



TECHNICAL PAPER

Site selection methodology for the Great Artesian Basin springs survey

Site selection and prioritisation

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Preamble

New information on the springs in the New South Wales (NSW) extent of the Great Artesian Basin (GAB) has become available since the *Water Sharing Plan for the NSW Great Artesian Basin Groundwater Sources 2008* (referred to as the WSP) started. The GAB WSP is now due for renewal. To ensure the WSP is robust and current, the Department of Planning, Industry and Environment has reviewed the springs schedule (Schedule 4).

Before the WSP, very little large-scale work was done on the characterisation of GAB springs in NSW. To better manage the GAB springs, we need to understand the ecological and hydrogeological features of the springs. These include:

- groundwater-dependent ecosystems (GDEs) supported by the springs
- water geochemistry
- spring flow processes.

The department initiated the GAB Springs Survey scientific project in 2017. We completed field work through 2018 and 2019 during three field events to ground-truth the site locations and start data collection.

This document provides the methodology on the site selection for the field events.

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Introduction

The *Site selection methodology for the Great Artesian Basin springs survey* documents the site selection process for the scientific springs survey (GAB Springs Survey) undertaken in 2018 and 2019.

The survey targeted springs within the NSW extent of the GAB likely fed by deep artesian groundwater, based on Schedule 4 of the WSP and new scientific information since the GAB WSP commenced in 2008.

The survey required three rounds of fieldwork: Round 1 started in March 2018, Round 2 in October 2018 and Round 3 in July 2019.

Scope

The scope of this document is to report on the selection process for spring sites surveyed during the GAB Springs Survey project.

Terminology on springs

Water emerges naturally from the GAB through a range of geological controls as springs. Springs is a collective term for where groundwater flows out of an aquifer at the surface. Specific terminology applies to the whole GAB to define springs:

- **Spring vent** is a conduit where groundwater discharges to the surface.
- **Spring complex** is a cluster of spring vents that share similar geomorphological settings and broad similarities in water chemistry.
- **Spring supergroup** is a cluster of spring complexes.

The GAB springs located in NSW belong to the Bourke and Bogan River Supergroups.

Importance

Wise water management of the GAB springs is fundamental to the future and wellbeing of Australians, as well as that of groundwater-dependent ecosystems.

In NSW, more than 200,000 people rely on GAB water, including landholders who rely on artesian springs for stock watering. We expect there are at least 35 artesian spring complexes fed from the deep GAB groundwater systems in NSW.

Natural water pressure across the basin has declined due to overuse. Evaporation and seepage from bores has wasted up to 95% of artesian water from the basin (Commonwealth of Australia, 2014b; NSW Department of Planning Industry and Environment, 2019) until the introduction of programs reducing losses through piping of drains and capping of bores.

Water from the GAB is also the lifeblood of many rural communities and agricultural, mining and tourism businesses. The water from the GAB as a whole contributes to at least \$12.8 billion annually of industry that operates within the Basin (NSW Department of Industry, 2016).

On a global platform, the GAB is the largest artesian basin in the world. The GAB springs support the oldest living culture in the history of the Earth. The springs are woven into the histories of local Aboriginal people, and continue to be linked to the Dreaming stories passed onto their children today. The Aboriginal Dreaming stories are of great spiritual importance and are closely tied to Aboriginal custom and law (NSW DEC, 2006; L'Espoir, 2007).

The GAB springs in NSW have watered megafauna dating back to 36–30,000 years, support endemic ecosystems and continue to sustain wetlands of international importance (Ramsar site)

today. The GAB spring formations at Peery Spring Complex are one of the rarest landforms in Australia and one of the largest active complexes in the Basin (Trueman *et al.*, 2005; NSW Department of Environment and Conservation, 2006; Fillios, Field and Charles, 2010).

The GAB springs have unique characteristics related to their chemistry, flow and wetland isolation. The nature and persistence of these surface water expressions through glacial and arid periods has provided a wetlands habitat refuge for relictual species. As a result, remarkable concentration of endemics exists, and has also evolved in these isolated communities throughout the geological epoch (Commonwealth of Australia, 2014a).

GAB springs are a matter of national and international environmental significance. They support endangered ecological communities protected under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Investigation area

Figure 1 shows the extent of the GAB. The investigation area covers the NSW part of the GAB, which is 25% of the state. This equates to an area of around 207,000 square kilometres, or approximately 12% of the basin (Department of Water and Energy, 2009). The shaded area of Figure 1 indicates the eastern recharge areas. Dominant flow directions are indicated by arrows. Spring supergroups are represented by dotted lines.

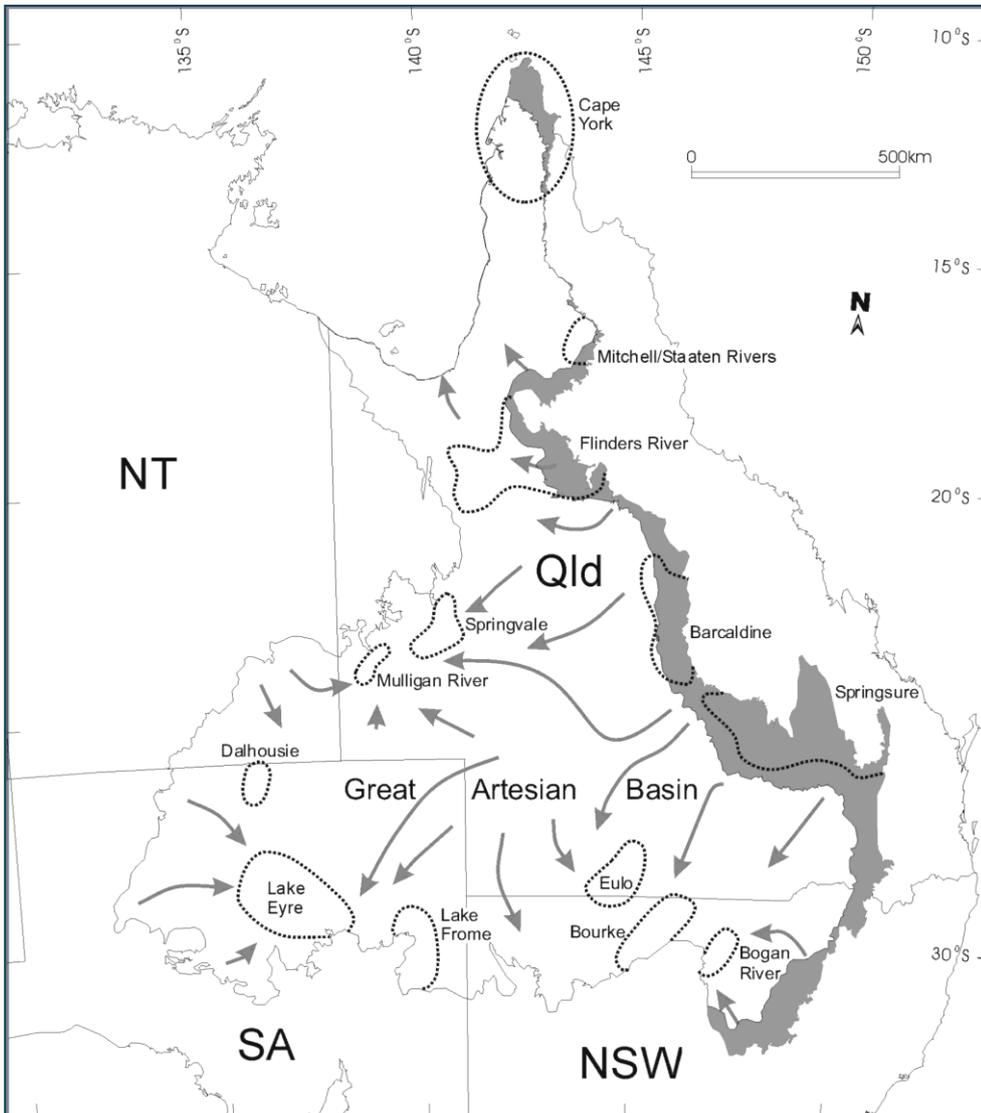


Figure 1. Map of the GAB (Commonwealth of Australia, 2014b)

Site selection

Available datasets at project initiation

The site selection process was based on the compilation of data from three datasets. Table 1 presents the bibliography of datasets reviewed for site selection. The source information column in the table describes where the data is located and data quality lineage related to the dataset document.

Table 1. Bibliography of datasets

Dataset document	Source
Water Sharing Plan for the NSW Great Artesian Basin Groundwater Sources 2008	The Department of Planning, Industry and Environment is the custodian of the WSP. The springs are documented as a single coordinate in a table of the published WSP, Schedule 4. Schedule 4 was developed by NSW Government based on historical datasets. Historical information used includes outcomes reported by Pickard (1992) of Macquarie University, who surveyed artesian springs in the western division of NSW.
Queensland Spring Database (Queensland Herbarium, 2015)	<p>The Queensland dataset is information that has emerged since the WSP was implemented in 2008. The documentation has GAB spring data from 1995 to 2015. The data has been checked, tested and compiled by the Queensland Herbarium. The data in the database comes from a range of people and agencies.</p> <p>The department requested the GAB spring dataset relevant to NSW from the Queensland Herbarium. The dataset was provided as an MS Excel spreadsheet. Supporting documents for the dataset were also provided from Queensland Herbarium.</p>
Groundwater-dependent Ecosystems spatial database (Referred to as Commonwealth GDE dataset).	<p>The Groundwater-dependent Ecosystems spatial dataset has lineage to data in the WSP spring schedules, Commonwealth listed EBPC Act 1999 listed GDEs and other datasets to maps springs for the extent of NSW.</p> <p>It is a spatial layer stored in the department's geospatial databases. It was extracted as a table using ESRI ArcMap into an MS Excel file for the NSW GAB groundwater sources extent.</p> <p>The dataset includes a single spring complex name, coordinate and brief description on data source and justification for site selection. Justifications include descriptors referring to work done by Pickard (1992).</p>

Spring information

The datasets came with a range of data. To compare the different datasets a common set of data fields were prepared. This was done for each spring where the attribute information for each spring vent was available.

Table 2. Spring attributes collated

Category	Description and rationale	Attributes
Nomenclature	Unique numerical identifiers, other names and assigned names for the springs	<ul style="list-style-type: none"> • Site Number • Vent ID • Aboriginal name • Previous name • Complex name • Supergroup name
Survey dates	Unique dates for each visit for each spring vent	<ul style="list-style-type: none"> • 1992 • 1999 • 2007 • 2010 • 2012 • 2013 • 2014 • 2015
Surface expression	Saturation of the spring vent. If there is moisture or flow. 'Other' flow types are ephemeral or uncertain or unknown based on known or inferred information (Queensland Herbarium, 2017).	<ul style="list-style-type: none"> • Permanent • Inactive • Other
Detailed water chemistry	General chemistry measurements recorded in the field or samples tested in a laboratory. Ions tested for a suite of analytes and were checked in the collated data set as for presence or absence of data.	<ul style="list-style-type: none"> • pH • Temperature • Electrical conductivity • General chemistry
Ecology	Taxa present for flora and fauna. Spring conservation rank applied at individual spring wetland/vent level as per the following rule set defined below this table ¹ .	<ul style="list-style-type: none"> • Flora • Fauna • Conservation rank¹
Spring wetland	Visual estimates of length and width of the saturated wetland. Wetland area is for springs that have more than fifty percent wetland vegetation cover.	<ul style="list-style-type: none"> • Spring wetland length • Spring wetland width • Spring wetland area
Region	Locality of the vent and source of the groundwater.	<ul style="list-style-type: none"> • Coordinates • GAB • Other non-GAB • Tertiary springs

¹ Conservation rank description as defined from (Queensland Herbarium, 2017):

Category 1a: Contains at least one GAB endemic species not known from any other location beyond this spring complex.

Category 1b: Contains endemic species known from more than one spring complex; or has populations of threatened species listed under State or Commonwealth legislation that do not conform to Category 1a.

Category 2: Provides habitat for populations of plant and/or animal species not known from habitat other than spring wetlands within 250km.

Category 3: Spring wetland vegetation without isolated populations (Category 2) with at least one native plant species that is not a weedy cosmopolitan plant species (Appendix R).

Category 4: a) Spring wetland vegetation comprised of exotic and/or only native weedy cosmopolitan wetland plant species (Appendix R) or a spring devoid of vegetation or b) the original spring wetland is destroyed by impoundment or excavation. The probability of important biological values being identified in the future is very low. No other wetland species.

Category 5: All springs inactive. Conservation ranking can only be applied to spring wetlands which have associated flora and fauna records.

This conservation rank is presented in the Queensland Spring Database (Queensland Herbarium, 2015) only. This data was not available in the WSP Schedule 4 or the Commonwealth GDE dataset.

Data quality assurance and control

The spring information was reviewed for quality assurance and control to check for consistencies and accuracies between datasets. This included checking nomenclature and coordinates of spring vents.

For nomenclature, there were discrepancies identified for the name of some springs. Some spring vents and complexes sharing the same locality had discrepancies in naming. The nomenclature was a mixture of Aboriginal naming, spelling differences, local naming from pastoral maps and naming of stations where the spring vents were located.

In order to have a dataset with consistent nomenclature, a tab was created in the spreadsheet recording the name discrepancy, adopted name and description of what was adopted name assessment.

Coordinate projections were inconsistent between the datasets. The Commonwealth GDE dataset was in meters projection Universal Transverse Mercator (UTM), the WSP was in decimal degrees with no projection provided, and the QLD Herbarium dataset was in latitude and longitude in projection Geocentric Datum of Australia (GDA94).

Checks for likeliness of springs occurring in the landscape at the coordinates were done. This was done after scoring and is described in the following section.

The spring attributes dataset was a live document at the time of writing this methodology. The results will be published as they become available, or may be provided for specific sites upon request to the department after quality assurance and control checks have been completed.

Map review

The collated data spreadsheet was imported into ESRI ArcMap. The map showed all the spring vent locations overlaid on aerial imagery. The labels for the spring complexes were displayed. Visual checks for locality of spring vents and their complex names were done in view of the landscape.

Most spring coordinates appeared around places that showed likely hydrological features or formations in the landscape. This included clay pans, ephemeral waterways or discoloured soil surfaces in lower parts of the landscape. This was accepted as places which potentially indicated spring expressions.

Some spring coordinates were showing in the landscape that were predicted as unlikely locations for spring vents. These were locations such as on top of red sand dune ridges, or next to the roadside in a paddock that showed no hydrological features on the surface. A visual search of the imagery and topographic maps was also done to check for historical notes printed in the vicinity of where the spring coordinates plot.

Site prioritisation using a multi-criteria analysis protocol

Hydrogeologists at the department developed the multi-criteria analysis protocol as a way to highlight priority spring complexes to target in the GAB Spring Survey field programs.

This was the initial site selection method. It was completed as a desktop review as part of preparation of the GAB Spring Survey fieldwork.

Scheduling of spring sites also considered distance, remoteness, fatigue, travel time and road conditions.

Scoring

The scoring for each spring vent was calculated based on attributes listed below. Each attribute was scored 1 or 0, to represent presence (1) or absence (0) of data for each spring vent. Table 3 presents the description for how each attribute was scored 1 or 0.

Table 3. Spring attribute score method

Attribute	Score = 1	Score = 0
Database source	Spring listed in WSP	Spring listed in Commonwealth GDE database or Queensland Spring Database (Queensland Herbarium, 2015), then score
Spring water expressing	Water is expressing	Water is not expressing. Or there is insufficient data to indicate of the spring is active or inactive (unknown).
Ecological conservation rank	Category 3 or lower (Category 1a, 1b, 2 or 3) Indicating presence of native vegetation and endemic species.	Category 4 or higher (Category 4 or 5) Indicating presence of exotic plants, or no wetland due to spring water inactivity.
Water source	GAB	Other non-GAB, tertiary springs or unknown.

The scoring presented in Table 3 was applied to each spring vent in the collated data.

The 1 or 0 scores were summed to calculate an overall score. This score ranged from 1 to 4 for each spring vent, there were no score 0 springs vents.

The spring vents were grouped by spring complex name and the complex as a whole was considered for surveys.

Spring complexes which presented a maximum overall spring vents score of 4 were targeted as high-priority springs complexes to survey first in the GAB Springs Survey project fieldwork.

This was followed by spring complexes with a maximum overall score for the vents of score 3, then score 2 and lastly score 1 and score 0.

Generally, the higher score spring vents for the complex also indicated the most likely sampling location to target during the field work (compared to the lower scoring spring vents), since the survey objectives focused on water sample collection and GDE surveys.

All spring vent attributes for the complex targeted for the field work were taken to the field for checking before sampling prior to commencing sampling activity as part of the reconnaissance. This allows an opportunity to focus the survey on a spring vent that best expresses water and supports GDEs.

Outcome

A summary showing the number of spring vents for each score are presented in Table 4. The outcomes of the scores were calculated ahead of Round 1 field work.

Table 4. Results showing scores for spring vents ahead of Round 1 survey

Spring score	Count of spring vents	Count of spring complexes
Score 1	10	5
Score 2	102	11
Score 3	60	15
Score 4	207	20
Total	379	51

Shortlist

The score 4 were the highest priority spring complexes to visit, which were targeted for surveying in Round 1 (March 2018).

Successively, score 3 springs were targeted for Round 2 (October 2018). Springs that were inaccessible in Round 1 were added as priority sites to visit in for Round 2 also.

Round 3 targeted springs which scored 1 and 2. And springs that were unable to be surveyed in Round 1 or Round 2.

Springs that held high cultural heritage values were also considered as priority for shortlisting. Bingawilpa had anecdotal information about Aboriginal Dreaming stories; however, it had no known spring survey records.

For each round, a schedule listing the scored springs complexes targeted for the respective round was created in Excel. The schedule listed spring details including data on ecology and hydrogeology to identify which single vent to potentially sample and for reference in the field.

Most spring complexes presented numerous vents. Counts of tens of vents was frequent for many complexes. Peery Spring complex had hundreds of spring vents.

While all vents (with the exception of Peery Spring) were targeted for visual inspection before the scientific sample collection began, only one vent at each complex could receive the full comprehensive hydrogeological and ecological survey. This was due to the limitations of time

constraints (the field program duration being up to three weeks, and sampling limited to the daylight hours), extensive remote travel requirements and few field scientists being available to do the survey. These factors were considered ahead of the field program and helped to frame the field program design.

Additionally, to achieve ground-truthing of spring vent coordinates and conduct a full survey for each complex within the GAB Spring Survey project timeframe (2018 to 2019), only one spring vent receiving the full survey treatment was possible.

The spring vents targeted as primary candidates for surveying were based on the scores generated from the multi-criteria analysis tool ahead of each round of field work. The results of this along with the spring details, were printed and referred to and checked at each site throughout each field expedition.

Where time and resources permitted, additional data would be collected to maximise unit of effort and information gathered where it fit the project objectives.

Repeat sites

Springs that had surface water expressions were repeatedly surveyed in Round 2 and Round 3 where possible. The same spring vent was surveyed for repeat site visits to help achieve the GAB Spring Survey objective of baseline dataset development.

Access to sites

Once the priority and locality of the spring complexes were identified, the springs were then targeted for landholder access. Landholder access consents and confirmed timing for site surveys formed the basis for the field program.

Consent from landholders was also a determining factor for some sites not being surveyed.

Sweetwater Spring was not visited due to access restrictions. Cumborah Springs was surveyed initially in Round 2; the landholder imposed consent conditions the department could not meet at the time for the repeat site visit in Round 3.

The remaining five springs that have not been surveyed in Round 1 to Round 3 were not listed in the WSP. The coordinates for four of these sites (Tego, Log, Deadman and Towry Springs) plot in Queensland, albeit in close proximity to the NSW state border.

Incidental sites

Springs surveyed in addition to the scored shortlist of spring and the repeat sites were springs that were identified incidentally throughout the field work. This included through personal communications with local landholders, Aboriginal Elders and NSW Parks rangers.

Observations of unrecorded sites realised during the field surveys was another way incidental spring vents were recorded.

Before the surveying of these incidental springs, a qualitative assessment to survey these additional sites was made by the surveying scientists during the program. If it was viable, these additional sites were adapted to the program or opportunistically recorded during the field work.

Results

Collation of datasets for the investigation area identified 51 unique spring 'complex' names (and 379 spring vents locations). Of the 51 identified 'complexes', 45 were targeted for the 2018 and 2019 fieldwork.

This left six spring complexes not to be visited during fieldwork. These were Sweetwater, Deadman, Toulby, Log, Towry and Tego.

Sweetwater was not visited due to access restrictions. Four springs (Tego, Log, Deadman and Towry) are in Queensland. Toulby has not yet been surveyed for logistical reasons.

The resulting dataset presents 38 spring complexes for a similar count of spring vents reported in the IESC springs report 'Ecological and hydrogeological survey of the Great Artesian Basin Springs' (Commonwealth of Australia, 2014a). The number of spring vents recorded to date is approximately 400. This increase is due to unrecorded spring vents identified in the field program. This is a more consolidated dataset. The updated list of springs by complex name is shown at Figure 2.

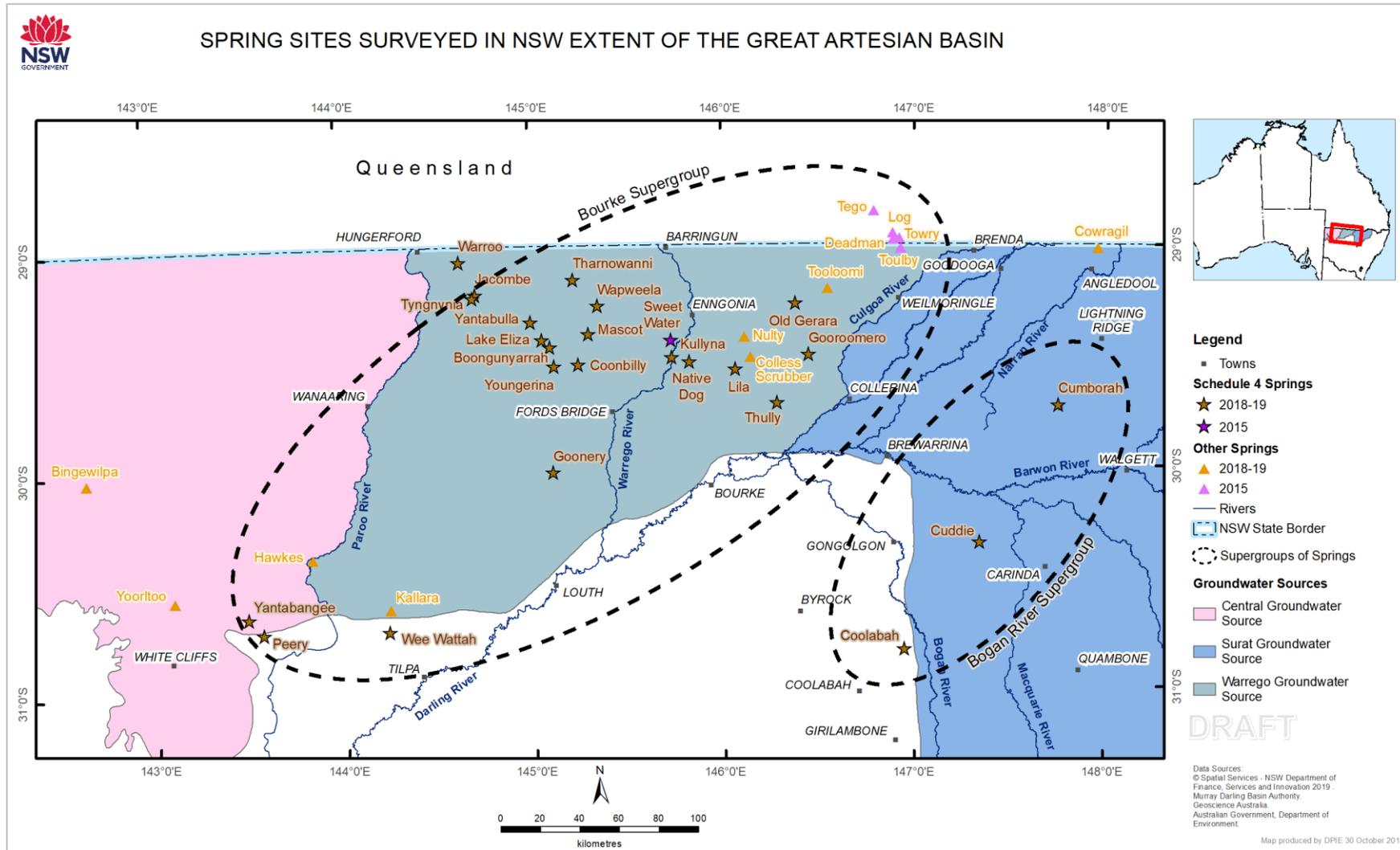


Figure 2. Map showing spring complexes visited in the GAB Spring Survey (2018-19)

Note: The map shows spring complexes from the collated dataset following Round 3 GAB Spring Survey. The database is still in development and subject to further updates for spring site descriptions. This is the latest information available at the time of writing. Use of the map outside the purpose of this document is not recommended.

Summary

The GAB Spring Survey targeted springs in the NSW extent of the GAB, fed by deep groundwater systems, focused to the springs listed in Schedule 4 of the *Water Sharing Plan for the NSW Great Artesian Basin Groundwater Sources 2008*.

Preliminary datasets collation was required in order to consider information from datasets that had emerged since the WSP was implemented. The datasets were the Queensland Spring Database (Queensland Herbarium, 2015), Schedule 4 list of springs in the *Water Sharing Plan for the NSW Great Artesian Basin Groundwater Sources 2008* and spatial Commonwealth GDE dataset.

This collated dataset formed the basis for spring site selection. The site selection methodology for springs visited was based on multi-criteria analysis of data available ahead of the field program, cultural values, accessibility to sites, repeat site visits for baseline dataset development.

The multi-criteria analysis was the primary tool used for prioritising springs to be targeted each round. Here, key spring attribute data to score GAB springs in NSW according to existing knowledge gaps in hydrogeology and GDE data. The attribute data included water quality, characteristics of wetland ecology and hydrogeology.

Overall, a count of 51 unique spring 'complex' names (at 379 spring vents locations) were identified ahead of Round 1. Of the 51 identified 'complexes', 45 were visited during the 2018 and 2019 GAB Spring Survey.

An outcome of the data entry following the Round 3 field work was dataset updates, which include new survey information being added, and consolidation spring vents description details. This resulted in 38 spring complexes, as presented in the map (Figure 2). The latest consolidated dataset is still in development at the time of writing this document, and subject to further updates.

There remain many knowledge gaps to truth in order to better characterise springs listed in the latest dataset and WSP for GAB springs in NSW.

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