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WHITE PAPER ON

Integrating microbial endpoints, including those related to antimicrobial resistance (AMR), into Australian and New Zealand guideline values for fresh and marine water quality

Executive Summary companion document

Australian Government
Department of Climate Change, Energy, the Environment and Water

Australian & New Zealand GUIDELINES FOR FRESH & MARINE WATER QUALITY

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SAAFE CRC is supported through funding from the Australian Government as well as contributions from valued research and industry partners. We gratefully acknowledge the support of our funding partners, whose contributions have enabled the research and development presented in this work. The views and opinions expressed in this publication are those of the authors and do not necessarily reflect those of the Australian Government or any other funding bodies.

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Purpose and Guide to the White Paper

This white paper explains why microbial endpoints, including those relevant to antimicrobial resistance, should be incorporated into default guideline values (DVGs) for toxicants within the Australian and New Zealand guidelines for fresh and marine water quality (ANZG).

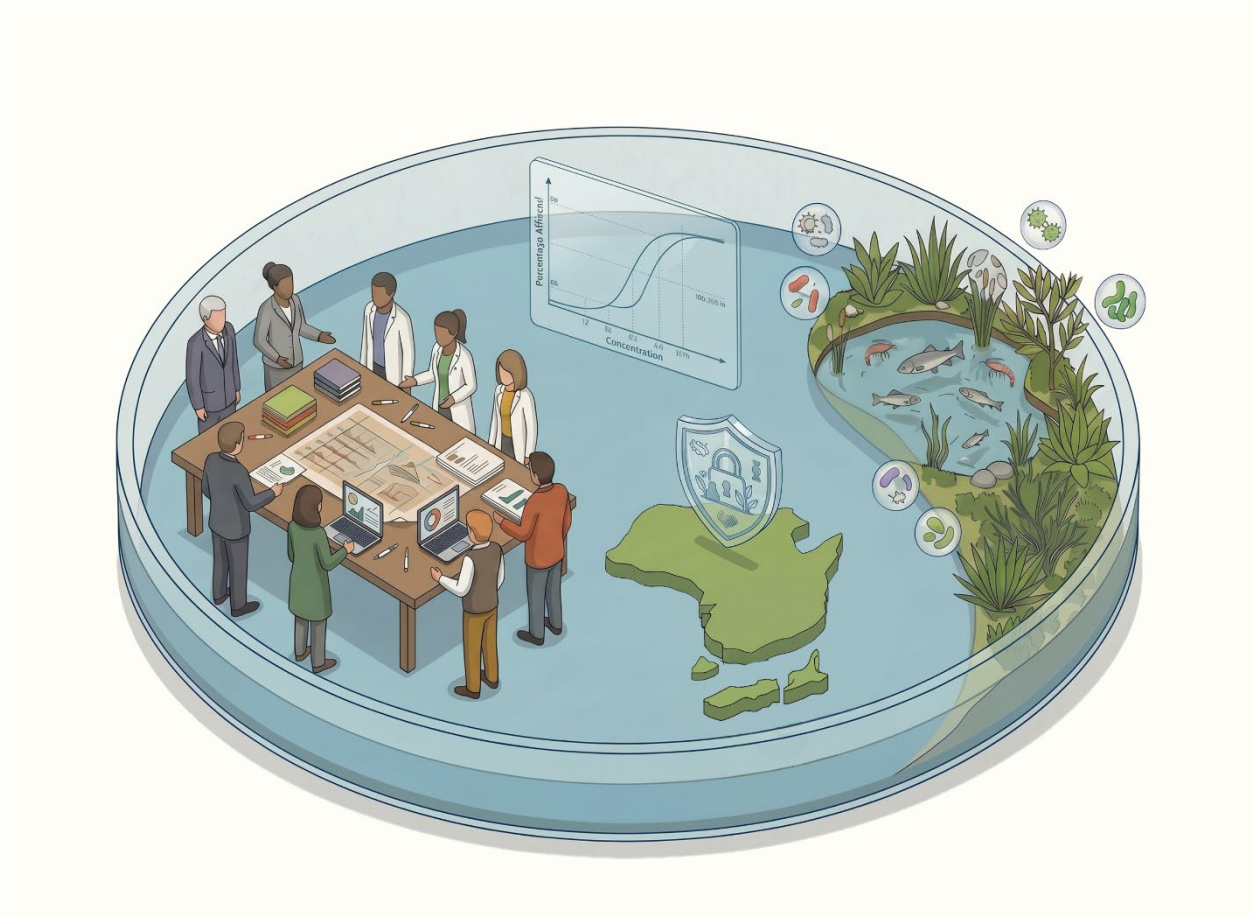
Drawing on syntheses from targeted workshops and conference sessions in Australia and New Zealand, it guides readers through the evidence, gaps, and actions needed to enable routine and defensible use of microbial endpoints when deriving guideline values.

The paper first proposes a co-created supplementary definition for “ecologically relevant microbial endpoints” to address a key gap in current ANZG guidance.

It then critically appraises priority endpoint categories, from single species assays to community function assays, genomics and multi-omics approaches.

Finally, the paper presents a gap analysis and a staged Action Plan and Roadmap (2026–2032) to guide method standardisation, governance, data stewardship, and regulatory readiness.

Together, these recommendations support more ecosystem-representative guideline values for toxicants in waters and sediments to strengthen One Health[1] protection outcomes.



[1] One Health is an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals and ecosystems. It recognises the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and inter-dependent. The approach mobilises multiple sectors, disciplines and communities at varying levels of society to work together to foster well-being and tackle threats to health and ecosystems, while addressing the collective need for clean water, energy and air, safe and nutritious food, taking action on climate change, and contributing to sustainable development (One Health High Level Expert Panel, 2023)

Research & Funding Acknowledgements

We would like to formally acknowledge the 36 workshop participants whose contributions were crucial to developing this white paper. Some have chosen not to list their names or affiliations, but we thank all equally.

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The views expressed in this paper are the views of the paper's authors or participants, as individuals, and not the views of the organisations they work for.

Official sponsors of workshops and conference sessions used to inform this white paper included DCCEEW, SAAFE^{CRC} and AIMS. The workshops and conference sessions were co-convened by CSIRO Minimising AMR Mission, SAAFE^{CRC} and the Society for Environmental Toxicology and Chemistry Australasian Chapter (SETAC AU).

This work was supported by SAAFE^{CRC} Kickstart Project K023, which received contributions from DCCEEW and SAAFE^{CRC}. SAAFE^{CRC} receives funding from the Australian Commonwealth government through the Cooperative Research Centre program along with partner organisations. This is SAAFE^{CRC} Approval number 3_K203_PB003.

Water Research Australia (WaterRA) provided administrative support, including publication and production of this white paper. Some member organisations of WaterRA were also represented within the project team and workshop participants.

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Suggested citation

Binet, M.T., Harford, A.J., Donner, E., Hayward, C., Ashbolt, N., Chariton, A., Luter, H., Thomas, M., Negri, A., Stauber, J.L., van Dam, R., Batley, G.E., Weaver, L., Pantos, O., Fisher, R., Adams, M.S., King C.K., Saaristo, M., Lepesteur, M., & Kumar, A. (2026). White paper on integrating microbial endpoints, including those related to antimicrobial resistance (AMR), into Australian and New Zealand guideline values for fresh and marine water quality. Executive Summary companion document. Prepared for the Department of Climate Change, Energy, The Environment and Water. SAAFE^{CRC} Publication number 3_K023_PB003, 21 pp.

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Problem Statement

Australian and New Zealand environmental water and sediment quality guideline values underutilise microbial endpoints, despite microorganisms underpinning essential ecosystem services and playing a critical role in One Health. This gap hampers accurate assessment of contaminant impacts on aquatic ecosystems, including antimicrobial resistance (AMR) risks, at a time when advances in genomic and multi-omics technologies offer strong potential for the integration of microbial endpoints into risk assessment frameworks.

Why integrating microbial endpoints now matters

Current Australian and New Zealand environmental water and sediment quality guideline values may not protect key ecosystem processes (nutrient cycling, disease regulation) that sit outside species level endpoints.

Microbial communities are often the most sensitive indicators of chemical stress, providing earlier warning than higher trophic levels.

AMR represents a distinct, escalating environmental, animal and public health risk not captured by existing guideline frameworks.

Advances in genomics and quantitative microbiome methods mean regulatory ready microbial data are now achievable.

Without clear guidance, regulators risk inconsistent or ad hoc use of microbial evidence.

Executive Summary

Overview

Aquatic ecosystem resilience and adaptive capacity are intrinsically linked to the compositional and functional dynamics of their associated microbiomes. However, current environmental water and sediment quality guidelines for toxicants predominantly focus on protecting organisms at higher trophic levels, with limited consideration of microbial communities. This white paper outlines why and how microbial endpoints, including those relevant to antimicrobial resistance (AMR), should be integrated into deriving environmental water and sediment quality default guideline values (DGVs) for toxicants in Australia and New Zealand (ANZ). It synthesises outputs from targeted conference sessions and expert workshops convened in 2025-2026 to identify barriers and enablers for incorporating microbial data into DGV under the Australian and New Zealand Guidelines (ANZG) for Fresh and Marine Water Quality (ANZG, 2018). The focus is on communities of environmental microbes (prokaryotic and eukaryotic microorganisms) as critical drivers of ecosystem services and as a key component of a One Health approach.

This white paper is intended to support regulators, guideline developers, consultants, and researchers in ANZ involved in derivation and/or application of DGVs, site-specific guideline values (SSGVs) for toxicants and direct toxicity assessments in waters and sediments. It consolidates findings into an action plan and roadmap centred around four overarching objectives, with fifteen actions to guide a staged implementation from 2026 to 2032.

In doing so, the white paper delivers four key outcomes that begin to address the problem statement:

1. **A new, co-created supplementary definition** of ‘ecologically relevant microbial endpoints’, tailored specifically for microbes and recognised as a gap in the current ANZG guidance (Warne et al., 2025).
2. **A critical appraisal of five categories of microbial endpoints:** cell-based assays; community functional endpoints; amplicon-based methods; metagenomic/meta transcriptomic approaches; and other omic/multi-omics. Each category was evaluated based on their ecological relevance, regulatory utility, and methodological readiness.
3. **Gap analysis** mapping identified barriers and enablers against current pathways for integrating microbial data into ANZG DGVs.
4. **An Action Plan and Roadmap** structured around four overarching objectives and fifteen key actions to guide staged implementation between 2026 and 2032.

This synthesis draws upon: two curated sessions at the joint conference for the Society for Environmental Toxicology and Chemistry Australasian Chapter (SETAC AU) and Australasian College of Toxicology and Risk Assessment (ACTRA) in Wellington, New Zealand (28 August 2025); an invitation-only workshop in Wellington, New Zealand (29 August 2025); and follow-on online workshops and surveys (October 2025- March 2026). The workshops included 36 participants spanning regulators, scientists, consultants and advisers, who contributed via facilitated discussions, Mentimeter polling, and scribed notes. Outputs were subject to thematic analysis to develop this white paper.

Key findings

What must change to enable better use of microbial endpoints

Ecological relevance must be redefined for microbes within ANZG guidance documents.

The current ANZG definition (Warne et al., 2025) of “ecologically relevant endpoints” for the derivation of DGVs is centred on species-level competitiveness and is only partially applicable to microbes. Participants overwhelmingly supported a supplementary definition tailored to microbiomes that recognises community structure, function and activity as the appropriate units of assessment, including holobiont contexts (host associated microbiomes). A new definition was co-created and is presented in this white paper.

Community and functional endpoints are most relevant, but difficult to operationalise.

Whole-community functional endpoints (e.g., respiration, nutrient cycling) align with ecosystem protection goals [2] but are constrained by context dependence and limited agreement on regulatorily defensible effect thresholds. Under current guidance, they are most readily used as supporting evidence within weight of evidence approaches, particularly for site-specific guideline values (SSGVs), but pathways for their routine contribution to DGV derivation remain unclear.

Sequencing-based endpoints are promising if standardised and quantitative.

Amplicon sequencing can detect community shifts across thousands of taxa. Regulatory application improves substantially when methods incorporate viability assessment and move from relative abundance to quantitative profiling (absolute cell/gene loads), enabling derivation of taxon-specific concentration-response relationships that can be aggregated into microbial sensitivity distributions. Metagenomic and meta-transcriptomic approaches provide mechanistic insights (functional potential, expression, resistomes) but currently lack validated, transferable effect thresholds and consistent quality assurance/quality control (QA/QC) expectations for regulatory decision making. Effective implementation will require agreed data governance, access and stewardship arrangements to enable reuse, transparency and long-term availability of microbial and AMR datasets used in DGV derivation.

[2] Ecosystem protection goals define what ecological components and functions are to be protected and the acceptable level of change, guiding endpoint selection. For microbiomes, which operate as highly dynamic, functionally redundant communities embedded within larger complex biological and environmental systems, impacts are more appropriately assessed at the community and functional level rather than through the loss of individual species.

AMR represents a distinct risk dimension.

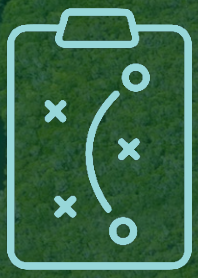
AMR-associated risk cannot be inferred from conventional single species toxicity endpoints or community functional endpoints alone. Metagenomic interrogation of resistance genes and mobile genetic elements is currently the most defensible direct approach for AMR hazard characterisation in environmental systems, but requires agreed endpoints, effect thresholds, and a clear decision context for how AMR information should influence DGV derivation and risk assessment.

Framework misfit is a core barrier.

The dominant DGV estimation method, the species sensitivity distribution (SSD), focuses on effects at the species level. This creates a misalignment between: (i) what is most ecologically relevant for microbes (community/function measures); and (ii) what is most readily incorporated into DGV derivation (single-species endpoints). Current rules limiting the combination of different taxonomic levels (e.g. species, family, community) in a single distribution, enforced to ensure interpretability, risk marginalising microbial evidence to “supporting” status, even when high quality data are available. Alternative metrics and approaches are needed.

Practical constraints matter.

Key implementation barriers include: limited method standardisation and accreditation; disagreement on the “chronic” exposure definition for microbes (the current >24 h convention was challenged); difficulty verifying exposure concentrations in small volume microbial assays at trace levels; and uneven regulatory appetite and awareness, including inconsistent prioritisation of AMR across jurisdictions.



The **Action Plan** and **Roadmap** propose a staged pathway

2026–2027
Establish governance, co-design and expert coordination to oversee and implement the action plan

2027-2031
Targeted research and guidance development

2031-2032
Delivery of endorsed guidance and microbial-inclusive DGV submissions

2030-2032
Capacity building activities for end-users

Key deliverables include

Guidance Briefs (2027 onward)

Microbial guidance addendum (planned 2031)

Formal guidance update (planned 2032)
alongside
Draft default toxicant DGV technical briefs for priority toxicants that incorporate microbial endpoints (planned 2032)

Research publications throughout

An advisory committee should be established early to prioritise the most critical actions within available funding, and to identify collaborations and additional funding sources to support the remaining actions.

Key Actions intended to support a staged transition of microbial endpoints from research approaches to regulatory ready application, with clear decision points and documentation requirements:

1 **Establish governance, oversight and delivery mechanisms.** Form a transdisciplinary expert advisory group to guide method development, interpretation and implementation, and to oversee roadmap delivery. This should include an expression of interest process, clear terms of reference, and quarterly reporting. Develop engagement, funding and communication plans to support implementation.

2 **Define ecosystem protection goals and ecological relevance for microbes.** Define and document ecosystem protection goals that explicitly incorporate microbial community and functional endpoints. Develop a clear and an explicit statement on the ecological relevance of microbial endpoints, and how they support ecosystem protection goals in DGV derivation to support future guidance updates.

3 **Define acceptable microbial endpoints and regulatory-ready methods.** Clarify which whole community and functional endpoints are acceptable for DGV derivation. Develop QA/QC and metadata standards for genomic and omics-based endpoints including access to bioinformatic workflows. Clearly define the regulatory applicability of amplicon sequencing, metagenomic and meta-transcriptomic approaches, including their roles as primary or supporting lines of evidence.

4 **Close key technical gaps for assay defensibility.** Revisit whether the microbial chronic exposure timeframe definition of >24 h remains appropriate or should be extended to better capture longer-term microbial responses. Develop and standardise affordable exposure verification approaches for small volume and trace level assays. Apply conceptual ecological models and adverse outcome pathways (AOP) to inform meaningful thresholds for microbial community-level and functional endpoints.

5 **Clarify and test microbial data integration pathways for DGVs.** Clarify current rules for integrating microbial data and combining evidence across taxonomic levels. Develop practical guidance applying SSD approaches to large, high-resolution community and omics datasets (e.g., weighting and aggregation). Conduct worked case studies on priority toxicants to assess the impact of microbial data inclusion on DGVs considering several integration approaches including separate microbial sensitivity distributions, combined approaches, and weight of evidence or multiple lines of evidence methods.

6 **Advance AMR endpoint development and application.** Define the policy framing and decision context for AMR endpoints in toxicant DGV derivation, with a clear focus on chemical drivers of AMR. This action does not seek to derive guideline values or conduct risk assessments for biological AMR determinants (e.g., antimicrobial resistant pathogens, commensals, and associated resistance genes), although methodological and evidence overlaps will likely inform both areas. Identify priority AMR-relevant microbial endpoints. Establish and validate assays and thresholds (particularly metagenomic approaches), including targeted datasets for priority contaminants including non-antimicrobial co-selectors.

7 **Capacity building for end-users.** Develop targeted capacity building training to enhance regulators' ability to integrate microbial endpoints into risk assessments and apply emerging knowledge in regulatory decision-making. Work with regulators to build awareness and understanding of new analytical technologies and the significance of results obtained.

Scope boundaries and intent

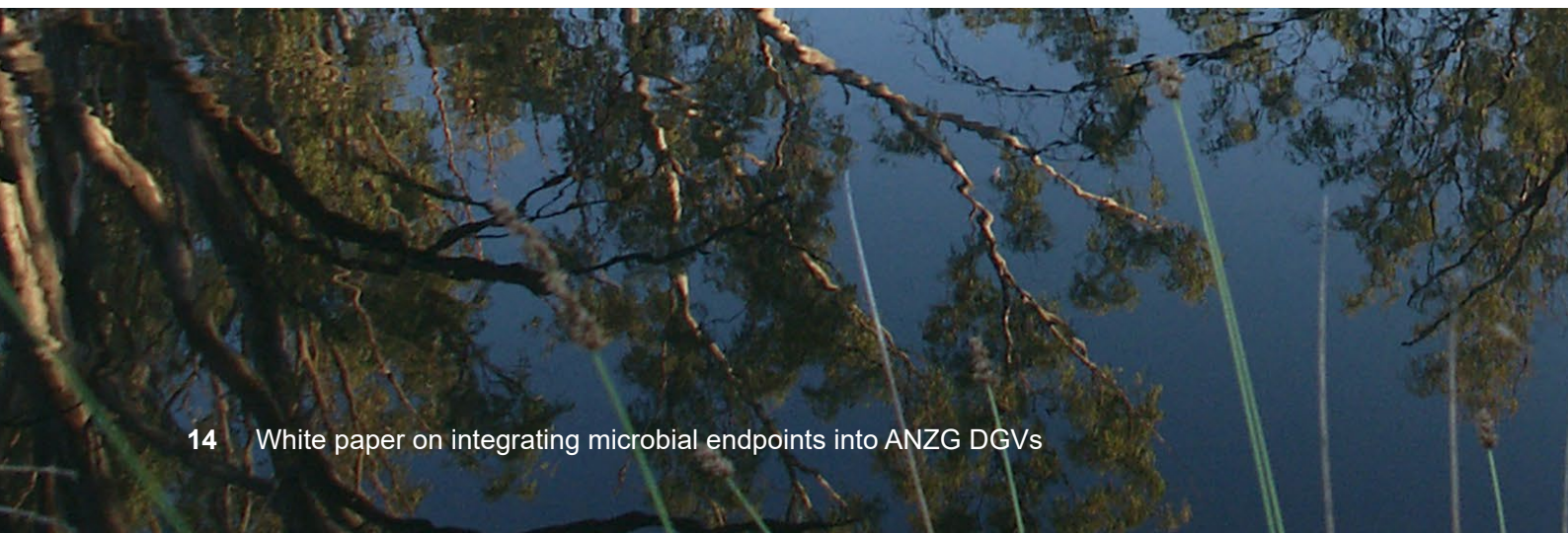
This white paper does not address other water quality guidelines within the National Water Quality Management Strategy (e.g., drinking, recreational, or recycled water). However, as AMR knowledge advances, coordinated engagement across responsible agencies will help align water quality guidelines under a One Health approach for environmental, animal and human protection.

This paper builds on (and does not replace) the ANZG (2018)/Warne et al. (2025) approach for deriving DGVs to protect aquatic ecosystems. Species level ecotoxicology and SSD methods remain essential for consistent guideline derivation across jurisdictions. Accordingly, toxicant DGVs derived using the current approach remain valid and applicable for use in water quality assessments. The paper also notes that endpoints used for higher organisms have recognised limitations in ecological relevance, and that some Action Plan outcomes, particularly for community based endpoints, may be applicable beyond microbial communities. Until more ecologically relevant microbial endpoints and datasets are available, this white paper does not recommend removing microbial endpoints currently used in DGVs.

The paper does not suggest or mandate universal use of metagenomics or multi-omics is not suggested or mandated in this white paper. These are presented as targeted, fit for purpose tools where they add clear ecological or regulatory value.

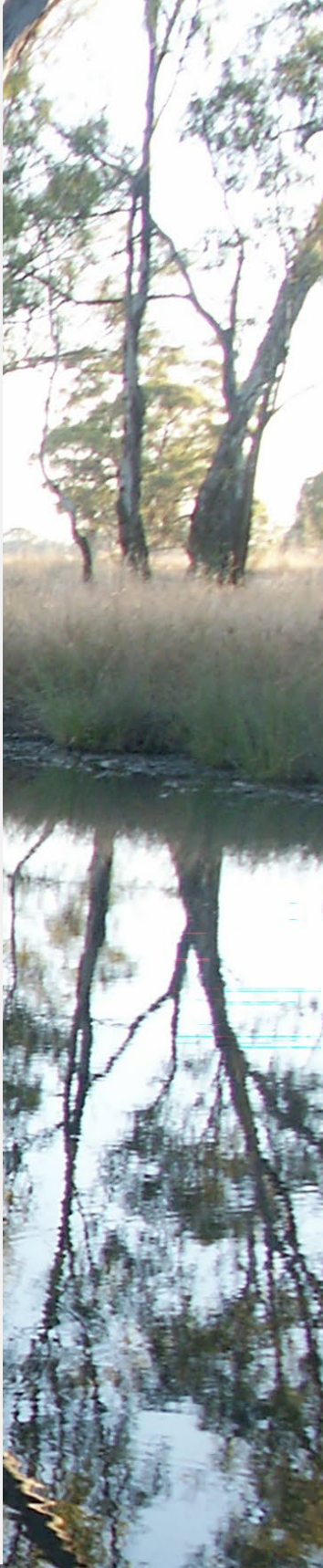
AMR is recognised as a distinct, evolving risk dimension, but the paper does not attempt to define all pathways, thresholds or regulatory responses at this stage. The focus is on preventing AMR driven by anthropogenic chemicals in the environment, with priorities identified for staged research, co design and guidance development.

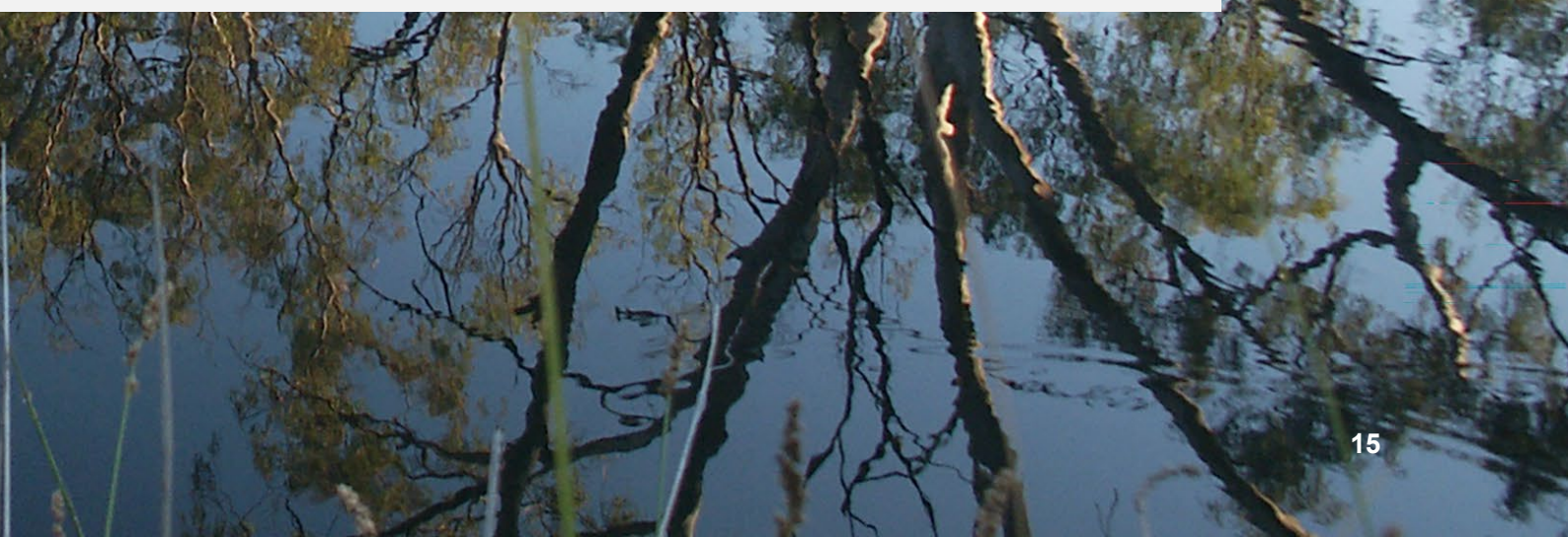
While this white paper primarily focuses on methodology for water quality guideline value derivation, these approaches are also applicable to sediment quality assessment and sediment quality guideline values when sediment-specific considerations such as toxicant bioavailability and exposure pathways are incorporated. Accordingly, the paper also considers the role of microbial endpoints in sediment quality guideline derivation, given the importance of sediment microbial communities in ecosystem function and contaminant cycling. Applying these findings to strengthen microbial endpoints for sediment quality assessments is a key next step, highlighted in the Action Plan. Likewise, many of the concepts discussed are also relevant to groundwater ecosystems, where microbial communities support critical biogeochemical processes and may be vulnerable to toxicant exposure, although groundwater-specific frameworks are not considered in detail. Finally, the overall scope and intent of this paper is consistent with the continual improvement philosophy espoused by ANZG (2018).



Outcome

This white paper establishes a **foundation for integrating microbial endpoints into ANZG DGV derivation**, supporting the development of more robust and comprehensive regulatory guideline values and associated guidance documents. Implementation of the proposed roadmap will enable DGVs to more accurately represent whole ecosystem hazards, including those at the microbial community level, which underpin key ecosystem services. The improved ability to incorporate whole-community endpoints, particularly those at the functional level, extends beyond microbial systems to benefit better use of all available taxonomic-level data in deriving DGVs. Ultimately, implementation of the action plan will enable routine, defensible inclusion of microbial endpoints (including AMR-relevant indicators) in DGVs, SSGVs and direct toxicity assessments (DTAs), strengthening environmental risk assessment, including wider **One Health outcomes and improving protection of aquatic ecosystems**.





Action Plan and Roadmap

All actions identified within this white paper have been consolidated into an action plan (Figure ES.1) and associated roadmap (Figure ES.2). There are four overarching objectives, fifteen key actions, and within each of these actions are specific targets. All targets deliver outcomes through foundational and/or research pathways to inform guidance. The action plan will be delivered through a suite of activities, workshops, projects and partnerships. Recognising the breadth of the plan, an early priority is to establish an advisory committee to guide prioritisation of the most essential actions.

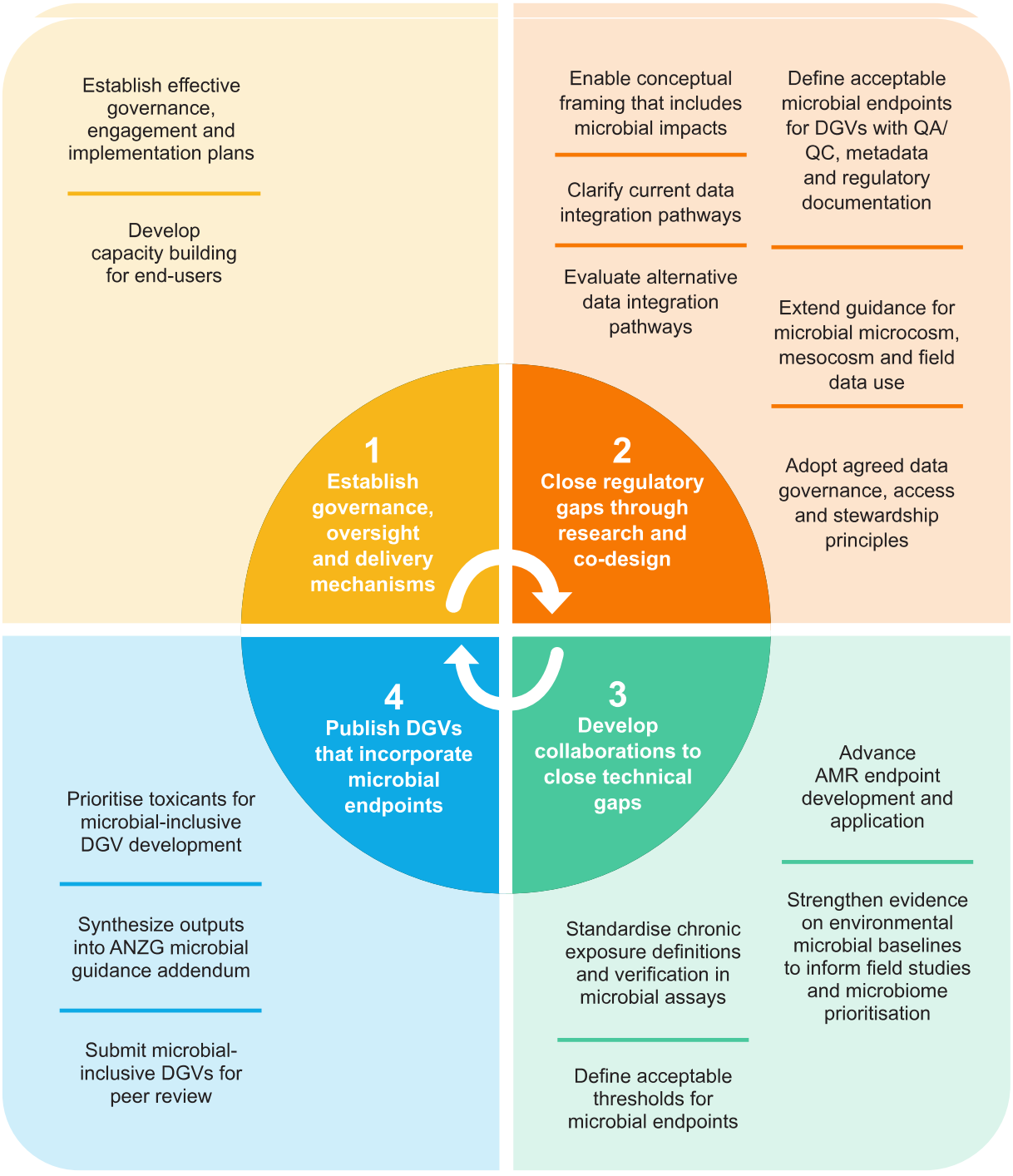
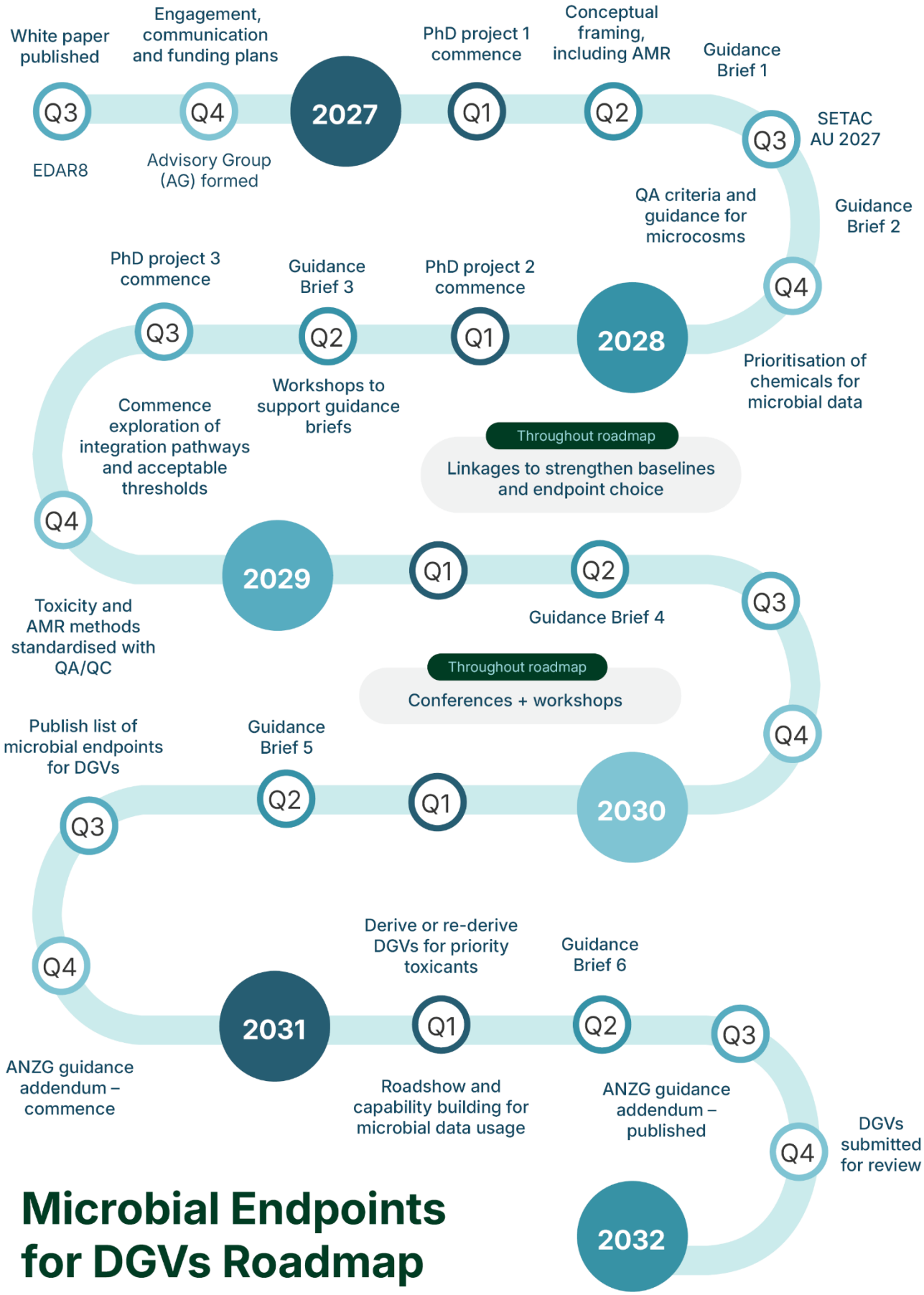


Figure ES.1. Action plan for enabling microbial endpoint use in ANZG DGVs for toxicants.



Microbial Endpoints for DGVs Roadmap

Figure ES.2. Roadmap for deriving DGVs that include microbial endpoints for toxicity and AMR. The staged actions shown here also address current limitations in data availability, methods, and regulatory readiness identified in this white paper.

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Cooperative Research Centres Program

This project is supported by the Australian Government Department of Industry, Science and Resources through the Cooperative Research Centres Program.