the process is focussed on spatial data. The steps in OSRAS are:
- hazard identification (OSRAS Handbook Chapters 4 & 5);
- consequence (sensitivity) analysis (Chapter 6); and
- risk estimation considering catchments and drainage (Chapter 7)

These steps are discussed below and an overview of the process shown as Figure 2.

Hazard Identification

Hazards contributing to the export of sewage from on-site facilities have been divided into natural hazards (physical characteristics) and built hazards (human-made characteristics). The process for classifying and hazards is shown as phases A1 and A2 in Figure 2.

On-Site Natural Hazard

Natural characteristics reflect the ability to assimilate effluent without loss to surface or groundwater. OSRAS provides a framework to classify natural hazard factors into classes from class 1 (little or no physical limitation to sustainable effluent application and minimal likelihood of loss of sewage to surface or groundwater from a well-designed and managed facility), through to class 5 (severe likelihood of failure).

Soil - Soil factors of particular relevance to on-site facility failure include flooding, surface water run-on, waterlogging, high water tables, shallow soil, degree of surface rock, slope, shrink/swell soils, sodicity, water holding capacity, permeability, salinity and fertility. A system of classification for each limitation was developed from industry standards, guidelines and other sources. Knowledge matrices are used to derive a natural hazard classification based on site soils and landscape factors.

Slope - Wastewater movement is largely driven by hydraulic potential. Slope is a good indicator of potential and is analysed in *OSRAS* with a digital elevation model (DEM). Slope hazard is classified from class 1 <6% (little limitation) to class 5 > 25% (severe limitation).

Climate - On-site facilities may surcharge during extreme rainfall events. The design of effluent application facilities is based on statistical analysis, with events in excess of these design parameters leading to surcharge. Poorly performing facilities may surcharge during less extreme events. Rainfall variability is used to classify natural climate hazards in *OSRAS*. Differences between mean and 90th percentile rainfall of <1000 mm are classified as low variability, of 1000-1500 mm as moderate variability and of >1500 mm as high variability.

On-Site Sewage Export Hazard

On-site sewage export hazard builds on the natural hazard characteristics of a site to classify the risk of sewage export considering the built environment. They range from class 1 (little or no risk of contaminant discharge from on-site facilities) through to class 5 (severe risk of contaminant discharge). Key characteristics contributing to this risk are allotment size (as a proxy for effluent land application area size) and the availability of reticulated water supply and sewerage services.

Effluent Land Application Area - The size of the effluent land application area is a target indicator because it influences the landscape's capacity to treat wastewater flows prior to entry into surface drains or streams and transport to receptors. Calculation of sustainable allotment size for decentralised sewage management is informed by work by Jelliffe and Hillier (2001). Allotment size (adjusted for a standard impervious area allowance of 200m^2) is used as a proxy for the size of the effluent application area. Case studies, notional allotment sizes of <1600m^2, 1600-10,000 m^2 and >10,000 m^2 were used to indicate the effect the size of an effluent application area has on the total on-site sewage export hazard.

Water Reticulation - Water usage in households with town water supply (or other reticulated supply from surface or ground water sources) is generally 30% higher than for those reliant upon rainwater tanks for potable water (AS/NZS 1547). On-site facilities serving premises with town water are rated one hazard class higher than those with rainwater tanks to reflect the likelihood of increased wastewater production.

Sewerage Reticulation - *OSRAS* assumes that reticulation of sewerage eliminates potential for on-site sewage contaminant export from the site. Risk assessment relating to leaky sewerage services or infill decentralised sewage services (e.g. greywater re-use) is not considered.

On-site Sewage Pollution Export Hazard Map

The export hazard map is a derivative map based on the characteristics previously identified. GIS algorithms and processes can be used to analyse the multi-layered spatial data to create maps. Maps are used for identifying sewage pollution export sites, determining management zones, planning facility audits, for settlement planning and for providing initial advice on development proposals. For example, sites with a high export hazard classification may require specifically designed sewage management facilities and regular performance supervision, while sites with a low export hazard classification may only require standard sewage facility designs with random audit supervision. Local health and amenity impacts and downstream environmental sensitivity must be considered in determining design standards.

Consequence (Sensitivity) Analysis

Sensitivity analysis is used to determine the consequence of on-site sewage facility failure and is a precursor to mapping receptor risk. Off-site sensitivity to sewage contaminants may have a health (generally pathogen-related) or environment (generally nutrient-related) focus (see Figure 2). Sensitivity is also related to the environmental value of the receptor and the water quality standard required to protect this value. For example, a progressively higher reduction in septic tank effluent (10^5–10^7 cfu/100 mL) is required to meet guidelines for secondary contact (<1000 cfu/100mL), aquatic foods (<14 cfu/100mL) and raw water supplies (<1 cfu/100 mL). Consequence analysis requires consideration of local environmental and health values including drinking water supplies, aquatic food industries and ecological communities and their conservation status.

Risk Estimation at Sensitive Receptors

Receptor risk is a function of both the probability and consequence of an outcome, such as contamination or environmental deterioration. The probability of an adverse impact at a receptor is influenced by the cumulative contributions from catchment hazards. The consequence is influenced by the sensitivity of the receptor. *OSRAS* handbook describes how GIS can be used to assess the cumulative effects of catchments and consider distance between hazards and receptors to estimate risk.

Catchment boundaries influence the fate of emitted pollutants and receptor risk. *OSRAS* describes how 'cumulative risk' in drainage lines can be mapped by 'hydrological' (flow-direction) tracking of pollutants using GIS and outputs from a Digital Elevation Model. This is used to determine the number of hazards upstream of any point in the drainage network. Risk to receptors can best be estimated when cumulative hazards are considered with distance and sensitivity factors. This process can be used to assess the likely extent of contamination of nominated surface and ground water receptors or likely impacts to high value ecosystems, such as wetlands.

The processes by which contaminants reach receptors are complex. Distance downstream from hazard to receptor has been used (Davidson *et al.* 2000) as a surrogate measure of risk reduction due to physical, biological and chemical processes during transport. *OSRAS* is conservative and does not account for downstream attenuation or risk reduction other than through consideration of distance.

Risk Reduction and Control

OSRAS aims to help local councils implement risk based settlement planning and management of decentralised sewage facilities for sustainable economic, environmental and public health outcomes. Management options may be modelled to determine their relative effectiveness in reducing or controlling identified hazards and risks. The potential impact of sewage pollution from new settlements in high-priority on-site sewage risk class areas may be modelled and sustainable development conditions specified. *OSRAS* provides a guide to specific action, as well as providing a systematic framework for a sustainable sewage management strategy.

Applications and Benefits of *OSRAS*

Table 2 Benefits of On-Site Sewage Risk Assessment System

***OSRAS* PROVIDES**	**THE BENEFITS ARE**
• A framework for risk-based management of decentralised sewage facilities.	• Systematic management of organisational exposure to risk and better targeting of effort and allocation of resources for decentralised sewage management.
• A process to identify likely sources of on-site sewage pollution.	• Regulatory inspections, support services and sewage infrastructure betterment programs can target identified 'high risk' areas.
• A process to identify areas most likely to be affected by on-site pollution.	• By locating values at risk (eg. streams, groundwater bores, oyster leases, wetlands) those most in need of monitoring and management can be focussed on.
• Simple model for 'what-if' analysis of decentralised sewage management options for land-use capability planning.	• OSRAS gives land-use regulators and developers a model for evaluating decentralised sewage management options and for more systematic assessment of sustainable development strategies.
• Assessment of likely performance outcomes for on-site facilities in differing environmental circumstances.	• Sustainable sewage management outcomes can be achieved by tailoring performance requirements to the circumstances of specific locations, having regard to downstream impacts and cumulative social, economic and ecological effects.
• Analysis of cumulative impacts of on-site sewage pollution and presentation of results in a highly visual manner.	• Maps are an excellent medium for communicating the cumulative impacts of sewage management choices and canvassing community expectations.

OSRAS is not a decision-making tool, nor is it a substitute for sound strategic planning. It is able to collate and present complex data relevant to the management of decentralised sewage facilities for decision making and planning. *OSRAS* is not a substitute for site inspection, but it can show which sites to look at. For councils supervising up to 12 000 septic systems this is important information.

Other Approaches to Sewage Pollution Risk Assessment

There is a range of catchment risk analysis and decision support systems in common use including simple checklists, spreadsheet 'prioritisation' systems and complex 'black box' models. *OSRAS* presents a new approach to mapping risks associated with diffuse pollutant sources that can be used to support other modelling applications. For example, water quality models typically rely on guesses as to the source and magnitude of potential hazards and OSRAS can locate and provide likely magnitude for some of these. Once hazards are located, generic checklists can be used during inspection programs to better quantify the hazard and to prescribe management measures. Importantly, *OSRAS* provides an objective and transparent data management system for accountable sewage management decisions.

Encouraging Continual Improvement

OSRAS is flexible, transparent and open to continual improvement. *OSRAS* depends on access to spatial and other data however, the accessibility, range and quality of spatial data sets are improving rapidly. At present there is relatively little spatial data relating to sewage facility management or performance. The following additional data can be worked into *OSRAS* to provide enhanced mapping detail:

- ***Lot Size Analysis*** – The risk associated with lot size may be refined based on development density modelling according to soil type and other factors;
- ***Climatic Data*** –In regions with high local climatic variability, spatial and detailed climate modelling may allow greater sensitivity in climate classification;
- ***Facility Audit Data*** – Verification of Natural Hazard classes and incorporation of facility performance data may enable further risk classification by "facility type";
- ***Facility Location*** - Remote sensing, aerial photography or GPS technology can be used to determine proximity of effluent application areas to drainage lines, assess 'effective' disposal area, identify local impacts (e.g. vegetation) or include other proximity factors;
- ***Facility Loading*** – water usage could be used to determine wastewater loads.

Other Catchment Sources - The focus of OSRAS is on the impact of sewage pollution from decentralised sewage services but these are not easily separated from other catchment sources such as stormwater, pump stations, intensive agricultural and areas of intensified human activity. The impact of water pollution from other sources must be considered to obtain a more complete picture of 'catchment' hazards and resultant risks. Activities involving the release of wastewater, (eg. leaky sewerage services, sewage treatment plants, intensive livestock husbandry and processing industries) may be a priority. Key factors contributing to risk need to be considered and spatial data and logic matrixes relevant to these factors compiled. These data may include volume of wastewater generated, a wastewater pollution rating, a treatment standard rating, a rating for number of animals or production units and available disposal area.

OSRAS and Septic Safe - *OSRAS* will provide the basic risk assessment methodology for the next stage of the NSW *Septic Safe* Program involving a systematic sewage pollution risk assessment in NSW coastal catchments. Regional OSRAS projects will train and coordinate participants from state agencies, councils and regional consultants in relevant data collection, mapping and assessment tasks.

Access - *OSRAS* is a conceptual model, not a product. It is free to use at your own risk.

Conclusions

OSRAS relies substantially on spatial data sets and the application of practical public health and environmental knowledge. The results are closely related to the quality of data and knowledge sources. *OSRAS* will assist long term catchment management and capability planning as well as facilitating improved environmental monitoring and management programs. *OSRAS* does not preclude the need for systematic supervision of on-site sewage facilities, however it can assess relative risks to assist targeted delivery of sustainable sewage management strategies and can facilitate delivery of 'front desk' advice to residents and development proponents.

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Figure 2. Overview of the On-site Sewage Risk Assessment System