PLANNING PROPOSAL FOR LAND REZONING

LOTS 70, 73 & 77 DP1006688

407 - 457 CROOKWELL ROAD

KINGSDALE. NSW. 2580

LOCAL FLOOD & OVERLAND FLOW STUDY

SUPERSEDES THE ORIGINAL REPORT DATED 19 MARCH 2024

Prepared by SOWDES
10 December 2024

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Executive Summary.

This *Local Flood and Overland Flow Study* has been prepared in support of a submission to the Goulburn Mulwaree Council for the rezoning of a parcel of land comprising three separate portions identified as Lots 70, 73 and 77 DP1006688 – 407 to 457 Crookwell Road, Kingsdale from a current zoning status of 'RU6 – Transition' to a mix of 'R2 – Low Density Residential' and 'R5 – Large Lot Residential'. The land rezoning opportunity has been identified in the *Urban and Fringe Housing Strategy* undertaken on behalf of the Goulburn Mulwaree Council by Elton Consulting which was adopted by Council in July 2020.

The submission of a *Local Flood and Overland Flow Study* for assessment of the land rezoning proposal satisfies the Ministerial Directions obligations under the Section 9.1 of the Environmental Planning and Assessment Act (1979) – Direction 4.1 Flooding.

The development property and surrounding lands are not identified in any current planning or mapping instruments as being within flood liable lands, however preliminary 'high level' studies have been undertaken for the Council as a separate exercise to the recently adopted *Goulburn Floodplain Risk Management Study and Plan* to identify areas outside of the mainstream riverine flooding that may be adversely affected by overland flows in large rain events. The subject development site is burdened by general overland flows associated with surface water runoff originating within adjoining lands and properties to the north, east, and to a lesser degree to the northwest of the site. This study is assessing the impacts of existing overland flow from these external sources and from stormwater drainage generated within the site on the land rezoning proposal and potential future residential subdivision development for the land.

The subject site is located at the intersection of the Crookwell Road and Chinamans Lane which is just on the northwestern outskirts of the city of Goulburn, directly opposite existing developed urban land release areas. The site is bordered by two separate formed roads; the Crookwell Road traffic corridor along the eastern boundary which is a Transport for NSW (TfNSW) classified road, and Chinamans Lane along the southern boundary. The site covers an area of 50.85 hectares which is comprised of three separate registered portions – two of which are held in one ownership, and the other is held in separate ownership, however throughout this submission they will be referenced as though they are a single parcel of land.

The property which has historically been used for livestock production is predominantly set to open paddocks of improved pastures and native grasslands, however there is a few discontinuous rows of radiata pine trees throughout to serve as wind breaks, and there is a scattering of eucalyptus trees and several exotic trees around the curtilage of an existing dwelling within the eastern portion of the holding.

The curtilage is in a defined area comprising several rural sheds and is predominantly surrounded by managed lands with access to the existing dwelling being from the Crookwell Road traffic corridor which borders the eastern boundary of the property.

The development property is burdened by several easements that influence the design of the proposed rezoning and future subdivision; a 24.385 metre wide easement for high pressure gas supply which traverses diagonally across the northern portion of the holdings, a separate 4.50 metre wide easement for optic fibre cable that sits immediately adjacent to the southern edge of the high pressure gas supply easement, and a 6 metre wide easement for 'water supply' that is used to transfer water from Wingecarribee Dam in the Southern Highlands to the city during periods of extreme drought. The water supply easement enters the property in the northeast quarter and sweeps through the northern portion of the property in a large radius curve before exiting into the neighbouring property to the west.

The terrain throughout the property has a general fall from the northeast toward the south-southwest and is dominated by a series of both defined and undefined drainage depressions located at three distinct locations across the site. The first of the systems runs through the northern half of the site in a northeast to southwest alignment and exits the property where there is a right-angled bend in the boundary that forms the southern aspect of the northern half. The second system is located in the northwest corner of the holding and for the length of its pathway through the property stays on the northern aspect of the high-pressure gas supply easement thereby only burdening two of the proposed larger 2 hectare Lots in a future subdivision of the land. The final mapped drainage corridor is located in the southeast quarter of the property which directs surface water runoff from the Crookwell Road traffic corridor and adjoining lands on the opposite side of the road through the lower southern half of the property. The first and third identified drainage systems merge just outside the lower southwestern corner of the site within the neighbouring property to the west.

A conceptual subdivision design for the property has been prepared which allows for varying Lots sizes based largely on the natural drainage regimes associated with the topography of the land and the proximity of environmentally sensitive areas, and the restrictions upon land development around the aforementioned easements. The largest portion of the site which is south of the gas supply easement has been identified as being suitable for 'R2 Low Density Residential' land zoning with minimum Lot sizes of at least 700m², whilst the land on the northern side of the gas supply easement has been identified as 'R5 Large Lot Residential' land zoning with the minimum Lot size of 2 hectares. A small portion of land on the western side of the site that drains toward the west but still on the southern side of the gas supply easement has been identified as future larger Lots with a minimum Lot size of 4,000m².

The potential yield for all land zones is 248 Lots in the 'R2' zoned area, 3 Lots of at least 2 hectares in the 'R5' zoned area on the northern side of the gas supply easement, and a further 5 Lots of 4,000m² in the western draining lands. In addition to the Lot yield potential the proposed development would include a new internal road network and several reserves for drainage, biodiversity values and vegetation management, and the protection of an area of Aboriginal Heritage.

At present the development site is not directly benefited by a Council maintained water supply or gravity sewer system however any future development of the land will require the installation of a reticulated water supply, a gravity sewer system and several pump stations, inter-allotment stormwater drainage services, and ancillary infrastructure to most of the Lots. All 'R2' zoned Lots on the southern side of the high-pressure gas main will be fully serviced by the aforementioned infrastructure, and the five 4,000m² 'R5' zoned Lots on the southern side of the gas main will also be serviced by the reticulated water supply. The larger Lots in the 'R5' zone on the northern side of the gas main will not be serviced by the reticulated water supply, and all 'R5' zoned Lots will not be connected to the gravity sewer system thereby each of these Lots will need to be self-sufficient in the management of onsite generated effluent, and stormwater drainage.

The aims and objectives of the local flood and overland flow study report are:

- demonstrate the existing extent and depths of overland flow, the proposed extent and depths of overland flow in the post-development scenario and identify any adverse impact on downstream properties.
- A detailed assessment and description of the catchment area which generates overland flow that drains to and through the development property – in particular where the access roads and residential Lots will be located.
- For the purposes of the land rezoning proposal establishment of suitable hydrological and hydraulic models to provide a robust assessment of the potential for flooding within the development property
- Detailed description of the data sources that form part of the background information within the models including terrain information and post-development regrading of the of the site.
- Identification of areas within the property and surrounding catchment that may be impacted by the proposed development in a range of 'design' rain events (10%, 5%, 1%, 0.5%, 0.2%, and the PMF) by undertaking pre-development and post-development comparison modelling.
- Identification and classification of the flood function and flood hazard categories associated with the range of 'design' rain events (10%, 5%, 1%, 0.5%, 0.2%, and the PMF) by undertaking pre-development and post-development comparison modelling.
- A summary of the findings and the implications (if any) on the proposed development.

Whilst this report has based its determinations and recommendations on a proposed subdivision design that is subject to a raft of considerations and approvals it is recognised that the next stage of the development process following rezoning of the land is the submission of a formal subdivision application that will include detailed engineering plans and addressing any matters for concern that may arise during the land rezoning assessment process.

It is considered that the proposed rezoning of the land from the current 'RU6 – Transition' to a blend of both 'R2 – Low Density Residential' and 'R5 – Large Lot Residential' and a subsequent subdivision of the land to create a total of 256 allotments plus internal access roads and ancillary infrastructure is consistent with the intent of the Goulburn Mulwaree Council Urban and Fringe Housing Strategy (2020), the NSW Flood Risk Management Manual (2023), and the publication titled 'Considering flooding in land use planning Guideline' (2021).

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19th March 2024

1/. Overview of the Rezoning Submission, Description of the Land and Proposed Subdivision.

The Goulburn Mulwaree Council commissioned *Elton Consulting* to undertake an *Urban and Fringe Housing Strategy* study for the urban centres of both Goulburn and Marulan which was completed and adopted by Council in July 2020. To gain an appreciation of how the aforementioned study triggers the submission of the land rezoning application being the subject of this assessment the following extracts have been taken directly from the completed report to provide context;

"This Urban and Fringe Housing Strategy (Strategy) investigates and identifies areas suitable for the provision of additional housing to assist Goulburn Mulwaree Council (Council) meet the housing demands generated by expected continued population growth.

The Strategy has been prepared in response to both the limited supply of residential land available to meet the short and medium term needs of the community and the directions of the South East and Tablelands Regional Plan 2036.

The scope of the Strategy includes looking at the urban areas of Goulburn and Marulan and identifying opportunities for an additional recommended 3,500 dwellings over the next 18 years to 2036. The Strategy also considers land for large lot residential development (typically greater than 2ha and often referred to as rural residential development) particularly on the urban fringe of Goulburn.

Growth across the LGA has been strong over the past decade increasing by 14 percent. In Marulan population growth has been significant with an increase in population between 2006 and 2016 of 27 percent.

With the Goulburn Mulwaree LGA expected to reach between 33,350 and 37,202 residents by 2036, approximately 5,000 to 7,000 additional residents are expected. Given the drivers of growth include proximity to economically viable regions and affordable housing, these growth rates may increase over time if prices in Sydney and the ACT continue to rise. Advances in technology and improvements in transport, for example higher speed rail, may further stimulate growth.

The majority of recent growth has been through residential subdivisions in Goulburn and Marulan. These new subdivisions have typically provided R2 Low Density Residential zoned land with a minimum lot size of 700sqm. The market responded well to these releases driving demand for additional land as the currently zoned land nears full utilisation."

Further to the demand for the typical 700sqm house block, there is an emerging trend for more compact living close to the urban core. Recent development activity and increasing supply in this form of higher density development indicate the acceptance of the market to sacrifice large block sizes for more compact living with improved proximity and access.

Anecdotal evidence gained through the initial community and stakeholder engagement process indicated demand for large lot residential blocks (2ha). This was corroborated by Council analysis of rural residential lot uptake on the western and south western Goulburn fringes over the past decade. Council found that 200 of the 290 lots registered had a dwelling approved, or a development application lodged. Most of which were within 2 years of lot registration.

The relatively low subdivision costs associated with creating these lots has resulted in this form of development being the preference of proponents looking to rezone land. These products offer diversity in lifestyle choice. Given the current and expected demand for residential land in Goulburn and Marulan it would be anticipated that small volumes of large lot residential land will be absorbed by the market, however, the actual annual demand is difficult to determine."

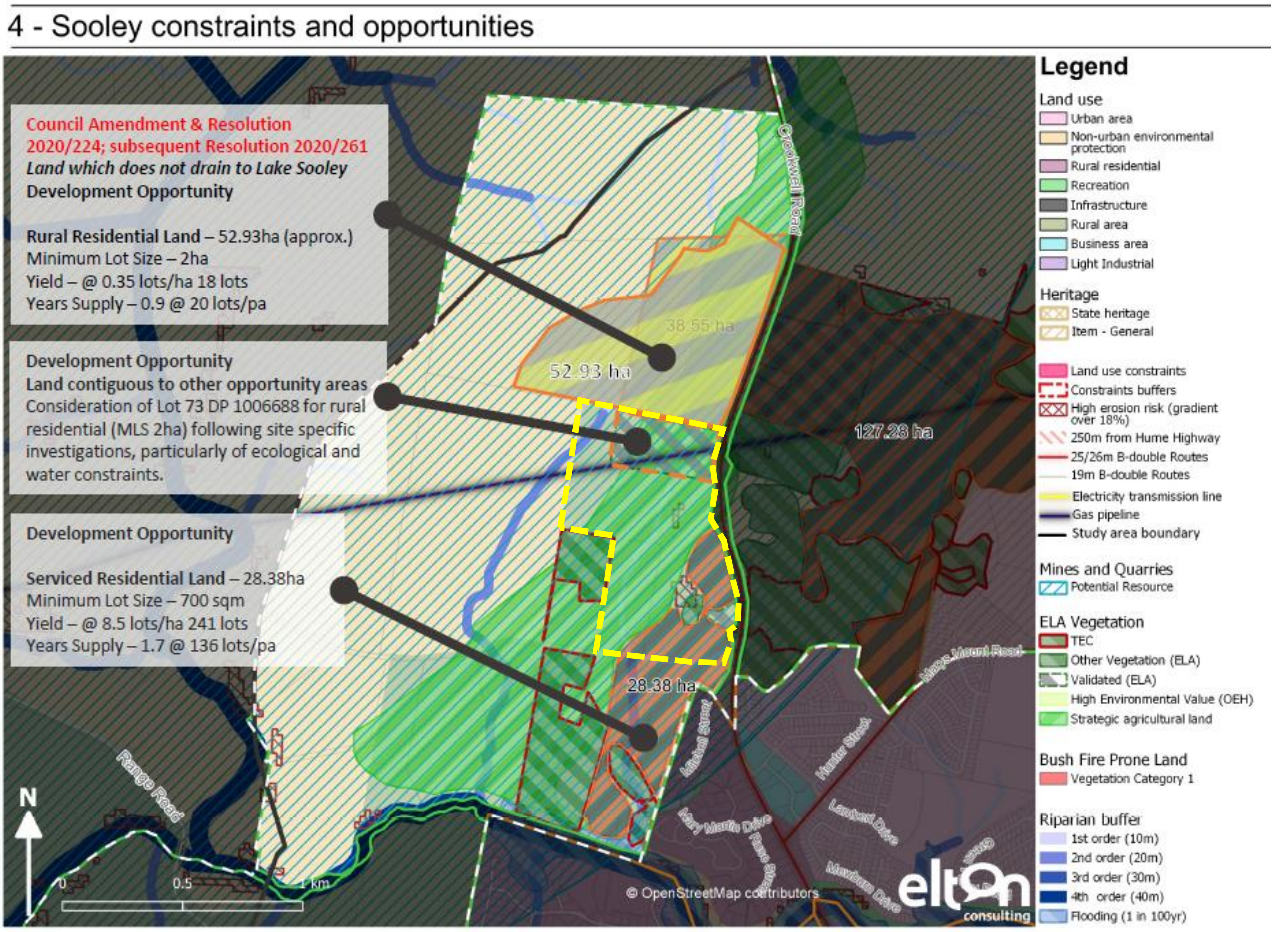


Image from the *Urban and Fringe Housing Strategy* report prepared by Elton Consulting showing the 'Sooley' development precinct and identified land rezoning opportunities. The boundary of the development site is highlighted by the dashed yellow lines in the centre of the image.

The development property is located on the northwestern outskirts of the city of Goulburn and is identified within the *Urban and Fringe Housing Strategy* study as a locality suitable for rezoning to a mix of both 'R2 -Low Density Dwelling' and 'R5 – Large Lot Residential' to help meet future land and housing demands. The property which falls within the *Sooley* development precinct and is currently zoned 'RU6 – Transition' has been identified within the study with an overall potential yield of 241 smaller Lots not less than 700m² in area, and 18 large Lots with a minimum area of 10 hectares – however these numbers may have been modified since the study was originally released. The development property is located within the eastern portion of the *Sooley* development precinct which is situated on the northwestern edge of the city and is an ideal location to leverage off existing services and utilities infrastructure that presently extends to established urban land developments to the immediate south of the site.

The proponent is seeking to rezone the land in accordance with Section 4.4.1 of the *Urban and Fringe Housing Strategy* study and in doing so establish the basis upon which to undertake a subdivision of the land. The site is burdened by two separate but adjacent easements for high-pressure gas supply and optic fibre cables that run diagonally through the northern portion of the holding which in part regulates the potential subdivision design and Lot sizes due to various constraints and permissible activities within specified distances around the easements. A third easement for water supply that is designed to transfer raw water from the Wingecarribee Dam in the Southern Highlands during periods of extreme drought also burdens the property – but to a lesser extent due its alignment and location through the site.

The conceptual subdivision design will potentially create a total of 248 smaller residential Lots not being less than 700m² and 5 Lots that average slightly more than 4,000m² on the southern side of the high-pressure gas and optic fibre easements, and an additional 3 Lots of at least 2 hectares in area on the northern side of the easements. Separate to the proposed residential allotments will be several reserves for drainage, biodiversity values and vegetation management, and the protection of an area of Aboriginal Heritage along with a network of new internal roads. It is assumed that an existing dwelling and several rural structures will be demolished, and therefore all new Lots will be seeking residential dwelling permissibility.

The development site is bordered by two separate named and formed roads that have a minimum corridor width of 20 metres:
1/. Crookwell Road along the eastern boundary which is a TfNSW classified road that provides an important transport link between Goulburn and other regional cities and townships to the north such as Crookwell and Bathurst. The road is a bitumen sealed formation that provides access to many rural land holdings between Goulburn and Crookwell, and to several smaller localities that lie between Crookwell and Bathurst. The posted speed limit along the section of Crookwell Road that lies parallel to the eastern boundary of the site is presently 100kph commencing from the southeast corner of the holding. It is noted that the width of the road reserve is variable along the property frontage with the minimum width at any point being 36 metres, and in some locations the width increases to be greater than 50 metres.

2/. Chinamans Lane which runs along the southern boundary of the development site commencing from the Crookwell Road traffic corridor and extending to the west where it links with Range Road which is a local road that services rural holdings between Goulburn and the village of Grabben Gullen. Chinamans Lane services several small and large rural holdings between the banks of the Wollondilly River and city's raw water storage facility at Sooley Dam.

The development property covers a total area of 50.85 hectares which is comprised of three separate portions: Lots 70, 73 and 77 in Deposited Plan 1006688. Lots 70 and 77 which comprise the bulk of the lands (41.18 hectares) are under the one ownership whilst Lot 73 which is in the northern portion of the holding is under separate ownership. The proponent of the rezoning submission has the option to purchase both sites upon successful approval of the application.

The existing dwelling within the site is currently accessed via a sealed carriageway that enters the property from the eastern aspect off the Crookwell Road traffic corridor. The carriageway is formed along the crest of a hill and meanders through a defined curtilage comprised of several rural sheds and structures before gradually sweeping down a part of the hill on the southern aspect and terminating at the existing dwelling.

The property is burdened by an overhead power transmission line that enters the property from the southern aspect and runs north → south through the site to service several adjoining properties further to the north with a feed line branching of this supply to service the existing dwelling. As mentioned previously, the development property is burdened by several easements that influence the design of the proposed rezoning; a 24.385 metre wide easement for high pressure gas supply which traverses diagonally across the northern portion of the holdings, a separate 4.50 metre wide easement for optic fibre cable that sits immediately adjacent to the southern edge of the high pressure gas supply easement, and a 6 metre wide easement for 'water supply' that can be used to transfer water from Wingecarribee Dam in the Southern Highlands during periods of extreme drought that enters the property in the northeast quarter and sweeps through the northern portion of the property in a large radius curve before exiting into the neighbouring property to the west.

The terrain throughout the property has a general fall from the northeast toward the south-southwest and is dominated by a series of defined drainage depressions located at three distinct locations across the site. The first of the systems runs through the northern half of the site in a northeast to southwest alignment and exits the property where there is a right-angled bend in the boundary that forms the southern aspect of the northern half. The second system is located in the northwest corner of the holding and for the length of its pathway through the property stays on the northern aspect of the high-pressure gas supply easement thereby only burdening two of the proposed larger 2 hectare Lots in a future subdivision of the land. The final mapped drainage corridor is located in the southeast quarter of the property which directs surface water runoff from the Crookwell Road traffic corridor and adjoining lands on the opposite side of the road through the lower southern half of the property. The first and third identified drainage systems merge just outside the lower southwestern corner of the site within the neighbouring property to the west. The conceptual subdivision design has identified the natural flow of stormwater across the site and accordingly has included dedicated reserves for the purposes of drainage at strategic locations which may be used in part or in full depending upon the final calculation requirements.

On either side of the main drainage line that runs through the northern half of the property is a series of slopes and ridges that combine to form a 'moderately' undulating topography through the central portion of the site. The slopes on the eastern and western sides of the central drainage depression are variable and, in some cases, terraced with the average slope being around 10° - however there are areas where the slope may exceed 15° in small sections. The elevation changes between the drainage depression through the centre of the site and the top of the adjoining ridge lines vary by approximately 20 to 25 metres whilst the distance from the centre of the drainage line to the top of the ridge lines averages between 110 and 120 metres, although some distances are slightly longer.

In the northwestern portion of the site there is a gentle and somewhat consistent fall averaging 5° from the crest of the western ridge line toward the western boundary and toward the drainage depression that runs through this portion of the site. The southern portion of the site has a general fall from the crest of a hillock where the existing dwelling and curtilage are located in an arc formation from the west and around to the southwest and then to the south at variable grades that average between 10° and 15°, the steeper section being the lower slopes to the west. The lower southeast corner of the site has significantly less slope with a more pronounced east to west fall of less than 5° following the alignment of the drainage depression that burdens the southern aspect of the site.

The vegetation formations throughout the property which has historically been used for grazing by sheep and cattle are dominated open paddocks of improved pastures and native grasslands, however over the past 5 or so years the property has seen less pasture improvement and only light grazing. There are a few rows of old radiata pine trees across the site, one in the northern portion where the larger 2 hectares Lots are proposed, and another along the ridge line around the curtilage in the central-eastern portion of the site. The pine trees are formed in single rows however due to their age many are now displaying signs of necrosis and die-back with gaps appearing between some of the trees. Scattered across the slopes that surround the existing dwelling and curtilage are numerous eucalyptus trees that are quite well spaced and without overlapping canopies.

The subject site is surrounded by a mix of both small and large rural holdings to the north, east, and west that are also set to open grasslands and improved pastures with some scattered trees – particularly on the eastern aspect. The southern aspect of the site is dominated by urban land developments with small Lots and a few small rural holdings. The two road corridors that border the eastern and southern boundaries of the site and are variable in width form a physical barrier between the development property and the adjoining developments.

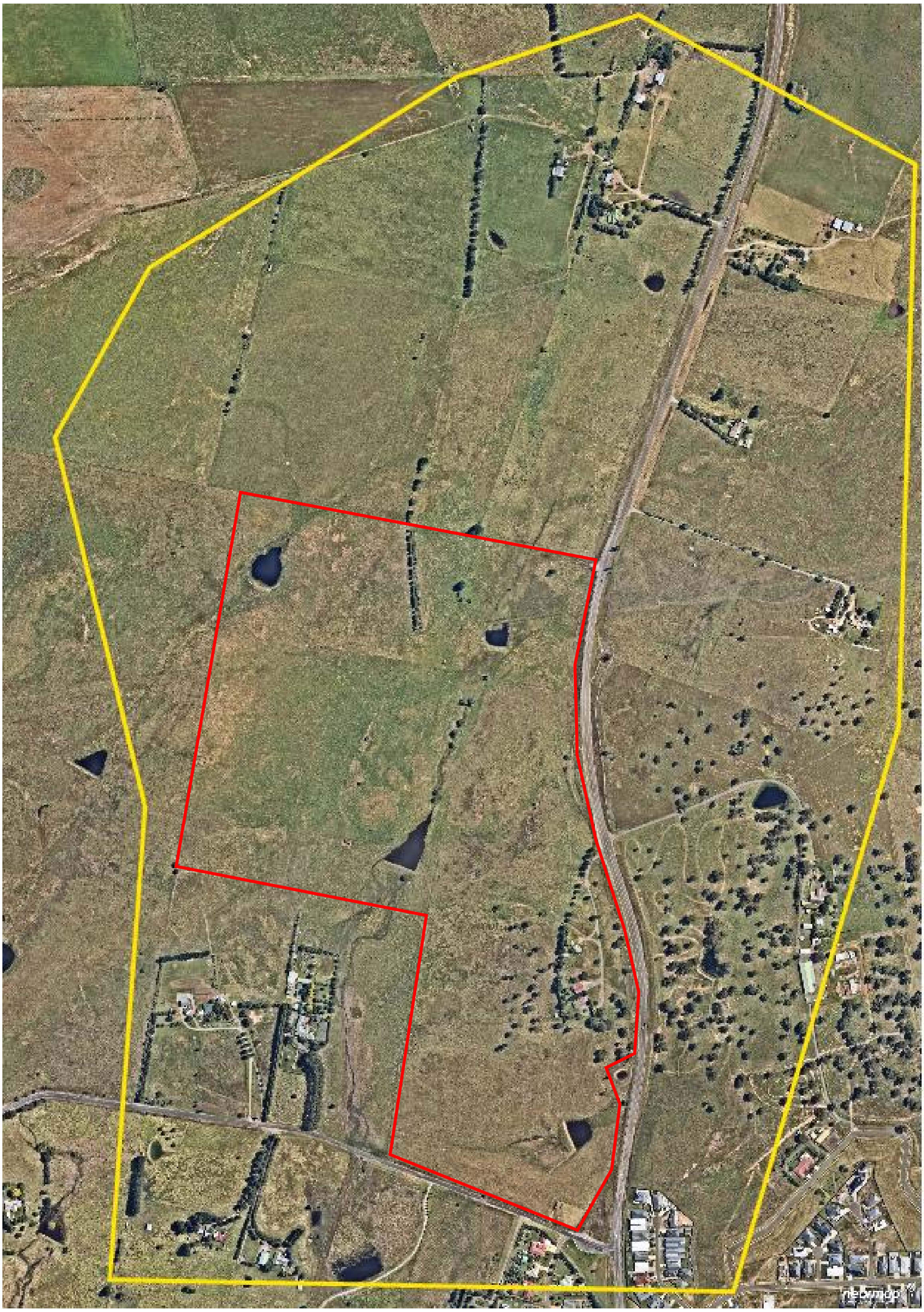


Figure 1. Recent aerial image of the development site (red) and the contributing catchment area within the bounds of the yellow line to the north, northeast, and east of approximately 107 hectares which generates overland flows and surface water runoff that burdens the site. It is noted that the surface types within the catchment areas are comprised of homogonous vegetation types and land uses associated with historical agricultural activities. The land to the west and south of the site that are within the yellow lines are included within the models to show the downstream effects between pre-development and post-development scenarios.

Future Subdivision Proposal.

Prior to preparing a conceptual subdivision design the identification and delineation of potential constraints associated with the rezoning of lands that are subject to periodic flooding and/or overland flows must be considered to satisfy the provisions of 'Section 9.1 of the Environmental Planning and Assessment Act (1979) – Direction 4.1 Flooding'. Direction 4.1 (2) and 4.1 (3) state that a planning proposal must not contain provisions that apply to the '*flood planning area*' which permit development in '*floodways*', result in significant impacts to other properties, or permit development for the purposes of residential accommodation in '*high hazard*' areas. Each of the terms in previous sentence that are in italics have very specific definitions within the NSW Government Department of Planning and Environment publication titled 'Flood Risk Management Manual – The policy and manual for the management of flood liable land' (June 2023), and these components need to be identified in the preliminary stages of the subdivision design to determine where development cannot occur.

In accordance with the Local Planning Direction 4.1 'Flooding' areas of the site identified as being within the flood planning area are to be zoned 'C2 – Environmental Conservation' which would therefore prohibit any future use of the land for residential or other development purposes. Within the context of this study which is assessing the major overland flows that burden the site the 'flood planning area' is defined as: the extent areas which act as floodways as well as areas where the depth of water in the 1% AEP rain event that is greater than 100mm. This approach is consistent with the methodology adopted by GRC Hydro for the recently conducted *Marulan Floodplain Risk Management Study* (2023) that was undertaken on behalf of the Goulburn Mulwaree Council.

By applying the aforementioned methodology to determine the flood planning area the parts of the site that are not suitable for residential development purposes were identified along with the flow paths and extents of other design events such as the probable maximum flood to determine the most appropriate layout of a future subdivision of the land. Due to the nature of the major overland flow paths that dissect the site which will be discussed in greater detail in following sections, and further to communications with Goulburn Mulwaree Council Strategic Planners the proposed subdivision layout was required to demonstrate that access and egress from all parts of the property can be maintained in design events up to and including the 1% AEP, however as the results of the study will demonstrate in later sections and based on preliminary but not final stormwater drainage designs, vehicle access can be maintained along all proposed internal roadways in a 'low-risk' environment up to a including the 0.2% AEP rain event. It is noted that with further engineering analysis it may be possible to achieve safe vehicle access throughout the entire site in the probable maximum flood event without excessive changes to current design of the road levels and drainage culverts.

In addition to the constraints on the subdivision design associated with overland flows other constraints such as biodiversity values and Aboriginal Cultural Heritage, and design considerations such as perimeter roads for bush fire protection purposes and adequate areas for the placement of inground infrastructure have been included in the proposed subdivision layout. The conceptual subdivision design for the development property will include a mix of 'R2 – Low

Density Residential' Lots with a minimum Lots size of 700m² and 'R5 – Large Lot Residential' allotments that will vary between 4,000m² and 2 hectares in area.

The location of the existing easements for high-pressure gas supply and optic fibre cable in the northern portion of the site significantly influences the distribution of land use zones and the design of the future subdivision, including Lot layout and road locations. There are certain restrictions related to permissible activities around and near both easements, the most limiting of which is generally associated with the high-pressure gas supply line as it is the wider of the two and has very specific and documented controls. The third easement that houses the water supply lines is less of a concern for the subdivision design as it is predominantly located along the margins of the defined drainage depression that runs through the northern portion of the site and therefore sits within an area that realistically is not suited for any other type of development purpose.

In lieu of the limitation imposed by the existing easements in the northern portion of the site and in combination with the natural topography the land area to the north of the easements is proposed to be zoned as 'R5 – Large Lot Residential' with a minimum Lot size of 2 hectares. The available land area on the northern side of the easements less provisions for a perimeter access road will generate no more than 3 Lots in this zone. The northwestern portion of the site that sits on the western side of the ridge line but also on the southern side of the existing easements will also be zoned as 'R5 – Large Lot Residential' however the Lot sizes here will be 4,000m² which is large enough to manage onsite generated effluent within the boundary of the Lot and thereby remove the need to provide gravity sewer in this portion of the site. The available land area in this portion of the site less provisions for a perimeter access road will generate no more than 5 Lots. The southern side of the two main easements comprises approximately 35.40 hectares of the overall land holding and is proposed to be zoned as 'R2 – Low Density Residential'. The conceptual subdivision design has demonstrated that approximately 248 residential allotments could be created in this area along with provisions for an internal road network and dedicated reserves in strategic locations for drainage, biodiversity values and vegetation management, and for the protection of areas of Aboriginal Heritage. The road network through this portion of the site will occupy approximately 8.342 hectares of land whilst the dedicated reserves will cover a combined area of 6.814 hectares. The resulting available land area for residential purposes therefore becomes 19.344 hectares which yields an average Lot size of 780m².

Access to the development site will be from the existing road corridors on the southern and eastern aspects with new entrances to be created at each location via dedicated turning lanes. The Crookwell Road traffic corridor is presently sign-posted with a 100kph speed limit commencing from the southeast corner of the development property – just north of the intersection with Chinamans Lane. Subject to approval from TfNSW a future land development of the property may also include a restricted speed limit of no more than 70kph for the portion of the Crookwell Road traffic corridor that lies between the Chinamans Lane intersection and the proposed entrance in the northeast corner of the holding – possibly reverting back to 100kph once beyond the northeast corner of the site.

The internal road network will be formed in corridors that have a minimum width of at least 18 metres with the sealed portion being at least 9 metres wide between kerbs.

Future subdivision of the site will include a reticulated water supply throughout the 'R2' and 'R5' 4,000m² zoned Lots on the southern side of the high-pressure gas main whilst the 'R2' zoned Lots will also be serviced with gravity sewer and interallotment stormwater drainage infrastructure. The reticulated water supply system will be installed to meet the requirements of the Council's engineering standards – including design layout and achieving minimum pressures and flow rates to meet the provisions of "AS2419.1.2021 - *Fire hydrant installations System design, installation and commissioning*" in relation to hydrant outlet spacing and locations. A detailed design of the stormwater drainage system for the internal road network capable of managing flows in the design events will be undertaken at the time of submitting the subdivision application.

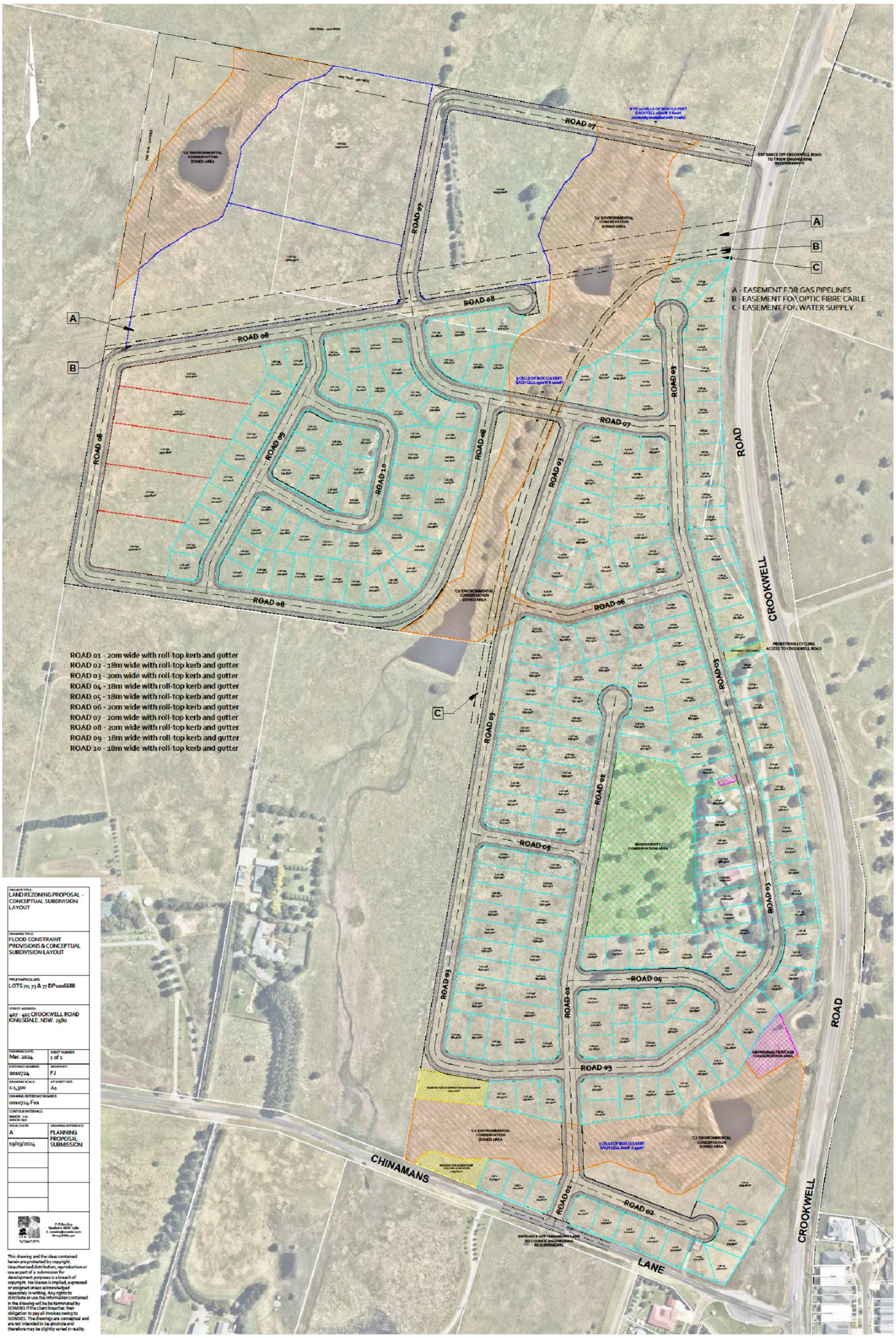


Figure 2. Reduced image of the conceptual subdivision layout showing the areas of 'C2 – Environmental Conservation' zoning as orange diagonal shading, Aboriginal Heritage as magenta coloured shading, biodiversity values as light green coloured shading, proposed stormwater and sewer infrastructure reserves and pedestrian / bicycle access as yellow coloured shading, the road network and proposed Lots. Refer to the accompanying pdf version of the plan (Ref: 0010724-F01) for enlarged detail of the conceptual subdivision layout.

2/. Stormwater drainage and overland flows.

The development property and surrounding lands are not identified in any current planning or mapping instruments as being within flood liable lands, however preliminary 'high level' studies have been undertaken for the Council as a separate exercise to the recently adopted *Goulburn Floodplain Risk Management Study and Plan* to identify areas outside of the mainstream riverine flooding that may be adversely affected by overland flows in large rain events. The subject development site is burdened by general overland flows associated with surface water runoff originating within adjoining lands and properties to the north, east, and to a lesser degree to the northwest of the site. This study is assessing the impacts of existing overland flow from these external sources and from stormwater drainage generated within the site on the land rezoning proposal and potential future residential subdivision development for the land.

The development property is burdened by a series of both defined and undefined episodic drainage corridors that traverse through the site in a varying array of alignments however these corridors are not a named river or creek system but are upstream tributaries that eventually discharge into the Wollondilly River which is located to the south of the site. The main sources of overland flows and surface water that burden the development site emanate from the northern, northeastern, and eastern aspects and form three separate flow pathways.

The first of the three drainage systems has an upstream catchment area that drains into the central portion of the property and comprises an area of approximately 68.10 hectares with the furthest part of the catchment being approximately 800 metres from the northern boundary. This catchment contains land on either side of the Crookwell Road traffic corridor and is comprised of homogonous land uses and surface finishes which are dominated by open paddocks of grasslands for stock grazing. The range of design rain event modelling undertaken as part of this assessment indicates that there is several locations along the Crookwell Road traffic corridor where surface water that is generated to the northeast of the development property crosses the roadway and enters the upstream catchment thereby directly contributing to flow of water that burdens the site. The overland flow that runs through the central portion of the property travels in a north - south alignment within a defined channel of varying width and comprises two dams and a series of small hollows and ponds that form a chain of storage zones within the range of modelled rain events. One of the dams is located where the gas and communication easements cross the site, whilst the other is located on either side of the property's southern boundary adjacent to where there is a right-angled bend in the perimeter fence line.

A separate catchment area of approximately 22.50 hectares also commences on the northern aspect of the site however it is separated from the main catchment by a ridge line that runs in a north – south alignment. Overland flow within this catchment enters the northwestern corner of the site and continues to flow in a northeast – southwest alignment with a single dam near to the northwest corner of the property within the flow path. Outflows from the dam and high-flow bypass water around the dam exit the western boundary of the property just to the north of the existing gas and communication easements.

The third drainage corridor that flows through the site is associated with a catchment area of approximately 16.63 hectares that is mostly generated on the eastern side of the Crookwell Road traffic corridor and includes surface water runoff from the roadway. The upstream end of the eastern catchment is located in privately owned lands on the opposite side of Crookwell Road and flows in a northeast to southwest alignment, exiting the property and crossing Crookwell Road approximately 180 metres to the north of the intersection of Crookwell Road and Chinamans Lane. The Crookwell Road reserve has a slight 'offset' where some of the surface water from the roadway is directed via a concrete drainage channel to a small dam that is located adjacent to the roadway and just outside the eastern boundary of the development property. Overflow from the roadside dam and the overland flows from the property to the east both enter the southeastern portion of the development site and flow into a moderate sized dam. In the larger rain events or when there has been a prolonged period of wet weather outflows from the dam along with general surface water runoff from the southern portion of the property below the existing dwelling and curtilage flow in an east - west alignment across the lower southern aspect of the site and exit the property near to the southwest corner adjacent to Chinamans Lane. The overland flows that cross the southern aspect of the site merge with the continued flow of water from the central portion of the site within the neighbouring property to the west, and the combined flows then continue in a north – south pattern and cross Chinamans lane enroute to the Wollondilly River.

The conceptual subdivision of the land does not propose to alter the existing flow paths or dams, the only impact of the proposed subdivision development on existing overland flows will be associated with the installation of box culverts within the drainage corridors to facilitate the construction of the proposed internal road network. The conceptual subdivision design includes three crossings of the existing drainage corridors; one over the southern drainage line for an entrance off Chinamans Lane; one that crosses the central drainage channel approximately 130 metres south of the existing gas and communications easements; and the third is located along the northern boundary and also crosses the central drainage corridor approximately 100 metres west from where the northern property entrance will junction off Crookwell Road.

Preliminary modelling of the post-development site conditions has provided a base upon which refined hydraulic design and modelling can be undertaken to ensure that the flow of water within the drainage corridors where the road crossings are proposed equals the pre-development flow rates. The post-development modelling that has been undertaken in association with this assessment has identified the minimum requirements for road design levels and culvert sizing at the proposed crossing locations such that 'low-risk' and safe evacuation can be achieved in the design rain events up to and including the 0.2% AEP which exceeds the requirements prescribed by Council's Strategic Planners. It is noted that when reviewing the post-development model results there is a slight afflux of water at these locations however the refined modelling will increase the number of box culverts cells at these locations to minimise the backwater effects and achieve flow rates that equal the pre-development conditions. Additional modelling of the road crossings has not been undertaken at this stage in the event that changes are required to the conceptual subdivision layout.

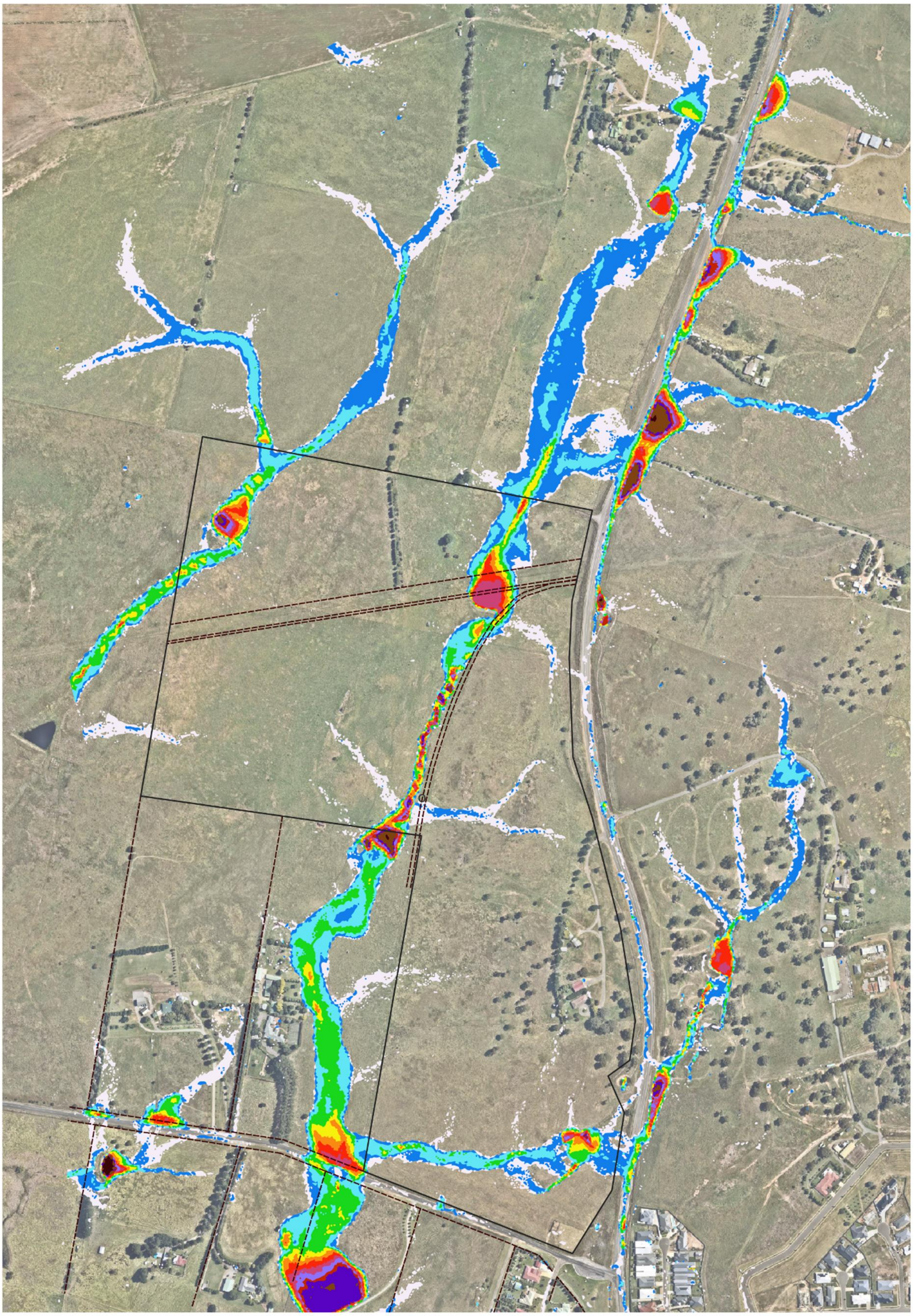


Figure 3. Image from the 1% AEP pre-development model showing the overland flow pathways through the defined catchment area that eventually reach the northern and eastern boundaries of the development site and then flow through the property along established drainage corridors and channels. Water depths less than 100mm but greater than 25mm have been left on which shows the dendritic nature of surface water runoff within the site.

3/. Localised flood and overland flow models.

To ascertain the impacts of overland flows and surface water drainage across the site a preliminary (pre-development) stormwater drainage and overland flow model was undertaken of the existing site and surrounding catchment area using a combination of detailed contour survey of the property and LiDAR mapping information. To create a terrain profile for the stormwater drainage and overland flow assessment outside of the detailed property and road corridor survey LiDAR information was obtained for the development area from the Geoscience Australia '*Elevation and Depth Foundation Spatial Data'* website (ELVIS). The defined catchment area and development property is captured within three datasets which each having a grid area of 2km x 2km (Goulburn201906-LID1-AHD_7466152_55_0002_0002, Goulburn201906-LID1-AHD_7466154_55_0002_0002, and Goulburn201906-LID1-AHD_7466156_55_0002_0002,) which was downloaded as point data in a compressed LAS format (LAZ file). The Geoscience Australia files were converted into terrain data through a point cloud transformation process and then paired with surveyed site contour information to prepare a base terrain profile that can accurately reflect the pre-development conditions within the site and throughout the catchment.

The primary objective of the modelling is to determine the existing overland flow patterns, water depths, and velocities within the development property and to conservatively estimate for the range of 'design rain events' – being the 10%, 5%, 1%, 0.5%, and 0.2% AEP's plus the probable maximum flood where the main impacts from external sources would be experienced. Results from the modelling exercise were also used to help define priority areas for future stormwater drainage infrastructure. Software used to undertake the modelling is the '*InfoWorks ICM Ultimate*' which is licenced, distributed, and supported by Autodesk. '*InfoWorks ICM Ultimate*' is a stormwater and flood modelling program incorporating 1D network and 2D scaled mesh operations to perform both above and below ground hydrology and hydraulic simulations. The digital elevation model was imported into the software to create a terrain profile which was paired with a georeferenced aerial image of the catchment area for ease of identification, correlation, and result analysis purposes.

Initial modelling looked at a range of rainfall durations and temporal patterns to determine the event that generated the greatest inflows and depths of water to the site. From this exercise it was concluded that for each design event excluding the 5% AEP that the 2-hour rainfall with temporal pattern #8 provided the greatest flows and depths, for the 5% AEP event the 2-hour rainfall with temporal pattern # 7 satisfied the same criteria. The 2-hour rainfall figures adopted in each of the models excluding the probable maximum flood are summarised as follows: 10% AEP (35.30mm), 5% AEP (40.10mm), 1% AEP (51.20mm), 0.5% AEP (57.40mm), and 0.2% AEP (65.90mm).

The determination of the probable maximum precipitation was calculated in accordance with the *Generalised Short Duration Method* (GSDM) as prescribed by the Bureau of Meteorology (2003), and the terrain within the modelled catchment which is 235 hectares in area was determined to be 100% 'smooth'. A 'Moisture Adjustment Factor' (MAF) of 0.68 was adopted, and the 'Elevation Adjustment Factor' (EAF) was '1' as the elevation of the site is less than 1,500 mAHD.

Via interpolation of the data within the '*Depth – Duration – Area Curves of Short Duration Rainfall*' the following probable maximum precipitation rainfall depths were determined for the site-noting that the 2-hour rainfall duration was adopted for the analysis purposes:

Duration (minutes)	30	45	60	90	120	180	240	300	360
Rainfall depth (mm)	228	286	337	347	428	476	511	561	598

As no previous flood modelling of the development area is available for comparison, correlation, or validation the current recommended guidelines for rainfall information and flood modelling for small catchments as prescribed by Engineers Australia - Australian Rainfall and Runoff (2019) and the NSW Flood Risk Management Guide (2019) were adopted. Within the model a direct-rainfall methodology was employed which is deemed suitable to determine overland flow paths, depths, and velocity information for small catchment areas. Design parameterisation and rainfall data for the site was obtained directly through the Australian Rainfall & Runoff Data Hub and the Bureau of Meteorology portal.

As the characteristics of the upstream catchment areas are reasonably homogonous and comprised of similar land use and surface types each of the models has adopted a uniform roughness coefficient (Manning's 'n') of 0.035 which represents the generally short to medium height grasses associated with grazing activities – this is consistent with Table 6.2.2 of the AR&R2019 guidelines. An initial loss of 16mm for each rain event has been included in each model in accordance with the storm loss figures from the Australian Rainfall & Runoff Data Hub for the geographical area, however as a conservative approach within the modelling a continuing loss which would equate to 2.7mm/hour was not included.

The catchment area within each of the models covers 235 hectares and is broken down into approximately 366,000 meshing triangles that have an average area of 7.63m², and each 'working' face allows normal flow conditions from one mesh triangle to the next. The large modelling area validates the effective upstream catchment areas that burden the development property by identifying other drainage regimes that occur outside, around, and beyond the property, and which therefore can effectively be ignored.

For analysis purposes in each of the rain events the 2-hour storm with temporal pattern #8 run for a 180-minute duration was adopted as this tended to have the greatest inflow of water, two bursts in the rainfall intensity with the last burst in the second period of the event and an irregular rainfall pattern continuing until the end of the run, and it was possible to observe how long the depths of water remained after the peak rain in the event. It is noted that in the model results all water depths less than 25mm have been isolated to help clear the image and to remove multiple areas of isolated and small ponding. For model results that are derived from the probable maximum flood water depths that are less than 100mm have been isolated which is consistent with the determination of the flood planning area, and because the images effectively become difficult to read due to the dendritic nature of shallow water that flows over the surface.

When viewing the results from the individual modelling each 'Figure' includes a pre-development image on the left-hand side of the page and a post-development image with subdivision layout on the right-hand side. There is also a title block with a description of the what the results are portraying and brief description of what the different colours represent.

From the pre-development models several 'constraint' plans were produced which provided the basis upon which the conceptual subdivision layout was undertaken and also satisfied some of the other general flood information requirements. The first of the constraint plans to be produced was the 'flood planning area' which has been mentioned earlier in the report. This assessment has adopted the determination of the flood planning area in accordance with the methodology proposed by GRC Hydro (*Marulan Floodplain Risk Management Study and Plan* - 2023) which prescribes that the flood planning area be based on the areas that form the floodway and where water depths for the 1% AEP event that are greater than 100mm. The extents of the flood planning area are contained well within the defined drainage channels and corridors, and all proposed roadways with the exception of the drainage line crossings and residential Lots are located outside the mapped flood planning area. Refer to Figure 05 for a visual interpretation of the defined flood planning area.

The flood planning area in combination with the extents of water depths greater than 100mm in the probable maximum flood event have been used to determine the areas of 'C2 – Environmental Conservation' that will be mapped throughout the site. By combining the flood planning area with the water depths in the probable maximum flood the areas of the site that represent the greatest risk to people, property, and the environment in a flood event are removed from potential development opportunities. Figure 06 shows the extent of the proposed 'C2 – Environmental Management' zoned land and includes the areas of proposed 'R2 – Low Density Residential' and 'R5 – Large Lot Residential' zoned lands which will assist with defining the proposed land zoning areas. It is noted in Figure 06 that there is a branch of 'C2 – Environmental Management' zoned land that extends for part of the way along the proposed internal road identified as 'Road 06' commencing from the junction with 'Road 03'. Despite being picked up in the probable maximum flood event the flood planning area model doesn't include this line and it would be recommended that this section of 'C2' zoning not be included in the final zoning plans.

The next set of results derived from the pre-development modelling is the 'flood function' where the water depths and flow velocity were used to define the 'flood conveyance', 'flood storage' and 'flood fringe' areas for the 5% and 1% AEP events, and the probable maximum flood. Classification of the three separate flood function components is important in determining the likely impact of development in a design flood event – including overland flows, with each of the separate flood function classifications responding differently to changes.

'Flood conveyance' is defined as those areas where a significant flow of water occurs and are normally associated with natural and man-made channels and are often the areas of deeper flows and/or where the higher velocities occur – changes in topography or development within these areas can cause a significant redistribution of flood flow or cause a significant rise in flood levels.

'Flood storage' are areas that temporarily store floodwater in a flood event and by doing so attenuate or slow-down the peak water flows and flood levels, and as the main flow of floodwater recede, they slowly release the stored water downstream – filling or removing flood storage areas reduces their ability to attenuate the flood flows and thereby flood flows and levels downstream may significantly increase. 'Flood fringe' is the remainder of the flood extent and is generally the areas where effects on flood function are not a constraint with development unlikely to significantly alter the flood behaviour.

Determination of the 'flood function' for overland flow within each design event has been undertaken using the criteria prescribed by *Howells et al (2003*) with the flood conveyance (floodway) defined as:
velocity x depth >0.25m/s and velocity >0.25m/s, or velocity >1.0m/s and depth >0.15m
Flood storage is the area outside of the floodway with a depth greater than 500mm, whilst the flood fringe is the area outside the floodway with a depth less than 500mm.

The pre-development and post-development modelling results for the flood function associated with the 5% and 1% AEP's and the probable maximum flood are presented in Figure 07 to Figure 09 and it is noted that the areas of proposed residential development and internal roadways are within the low risk 'flood fringe' mapped areas. It's not until the probable maximum flood event that the 'floodway' begins to encroach on the residential areas, and even then, the floodways are essentially confined to the road corridors.

The last of the general constraint maps to be produced from the pre-development and post-development models is the 'Flood Planning Constraint Categories' which helps to determine the different parts of the floodplain that are suited to a range of different land uses, with particular emphasis on the more sensitive and vulnerable developments being excluded from the higher risk areas. The flood planning constraint categories are derived from a combination of sources that produce the other mapping outcomes, and their collective information can provide a description of the flood behaviour and assist with land use planning decisions. The flood planning constraint categories are separated into four groups with 'FPCC1' being the most constrained and therefore less suitable for intensification of land use or development, whilst 'FPCC4' is the least constrained areas and therefore suitable for intensification of land use or development. The intermediate flood planning constraint categories ('FPCC2' and 'FPCC3') represent different development opportunities, and to help guide Council and potential developers on the permissible land uses within the different categories, a 'flood planning control' matrix has been developed which is included in Appendix J of the Council's Development Control Plan. The various sources of information and contributing flood model results that make up the flood planning constraint categories is a collection of different water depths, velocities, and hazards from different rainfall events hence there is generally only the one set of Flood Planning Constraint Category plans produced for the site or area under consideration. Figure 10 shows the Flood Planning Constraint Categories determine by the flood study and it is evident that where there is a portion of the flood planning constraint categories that affects a residential Lot or roadway it is only 'FPCC4' which is the least constrained area of the floodplain and therefore very few limitations apply to residential development.

It is highlighted that the post-development images for the flood planning area (Figure 05), the land zoning areas (06), and the Flood Planning Constraint Categories (Figure 10) show the relevant flood model result for the pre-development conditions with the conceptual subdivision layout simply as an overlay for definition purposes in the post-development result. All other post-development images are based on the results of the post-development model and therefore include the impacts or effects associated with the proposed subdivision conditions such as regrading and landforming for the internal road network.

Of the other maps produced from the flood study there is a series of water depth and flood level images for each of the design rain events being the 10%, 5%, 1%, 0.5% and 0.2% AEP's and the probable maximum flood, and these are presented from Figure 11 to Figure 17. There are two versions of the probable maximum flood event; Figure 16 has all water depths less than 100mm turned off for clarity and to correspond with the boundaries of the 'C2 – Environmental Conservation' zoned areas, whilst Figure 17 has all water depths less than 25mm turned off and therefore showing the greater extent and dendritic nature of surface water runoff across the catchment and development site. To view the flood levels which are included at every metre interval it may be necessary to zoom into the individual images, the scale at which the images are produced to fit within the available paper space makes the numbers difficult to read otherwise.

For the post-development models at each rain event it will be apparent that the proposed road corridors provide an effective conveyance mechanism for the stormwater drainage system which will only be enhanced once a fully developed stormwater engineering design and model is undertaken for the subdivision application stage. The road corridors represent an opportunity to intercept any existing flows of surface water which are generally very shallow and therefore the proposed residential Lots are not adversely affected with future inter-allotment stormwater drainage assisting to manage the remaining surface water in the minor rain events.

Finally, and following on from the water depths and levels images is a set of images from Figure 18 to Figure 24 that represent another but separate interpretation of risk in the various flood events. This suite of analysis is termed the 'hydraulic hazard' or 'flood hazard' and is a flood depth and velocity assessment based on the guidelines within Chapter 7 of Book 6 within AR&R2019 – Section 7.2. The models have categorised the flood hazard into six separate risk profiles in accordance with the hazard curves and property tables based on work undertaken by Smith et al. (2014). The flood hazard is a measure of the risk to human life and evacuation opportunities as a consequence of water depths and flows velocities with a scaling chart system used to identify suitable thresholds for different population demographic groups, structures, and vehicular transport options for evacuation situations. The flood hazard is comprised of six critical levels, with levels 'H1' to 'H3' generally being acceptable for a range of human occupancy and transport options, although small vehicles may be affected in flood water associated with levels 'H2' and above. Hazard levels 'H4' to 'H6' are essentially unsuitable for people and vehicles but may be suitable for different types of building structures – although Level 'H6' is essentially not suitable for any form of land use.

The modelling results for the post-development conditions indicate that where a hydraulic hazard is created it generally follows the alignment of the proposed internal road network. The associated depths and velocities of water for all rain events up to the probable maximum flood are within the lower end of the risk scale being predominantly 'H1' which is considered suitable for all demographic groups, buildings, and transport options. In the probable maximum flood, the risks increases and therefore the hazard ratings are significantly greater however there may well be an improvement on the outcomes once further drainage design work is undertaken for the subdivision application stage. As with the water depths and levels images, two version of the flood hazard for the probable maximum flood event have been prepared at the different water depth parameters (greater than 100m and greater than 25mm) for general information purposes, and these are presented in Figure 23 and Figure 24.

Farm Dams and Proposed Detention Basins.

The field survey data collected within the development site captured the high-water level or 'top of bank' elevation points around each of the existing dams together with the downstream embankment details. The drawing software program that converts the field survey data points into terrain models triangulates between each of the data points and creates a level plane based on the elevation details. By processing the area between each data point as a triangle the elevation value is preserved and therefore a uniform surface is created. The effect of this interpolation is that the terrain over the area of the dam is model as a level surface which is closely related to or equals the top water level and therefore the dam being full. Figure 4 shows an example of the field survey data collection points (in red) around one of the existing dams.

Within each of the modelled rainfall events the depths of water associated with each dam is created by the retarding effect associated with the embankment at the discharge end. For each dam the height to the crest of the embankment above the normal high-water level varies, however the height can be estimated from the model results which shows the depths of water changing for each event magnitude, and the respective rainfall event where the spillway begins to flow freely.

The existing farm dams which have been established for a long time and appear to be structurally integral will be retained in their current form, noting that there is no intent to remove, enlarge, or re-shape them. The proposed development of the site would include a due-diligence visual assessment of each dam to ensure that there no obvious signs of erosion or damage to the embankments or spillways, and that no vegetation has established itself to or within the dams that could eventually impede the normal function – such as trees or woody shrubs. If there is any apparent sign of damage, fatigue, or unwanted plant growth then these features will be remediated to the extent necessary to return the dams to their original design and functionality.

In association with water quality assessment undertakings the post-development conditions for the main portion of the site which comprises approximately 30 hectares has been divided into 11 separate sub-catchment areas based on the natural terrain and the proposed road network.

Each of the sub-catchment areas is further divided into residential and road runoff 'nodes' with the area for each node used to determine the peak flows in both the pre-development and post-development conditions for different rainfall events. The development areas around Lots 1 to 3 on the western side of the southern entrance off Chinamans Lane and the larger rural Lots to the north of the gas line easement have not been included in the catchment calculations as they are areas that can manage surface water runoff and water quality requirements quite simply.

Through the use of hydrological modelling for the design rain event (being the 1% AEP) for the largest of the defined sub-catchments which is just over 6 hectares in area it is determined that a small 'dry' detention basin having a nominal detention volume of 250m³ with an orifice regulated base outlet would be sufficient to ensure that the post-development discharge flow rate is less than the pre-development flow rate for the same area, along with some minor attenuation of that flow. All other sub -catchment areas which range in size from 0.54 hectares to 5.16 hectares would require proportionally smaller basins to achieve the same post-development peak discharge provisions.

The use of a 'dry' detention basin which would essentially present as a grass-lined depression or bowl outside of the larger rain events removes any long-term risks to public safety that might otherwise be associated with a permanent storage arrangement.

The post-development flood modelling currently does not include the proposed 'dry' detention basins due to their relatively small size and spatial distribution across the site, and the possibility of design changes at the subdivision application stage. Further, each basin would drain into an adjoining biofiltration system of varying sizes to treat the water runoff to a quality that satisfies the NorBE criteria, and this complex interaction of passive drainage with gradual percolation through engineered filtration and drainage media prior to discharge is difficult to accurately represent as a singular output with the available software modelling programs.

By not including the proposed 'dry' detention basins with the post-development model there is no loss or attenuation in the peak flow of each modelled rainfall event which is the equivalent of assuming that the existing farm dams are full at the commencement of precipitation. It is noted however that the conceptual location of the 'dry' detention basins would be above the high-water level associated with the 1% AEP design rain event, possibly within the margins of the 'C2' zoned areas or between the 'C2' zoned areas and the road reserves where suitable land area allows. The conceptual location of the 'dry' detention basins is outside the main overland flow pathways that are identified within the models and therefor any impact or influence on flooding to downstream properties or catchment areas would be minimal.

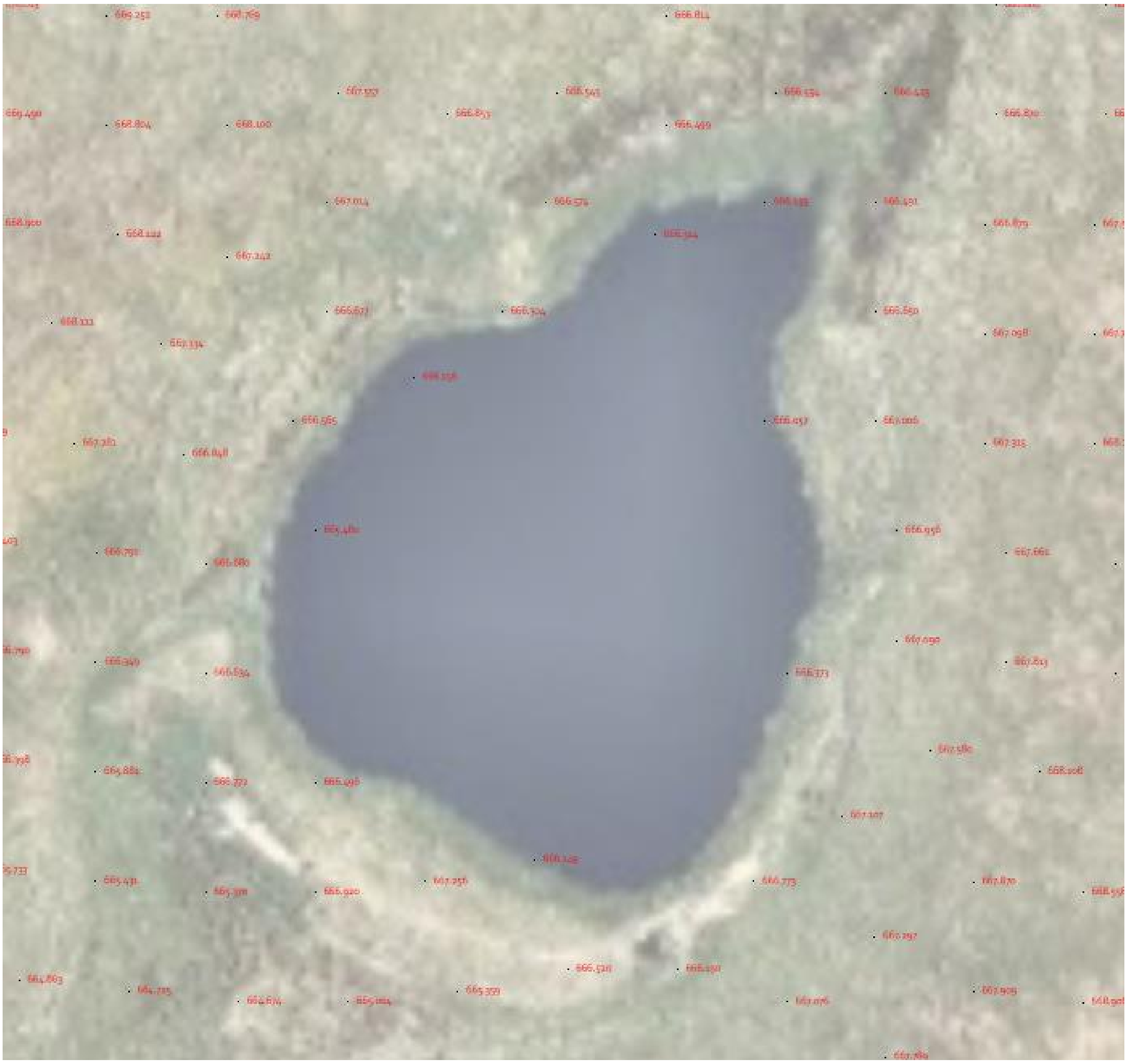


Figure 4. Screenshot from the drawing program that processed the field survey data showing the location of the collection points around the perimeter of the dam which is equal to the high-water level or top of bank. Note that the field survey data was collected at a different time to the aerial image of the dam.

4/. Post-development impacts and summary.

The post-development models for water depths and levels, and flood hazard indicate that the internal road network and proposed residential Lots will generally be in a low-risk flood environment for all events up to and including the 0.2% AEP. Even in the probable maximum flood it is mainly the sections of the internal road network where they cross the natural drainage lines that issues associated with water depths and flood hazard become apparent.

The current design of the internal road network has intentionally limited the height of the road profile across the drainage lines to the minimum amount required to provide a suitable horizontal road geometry across the depression whilst at the same time satisfying the minimum requirement for cover over the top of the proposed drainage culverts. Each of the three proposed crossing were specifically designed to be at the narrowest section and ideally with the shallowest water depths in the drainage system to minimise the amount of civil works required, and to limit the extent of possible changes to the existing overland flow characteristics. The number and size of the box culverts cells at each of the proposed road crossings were adjusted within the models until each meet the criterion of all crossings being passable by vehicles and pedestrians in rain events up to and including the 1% AEP, additional modelling beyond satisfying this objective has not been undertaken until there is some level of surety around acceptance of the conceptual subdivision layout.

The crossing of 'Road 01' over the drainage corridor in the southern portion of the site off Chinamans Lane is currently modelled with three box culvert cells that are each 1.20 metres wide and 450mm high, however the width of the water at this crossing in the 1% AEP event is approximately 32 metres hence there is ample opportunity to add additional culverts at the centre of the crossing to improve the flow of water under the roadway. The crossing of 'Road 07' over the central drainage corridor is currently modelled with a 1.50-metre wide by 1.20-metre-high box culvert cell immediately adjacent to a 3.00-metre wide by 1.20-metre-high box culvert cell. In the 1% AEP event the width of the main flow of water under this section of the roadway is approximately 20 metres, so again there is opportunity to provide additional culvert cells to improve the flow of water at this point. The width of overland flow entering the property across the northern boundary at the location of the third road crossing which is where 'Road 07' crosses for a second time varies between 40 metres and 65 metres in the 1% AEP pre-development rain event. Presently the post-development model includes seven box culvert cells that are each 1.80 metres wide by 300mm high, and each is slightly spaced apart so that they are located where water depths appeared to be the greatest. Because the width of water at the crossing is so wide additional culvert cells will be required to support the proposed roadway and minimise any fill requirements, and this will result in an improved flow of water in the post-development conditions.

The aforementioned details of the current modelled stormwater drainage provisions identify that additional box culverts cells can be installed at each of the proposed drainage line crossings to improve overland flows which will therefore reduce any backwater and afflux effects that are presently shown in the post-development models – particularly along the northern boundary.

Additional stormwater drainage infrastructure within the proposed subdivision will improve the conveyance of stormwater through the site and away from the roadways and residential Lots. Whilst there will be an increase in hardstand area and therefore an increase in rainwater runoff across a range of rain events Council's stormwater drainage policy requires each Lot to manage the peak flow rate for stormwater runoff in the post-development conditions to not exceed the pre-development flow rates. This requirement in combination with the Council's rainwater tank policy which requires individual Lots greater than 700m² to install a tank of at least 22,500 litres and satisfying BASIX commitments will help to manage the peak discharge of stormwater from the fully developed site.

Based on the assumption that the individual residential Lots will manage the peak discharge of stormwater in the post-development conditions such that it does not exceed the pre-development flow rates then the modelling results for post-development in this assessment indicates that the proposed subdivision of land would not have an adverse effect on downstream propeties. By comparing the pre-development and post-development models against each other in the following Figures it is observed that there is very little to no change in downstream water levels or extents, and if additional culverts are added at the proposed road crossings as suggested afflux effects will be removed and therefore existing overland flows will be preserved.

It is acknowledged that the post-development models in this study do not accurately reflect a fully developed subdivision site with additional stormwater drainage information to be included at the subdivision application stage, however the nature of the terrain within the site which in a geophysical sense is best described as 'very well drained' due to the natural slopes does promote the rapid drainage of surface water from, through and off site such that flooding of a nature that could be considered a high-risk essentially does not occur. Retention of the existing overland flow corridors with additional buffer areas either side of the flow paths that extent out to the margins of the probable maximum flood provides areas that are not suitable for development, and the inclusion of road reserves adjacent to the buffer areas where practical provides a better outcome.

Climate Change.

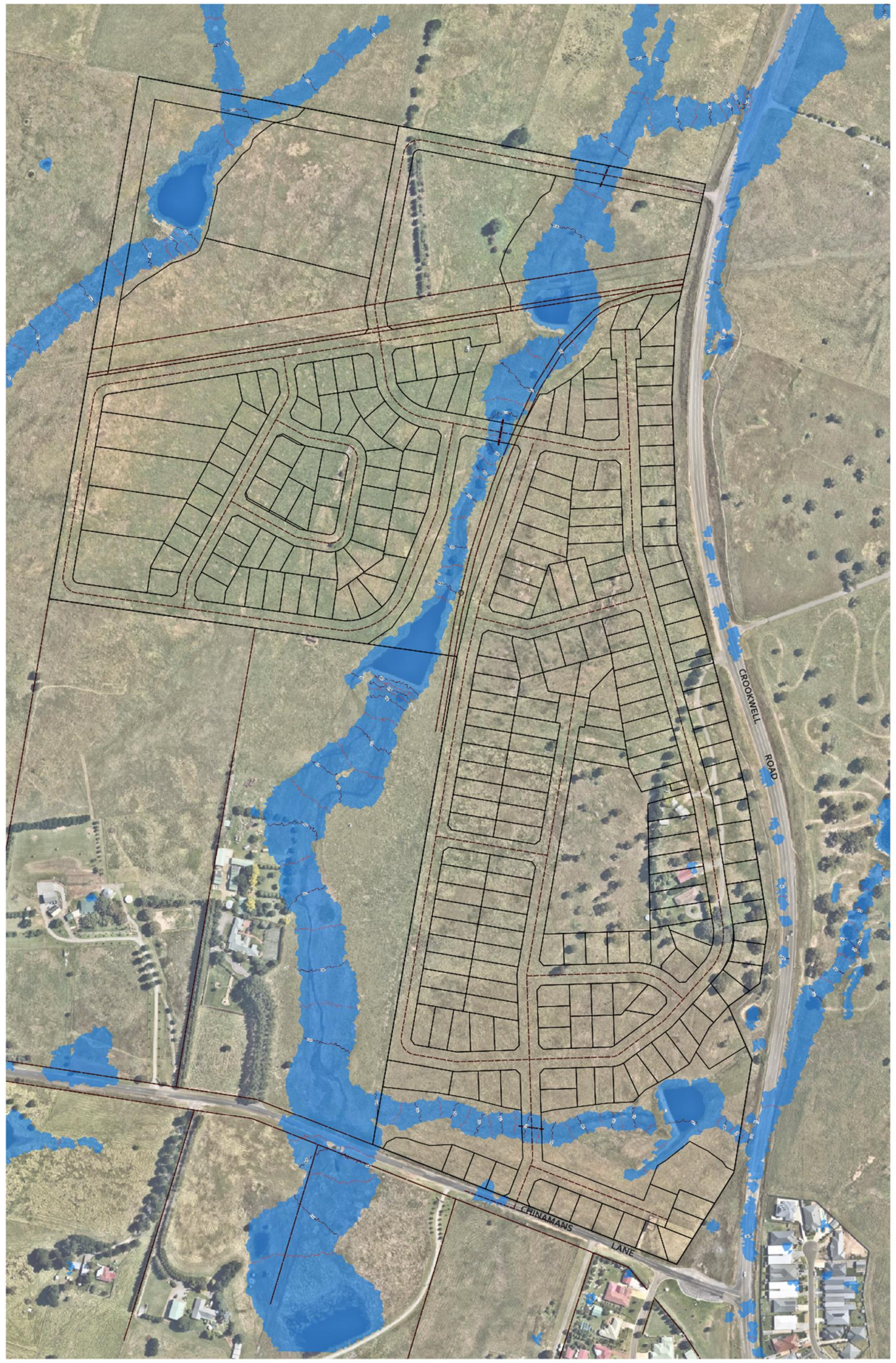
An assessment of 'climate change' on the proposed subdivision of the site has been undertaken, which is effectively using the existing models for two of the 'rare' rain events as a proxy for the projected increases in rainfall over time. Book 1 – Chapter 6.2 of Australian Rainfall and Runoff (2019) guidelines in part states the following in relation to the climate change estimates:

"*Climate change projections are focussed on Natural Resource Management (NRM) 'clusters'. Projected changes from Global Climate Models (GCMs) can be explored for 14 20-year periods and the four Representative Concentration Pathways (RCPs) for greenhouse gas and aerosol concentrations that were used to drive the GCMs. The RCPs are designated as 2.6, 4.5, 6.0 and 8.5, and are named according to radiative forcing values (W m^{-2}) in the year 2100 relative to pre-industrial values. Use of RCPs 4.5 and 8.5 (low and high concentrations, respectively) is recommended for impact assessment*".

The 'Australian Rainfall and Runoff Data Hub' provides a continually updated estimated percentage increase in rainfall for RCP's 4.5 and 8.5 for locality of the study area for each decade commencing at the year 2030 and extending out to 2090. For the study area the percentage increase at the year 2090 is 9.5% for RCP 4.5 and 19.7% for RCP 8.5. Adopting the 1% AEP event with a 2-hour rainfall value of 51.20mm as the design event upon which to assess the impacts of climate change, the increase in estimated rainfall would equate to 56.06mm for RCP 4.5, and 61.28mm for RCP 8.5.

To assess the impacts of climate change on the proposed subdivision development the water depth and flood hazard results from the 0.5% and 0.2% AEP's which have 2-hour rainfall values of 57.40mm and 65.90mm respectively and which exceeds the estimated rainfall increases provide a suitable base for analysis. In each event the proposed road network and residential Lots are outside and above the modelled extents of water depth with only low flood hazard levels of 'H1' within the proposed roadways, and therefore 'climate change' under current best practice estimates should not be a constraint for the development.

The following suite of images from the range of design rain events and hazard assessments are presented in an order that essentially represents the flow of information presented within this document. The intent of the presentation is that as the reader reviews each image or set of images there is a sequential flow onto the next step in the design, modelling, and assessment process. The flow of information commences with the identification of the flood planning area, the proposed land zoning areas, working through to the identification of the development constraint and hazard areas, and finishing with the probable maximum flood in the developed site conditions.



LAND REZONING
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FLOOD PLANNING AREA PRE-LAND REZONING & POST-DEVELOPMENT WITH SUBDIVISION LAYOUT

FIGURE: 05

Site boundary

Cadastral boundary

Flood Planning Area

Flood levels are shown at 500mm intervals for use in defining the 'Flood Planning Levels'.
Water depths of less than 100mm in the 1% AEP rain event have been isolated in determining the Flood Planning Area (GRC Hydro 2023)

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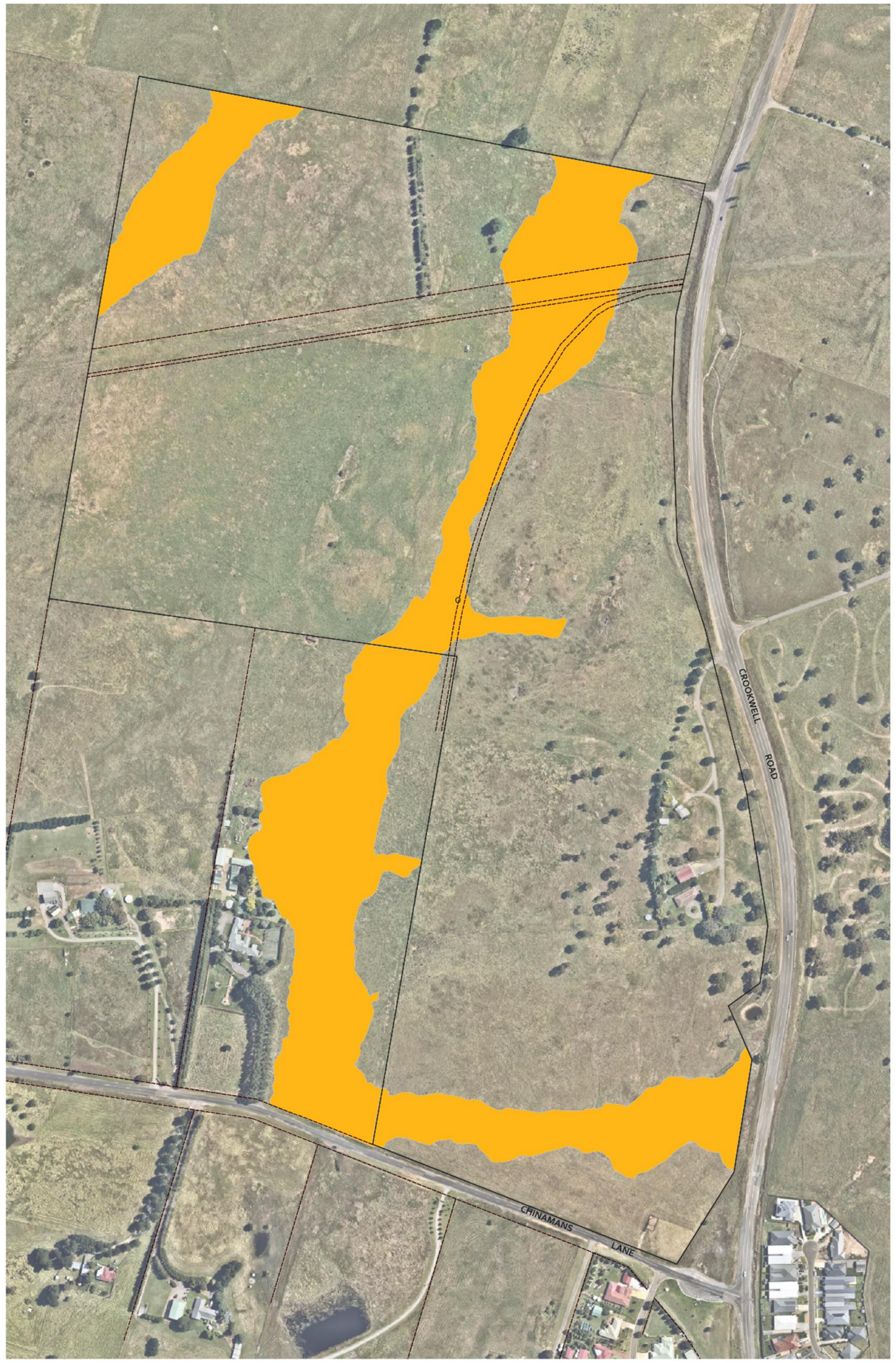

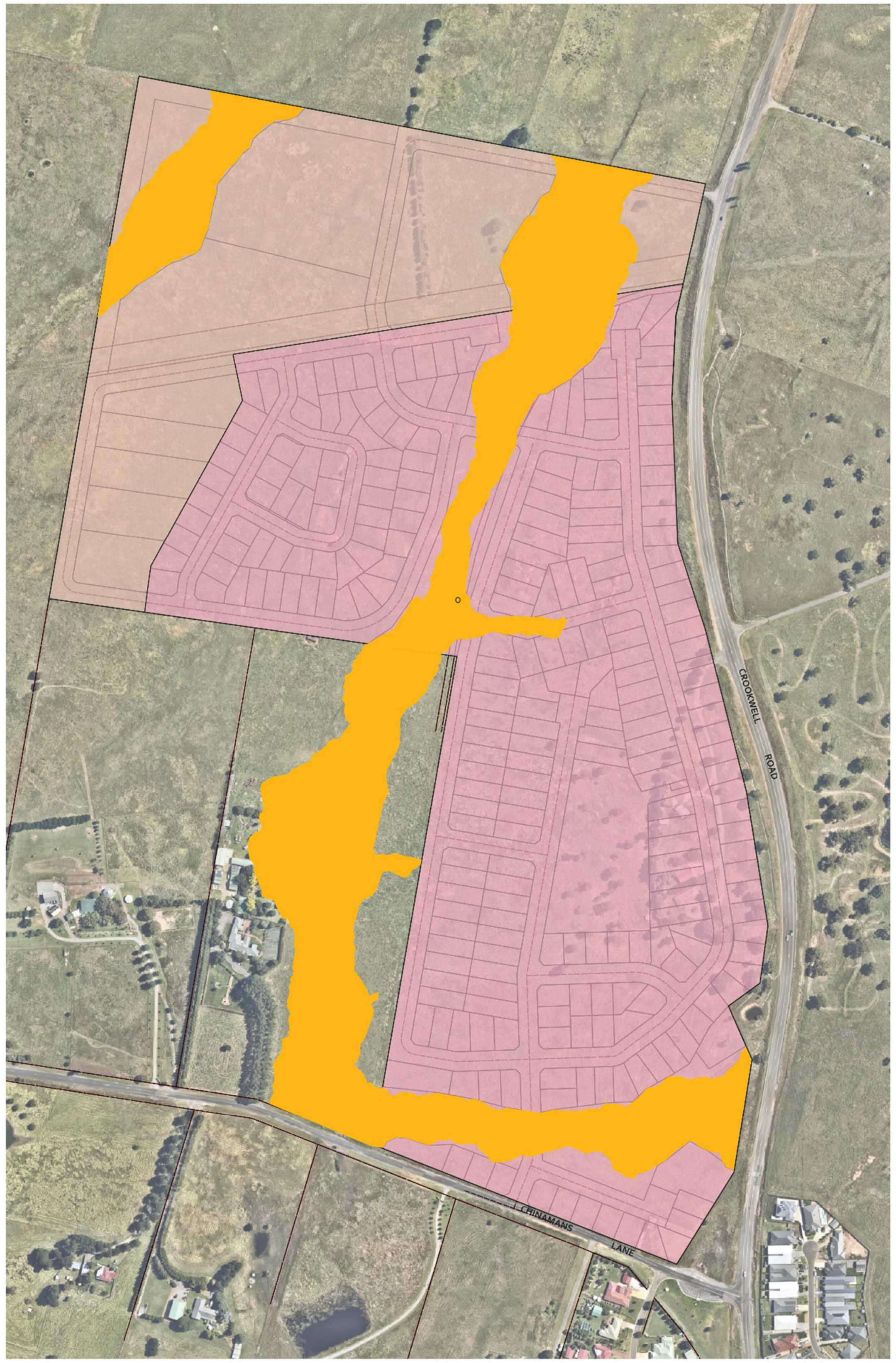

LAND REZONING
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REZONING BOUNDARIES
PRE-LAND REZONING &
POST-PLANNING PROPOSAL
FOR LAND REZONING

FIGURE: 06

Site boundary

Cadastral boundary

Function Category

C2 Environmental Conservation
Minimum Lot size 100 hectares

R1 – General Residential
Minimum Lot size 700m²

R5 – Large Lot Residential
Minimum Lot size 4,000m² and 2 hectares

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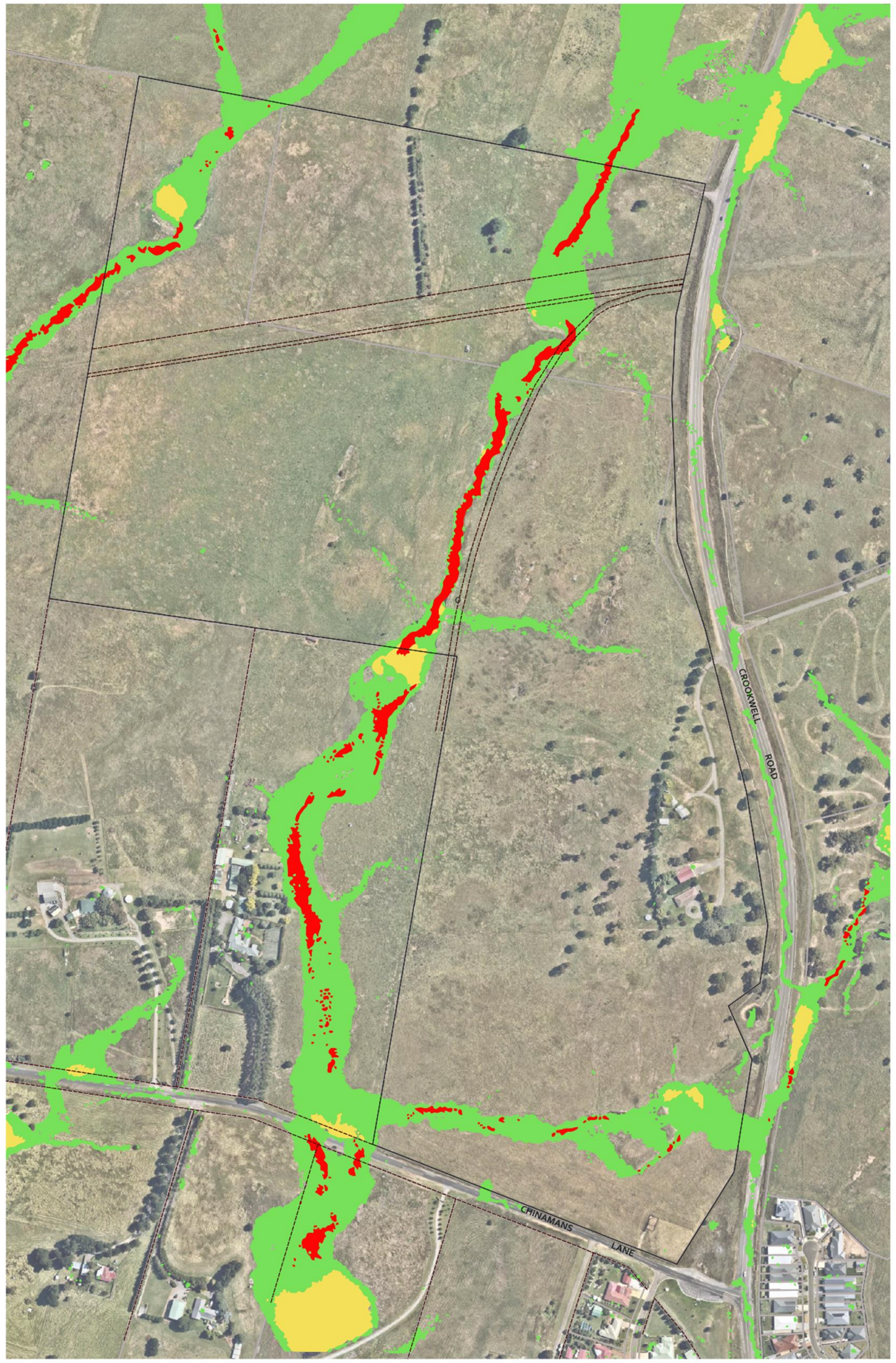

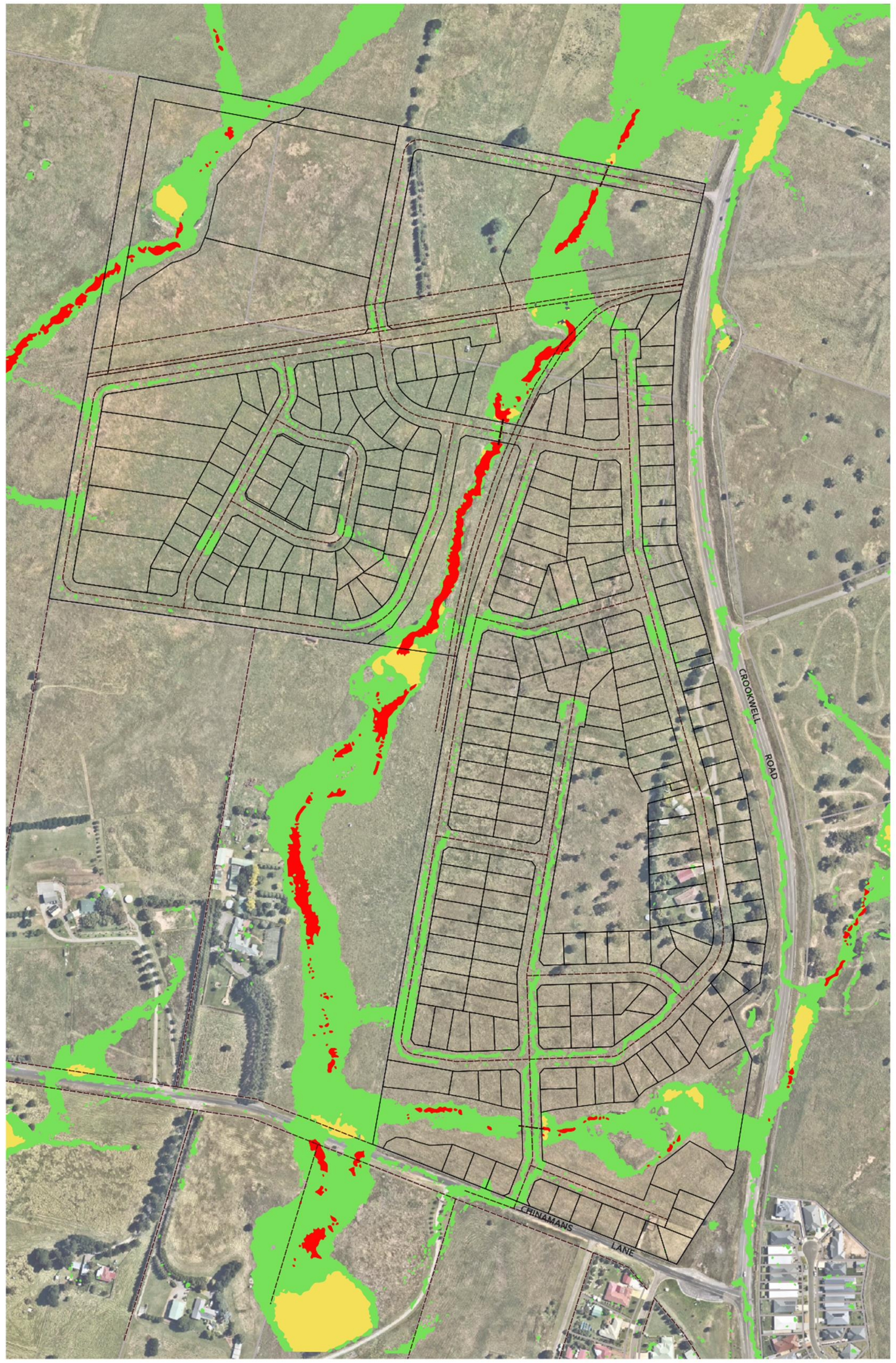

LAND REZONING
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5% AEP
PRE-DEVELOPMENT & POST DEVELOPMENT FLOOD FUNCTION CATEGORY

FIGURE: 07

Site boundary

Cadastral boundary

Function Category

Floodway
Areas where a significant flow of water occurs and are normally associated with natural and man-made channels and are often the areas of deeper flows and/or where the higher velocities occur

Flood Storage
areas that temporarily store floodwater in a flood event and by doing so attenuate or slow-down the peak water flows and flood levels, and as the main flow of floodwater recede, they slowly release the stored water downstream

Flood Fringe
The remainder of the flood extent and is generally the areas where effects on flood function are not a constraint with development unlikely to significantly alter the flood behaviour

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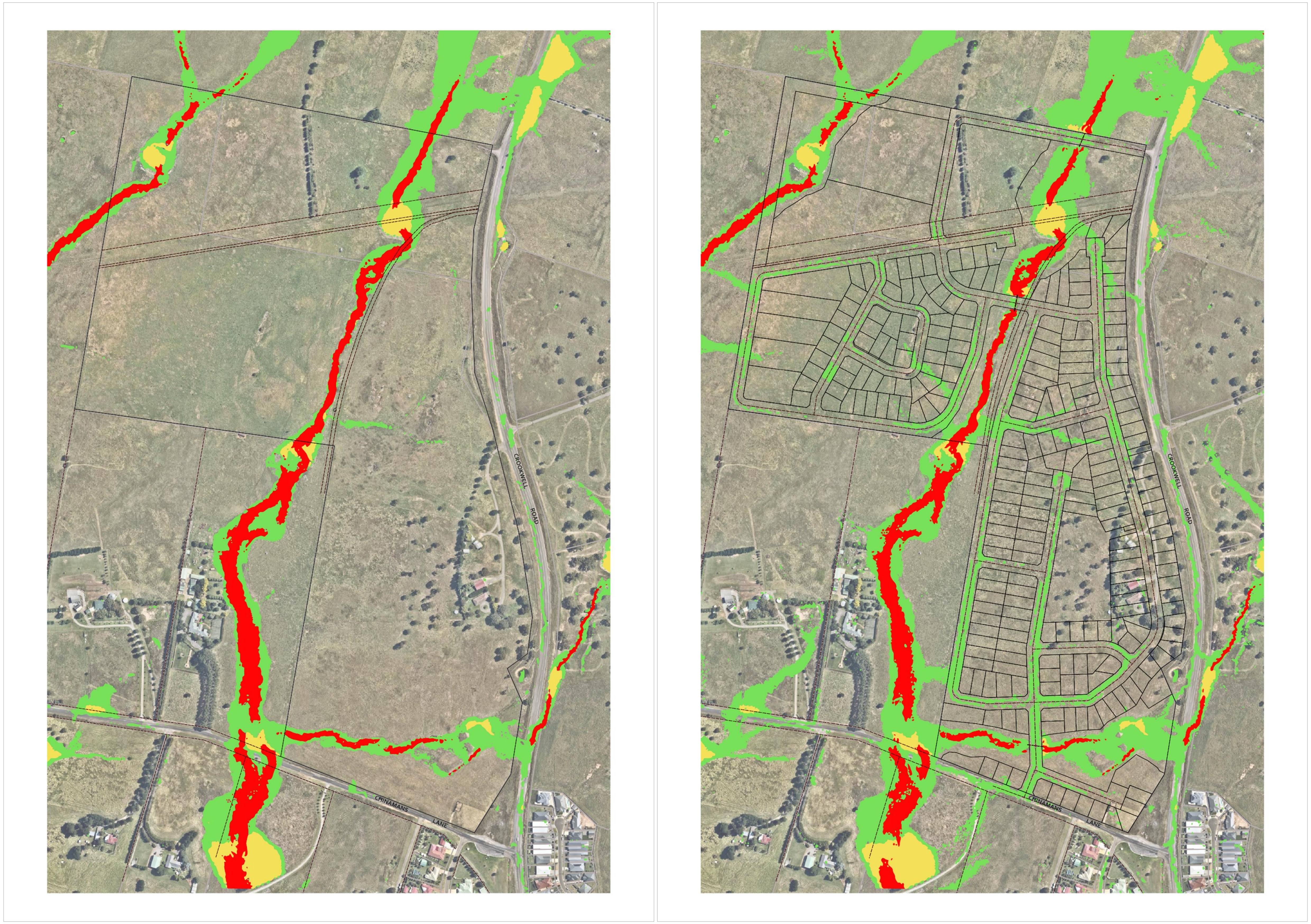

LAND REZONING
407 - 457 CROOKWELL ROAD
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1% AEP
PRE-DEVELOPMENT & POST DEVELOPMENT FLOOD FUNCTION CATEGORY

FIGURE: 08

Site boundary

Cadastral boundary

Function Category

Floodway
Areas where a significant flow of water occurs and are normally associated with natural and man-made channels and are often the areas of deeper flows and/or where the higher velocities occur

Flood Storage
areas that temporarily store floodwater in a flood event and by doing so attenuate or slow-down the peak water flows and flood levels, and as the main flow of floodwater recede, they slowly release the stored water downstream

Flood Fringe
The remainder of the flood extent and is generally the areas where effects on flood function are not a constraint with development unlikely to significantly alter the flood behaviour

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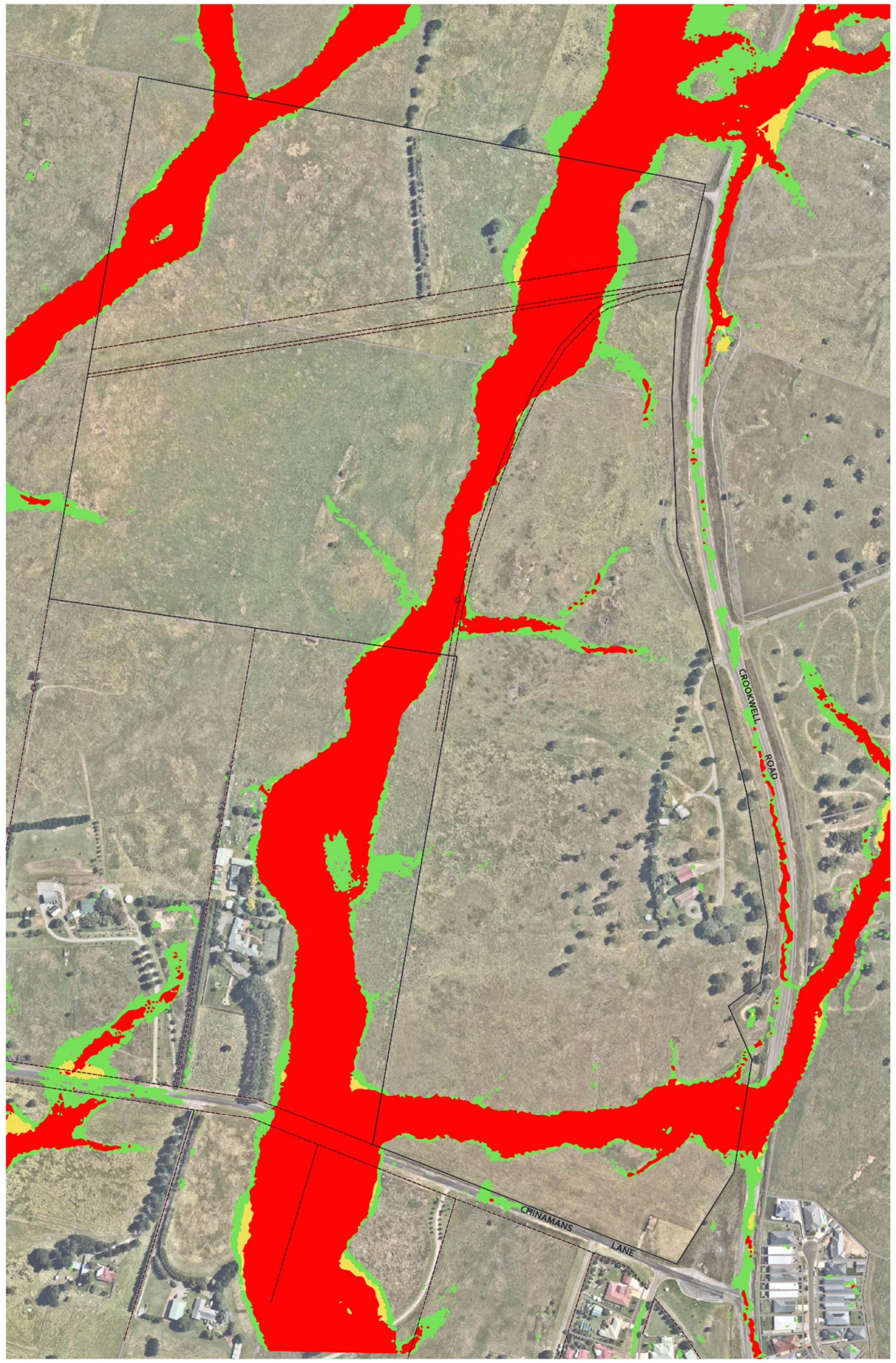

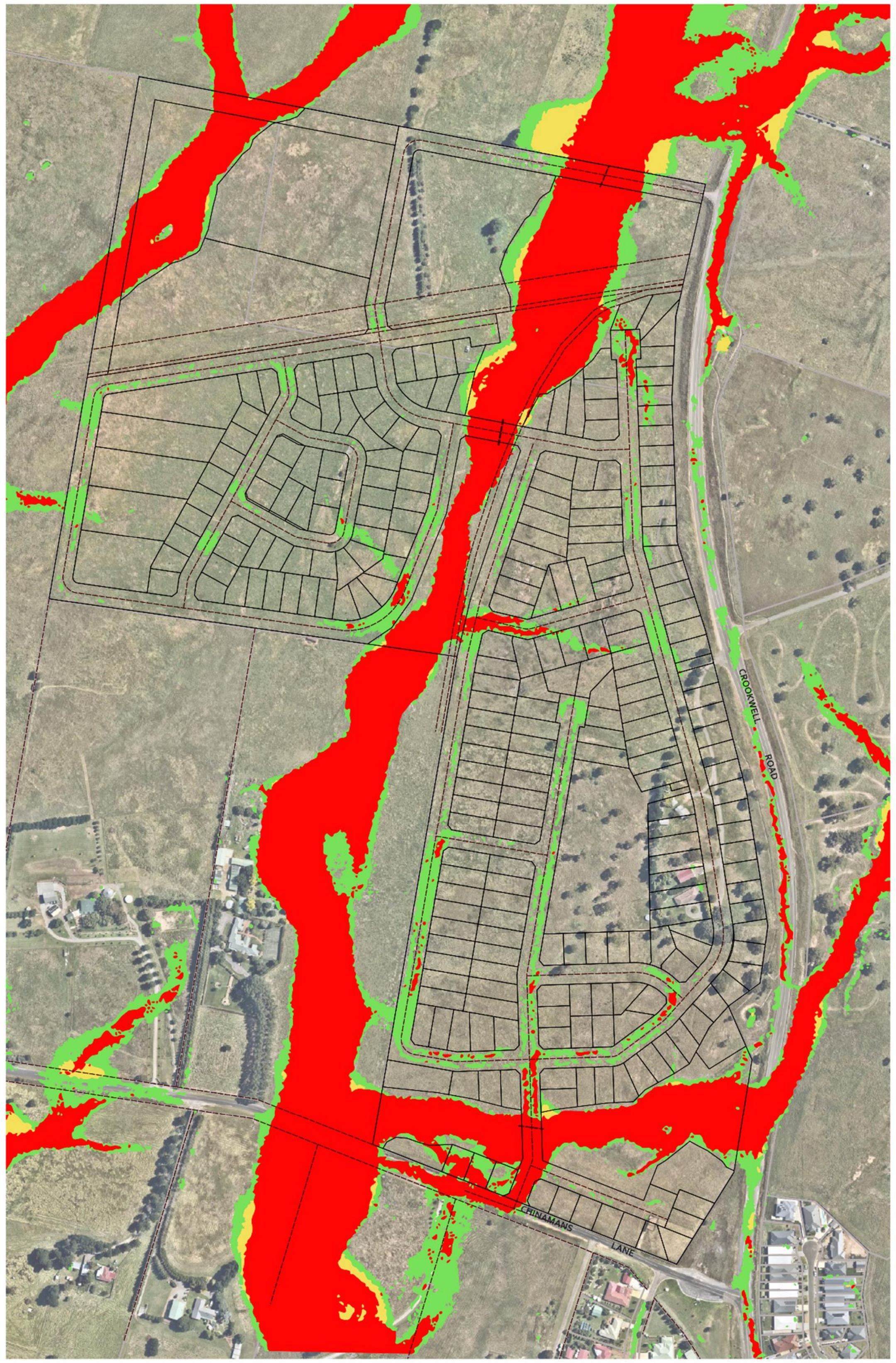

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PROBABLE MAXIMUM FLOOD – (DEPTHS > 100MM) PRE-DEVELOPMENT & POST DEVELOPMENT FLOOD FUNCTION CATEGORY

FIGURE: 09

Site boundary

Cadastral boundary

Function Category

Floodway
Areas where a significant flow of water occurs and are normally associated with natural and man-made channels and are often the areas of deeper flows and/or where the higher velocities occur

Flood Storage
areas that temporarily store floodwater in a flood event and by doing so attenuate or slow-down the peak water flows and flood levels, and as the main flow of floodwater recede, they slowly release the stored water downstream

Flood Fringe
The remainder of the flood extent and is generally the areas where effects on flood function are not a constraint with development unlikely to significantly alter the flood behaviour

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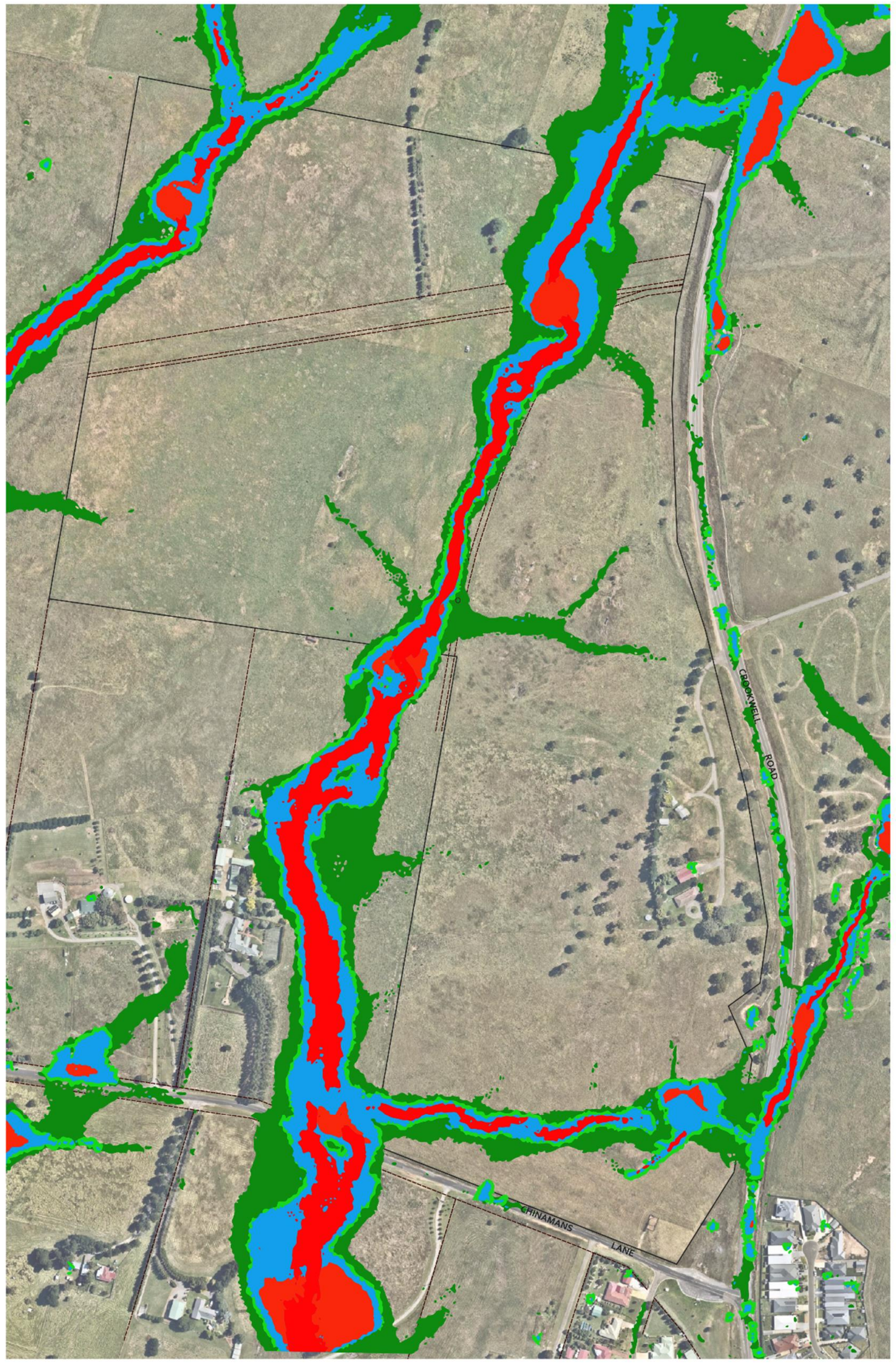

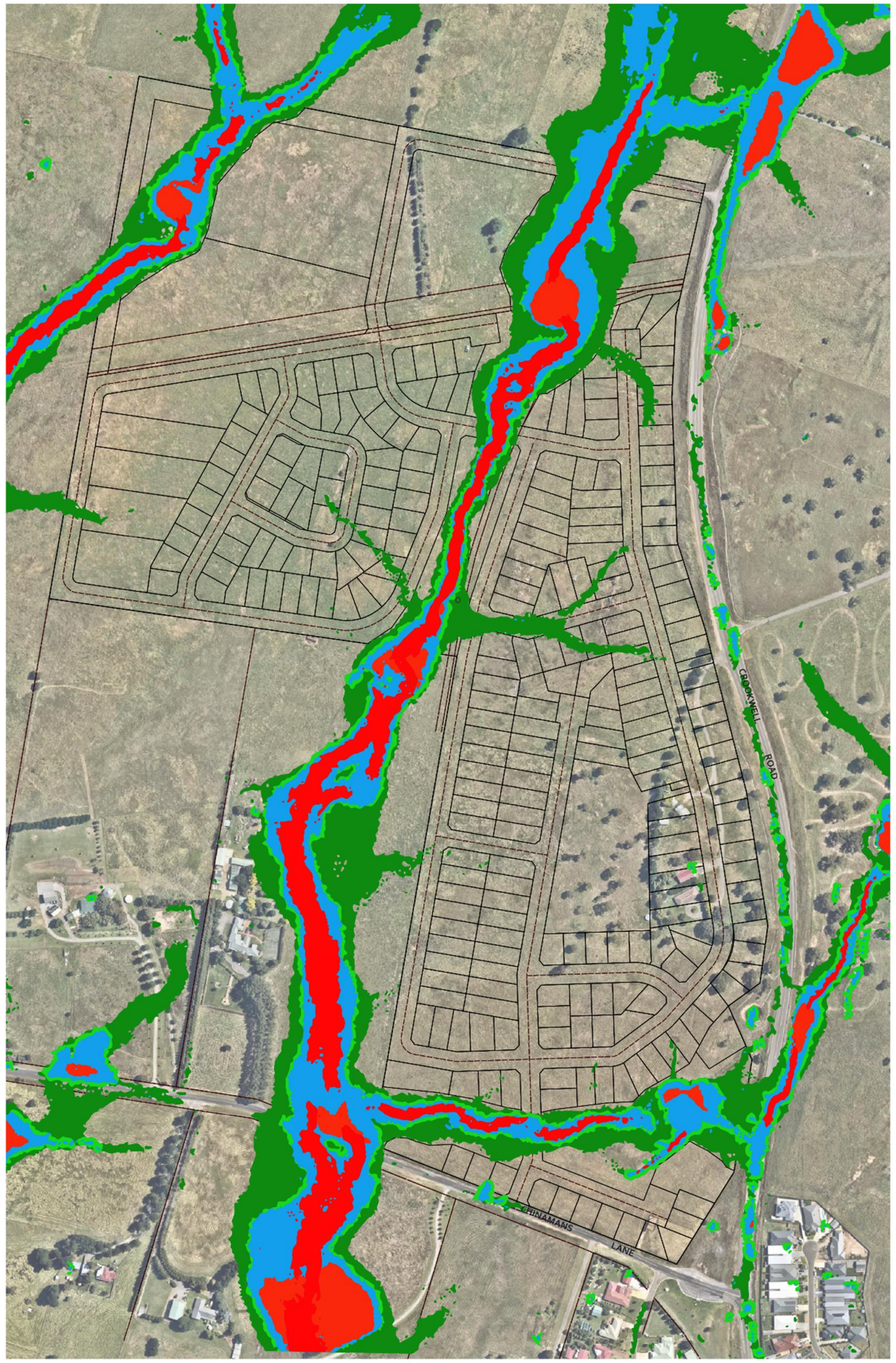

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FLOOD PLANNING CONSTRAINT CATEGORIES
(FPCC) - BASED ON THE 1% AEP DESIGN EVENT PRE-DEVELOPMENT & POST DEVELOPMENT WITH SUBDIVISION LAYOUT

FIGURE: 10

Site boundary

Cadastral boundary

Hazard Category

FPCC1
Flow conveyance and storage areas in the 1% AEP design event.

FPCC2
Flow conveyance in events larger than the design event, Flood Hazard H5 in the design event, areas that are isolated in the extreme events, and Flood Hazard H6 in floods larger than the design event

FPCC3
Outside FPCC2 and generally below the adopted Flood Planning Area

PFCC4
Outside FPCC3 but within the extents of the probable maximum flood

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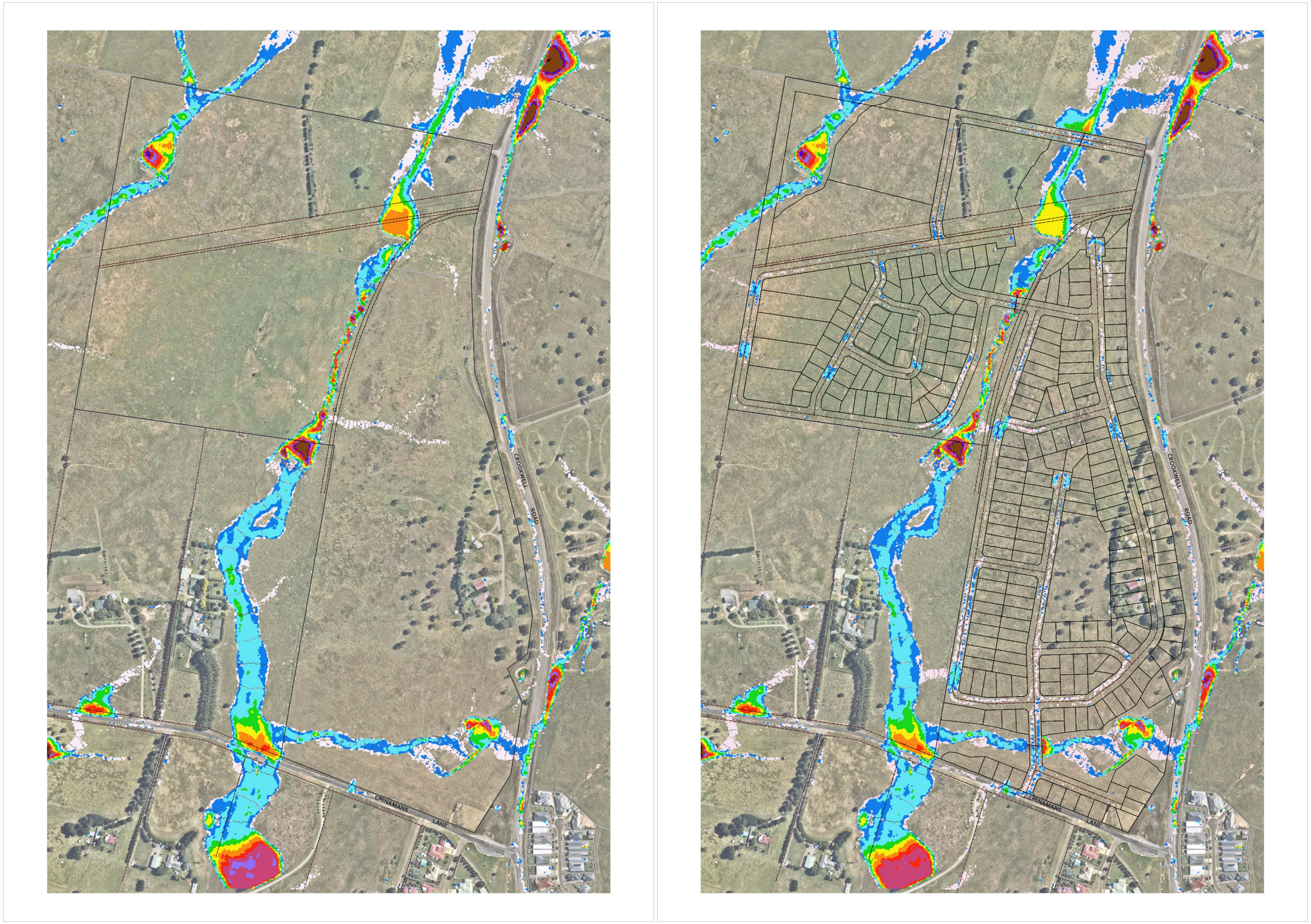

LAND REZONING
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10% AEP
PRE-DEVELOPMENT & POST DEVELOPMENT OVERLAND FLOW WATER DEPTHS & LEVELS

FIGURE: 11

Site boundary

Cadastral boundary

Water Depths (m)

0.025 – 0.050
0.050 – 0.100
0.100 – 0.200
0.200 – 0.300
0.300 – 0.400
0.400 – 0.500
0.500 – 0.600
0.600 – 0.700
0.700 – 0.800
0.800 – 0.900
0.900 – 1.000
1.000 – 1.500
> 1.500

Major water level – 1.0m

Minor water level - 0.5m

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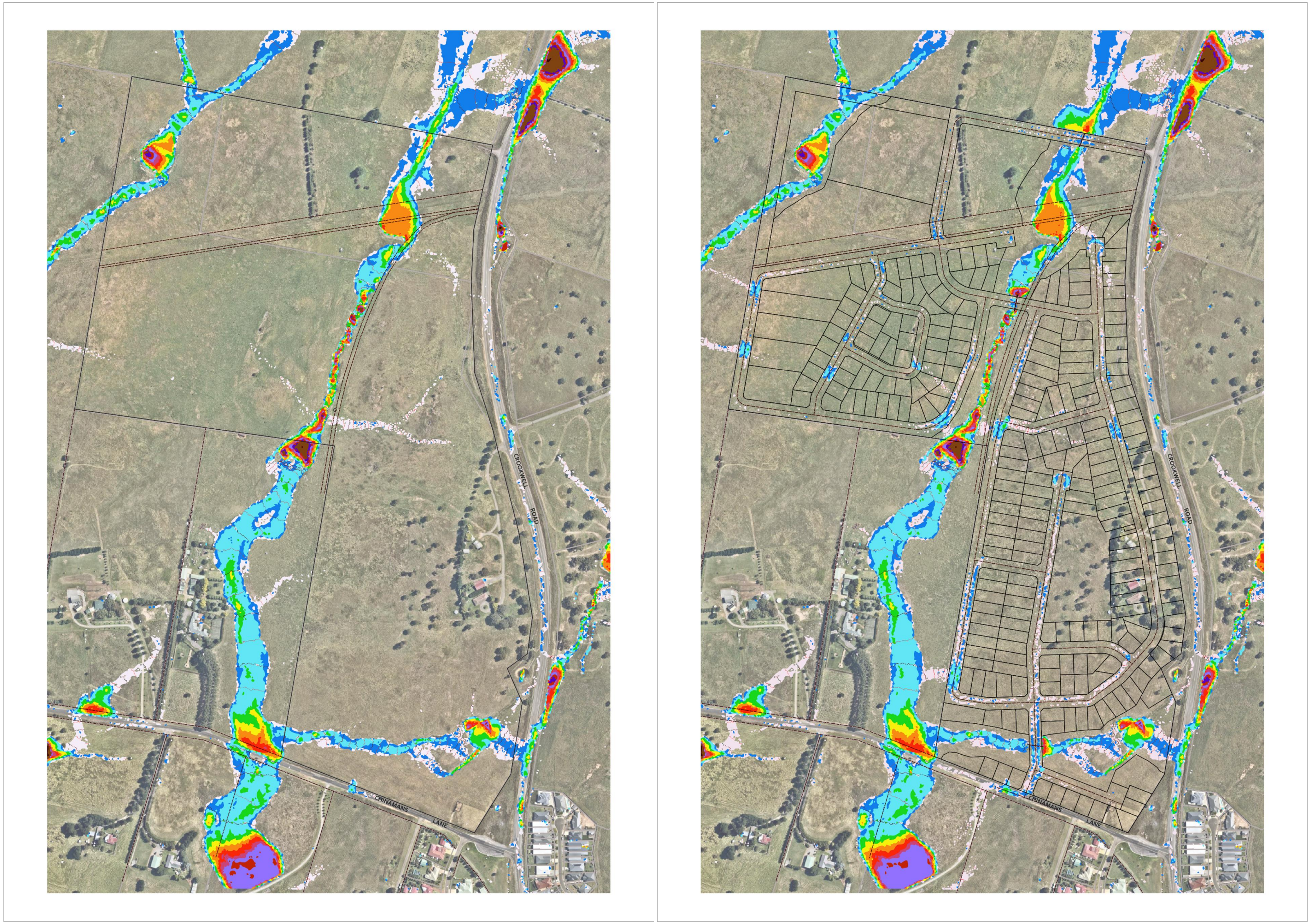

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5% AEP
PRE-DEVELOPMENT & POST DEVELOPMENT OVERLAND FLOW WATER DEPTHS & LEVELS

FIGURE: 12

Site boundary

Cadastral boundary

Water Depths (m)

0.025 – 0.050
0.050 – 0.100
0.100 – 0.200
0.200 – 0.300
0.300 – 0.400
0.400 – 0.500
0.500 – 0.600
0.600 – 0.700
0.700 – 0.800
0.800 – 0.900
0.900 – 1.000
1.000 – 1.500
> 1.500

Major water level – 1.0m

Minor water level - 0.5m

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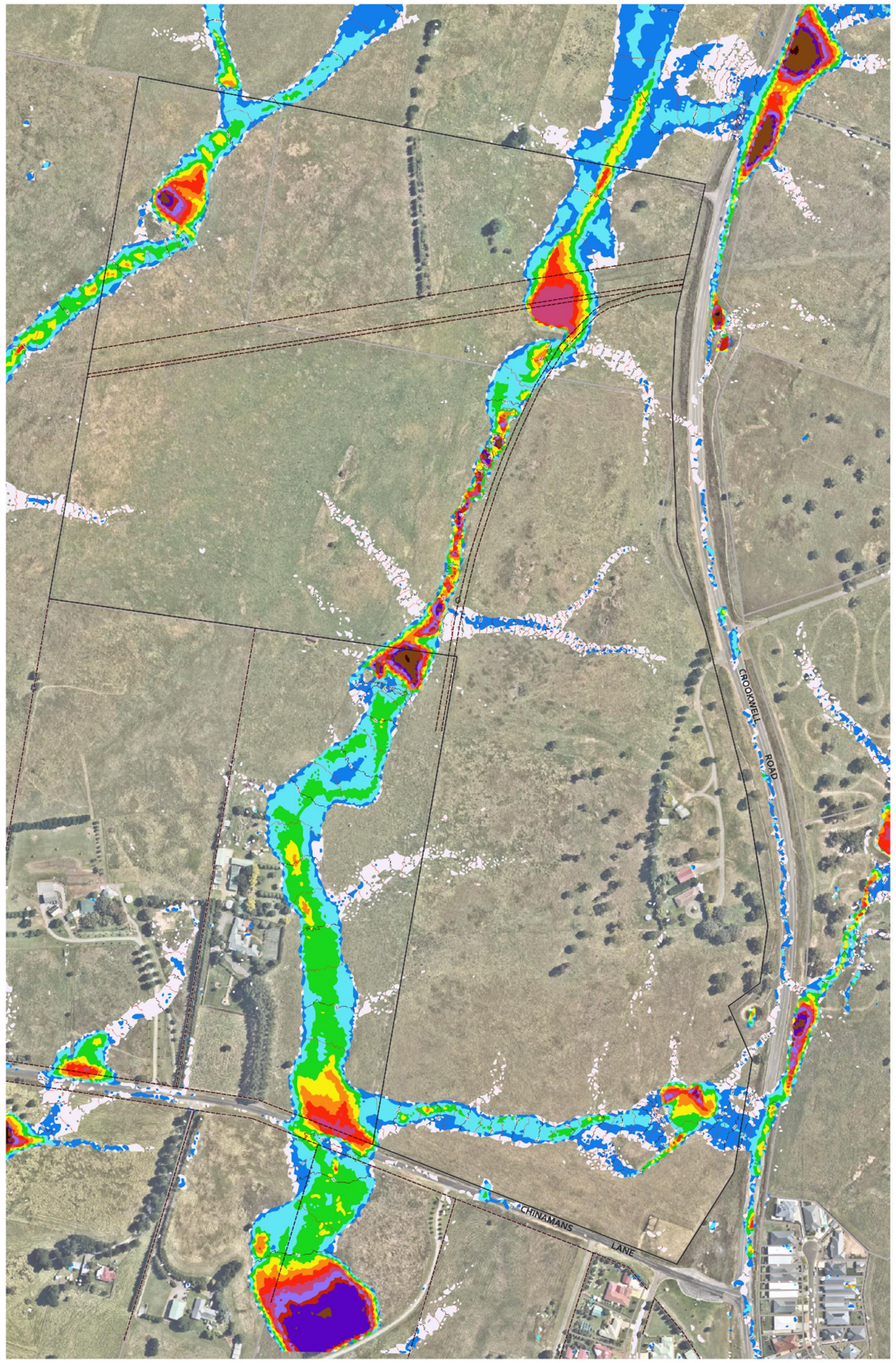

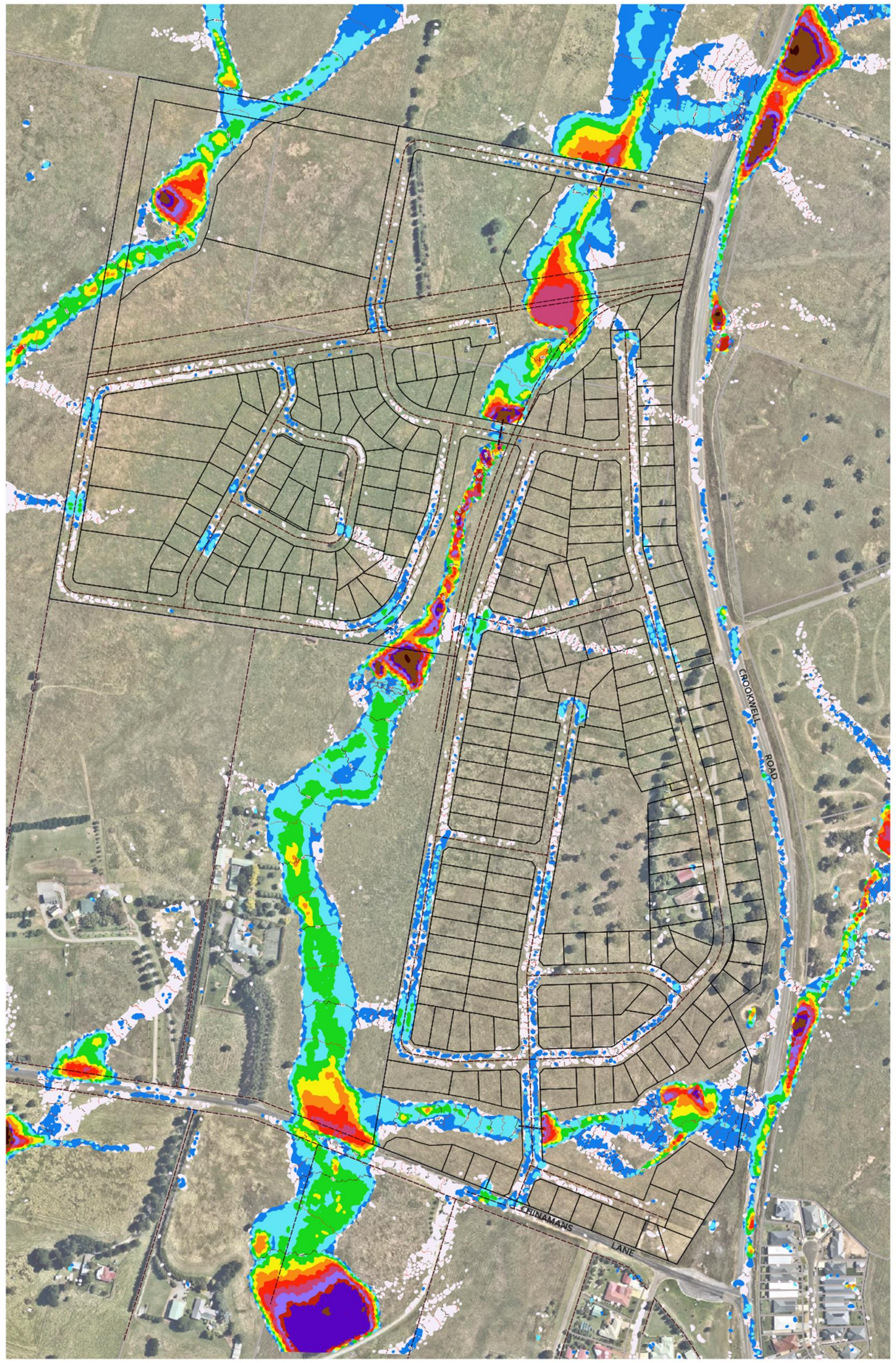

LAND REZONING
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1% AEP
PRE-DEVELOPMENT & POST DEVELOPMENT OVERLAND FLOW WATER DEPTHS & LEVELS

FIGURE: 13

Site boundary

Cadastral boundary

Water Depths (m)

0.025 – 0.050
0.050 – 0.100
0.100 – 0.200
0.200 – 0.300
0.300 – 0.400
0.400 – 0.500
0.500 – 0.600
0.600 – 0.700
0.700 – 0.800
0.800 – 0.900
0.900 – 1.000
1.000 – 1.500
> 1.500

Major water level – 1.0m

Minor water level - 0.5m

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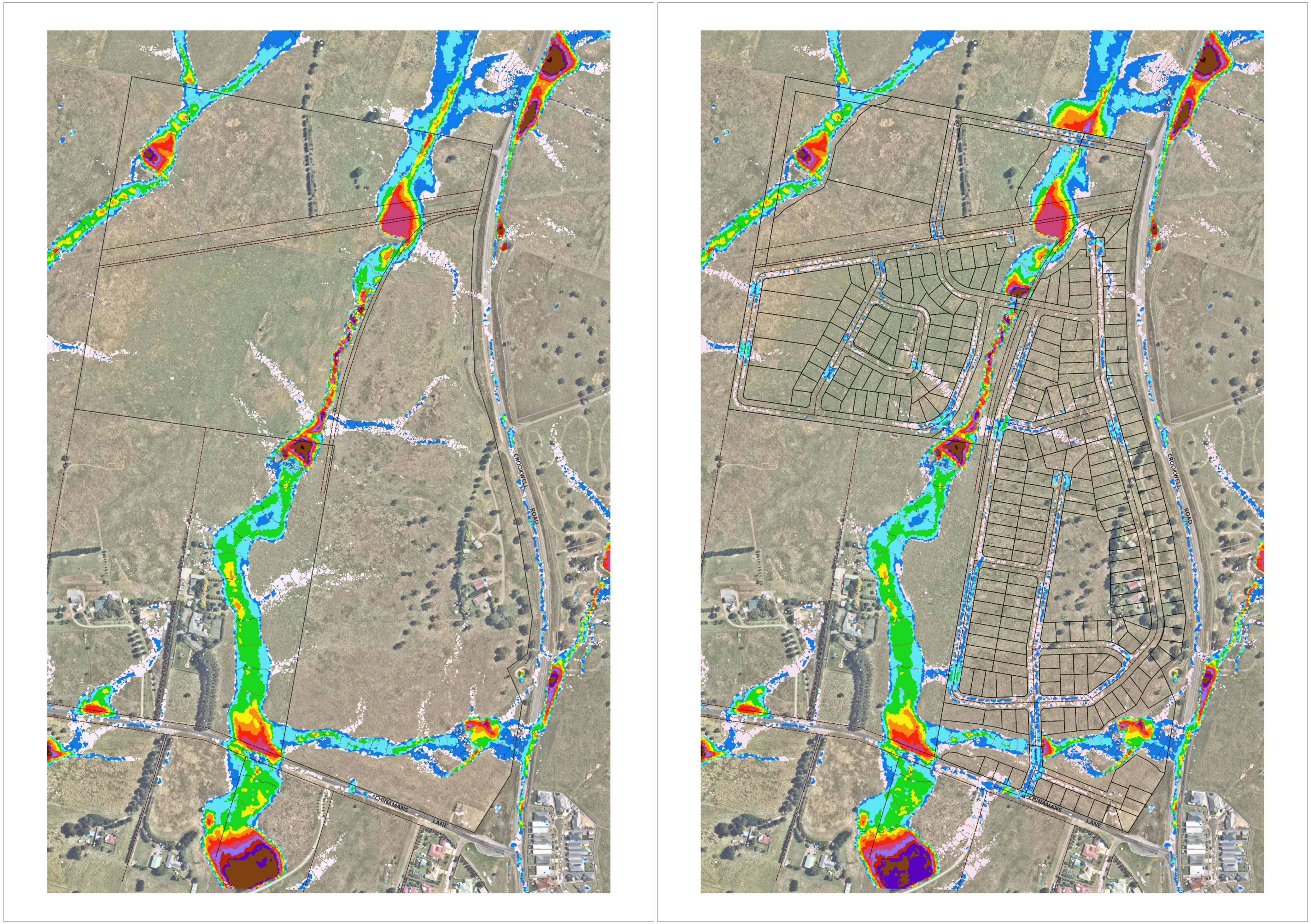

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0.5% AEP
PRE-DEVELOPMENT & POST DEVELOPMENT OVERLAND FLOW WATER DEPTHS & LEVELS

FIGURE: 14

Site boundary

Cadastral boundary

Water Depths (m)

0.025 – 0.050
0.050 – 0.100
0.100 – 0.200
0.200 – 0.300
0.300 – 0.400
0.400 – 0.500
0.500 – 0.600
0.600 – 0.700
0.700 – 0.800
0.800 – 0.900
0.900 – 1.000
1.000 – 1.500
> 1.500

Major water level – 1.0m

Minor water level - 0.5m

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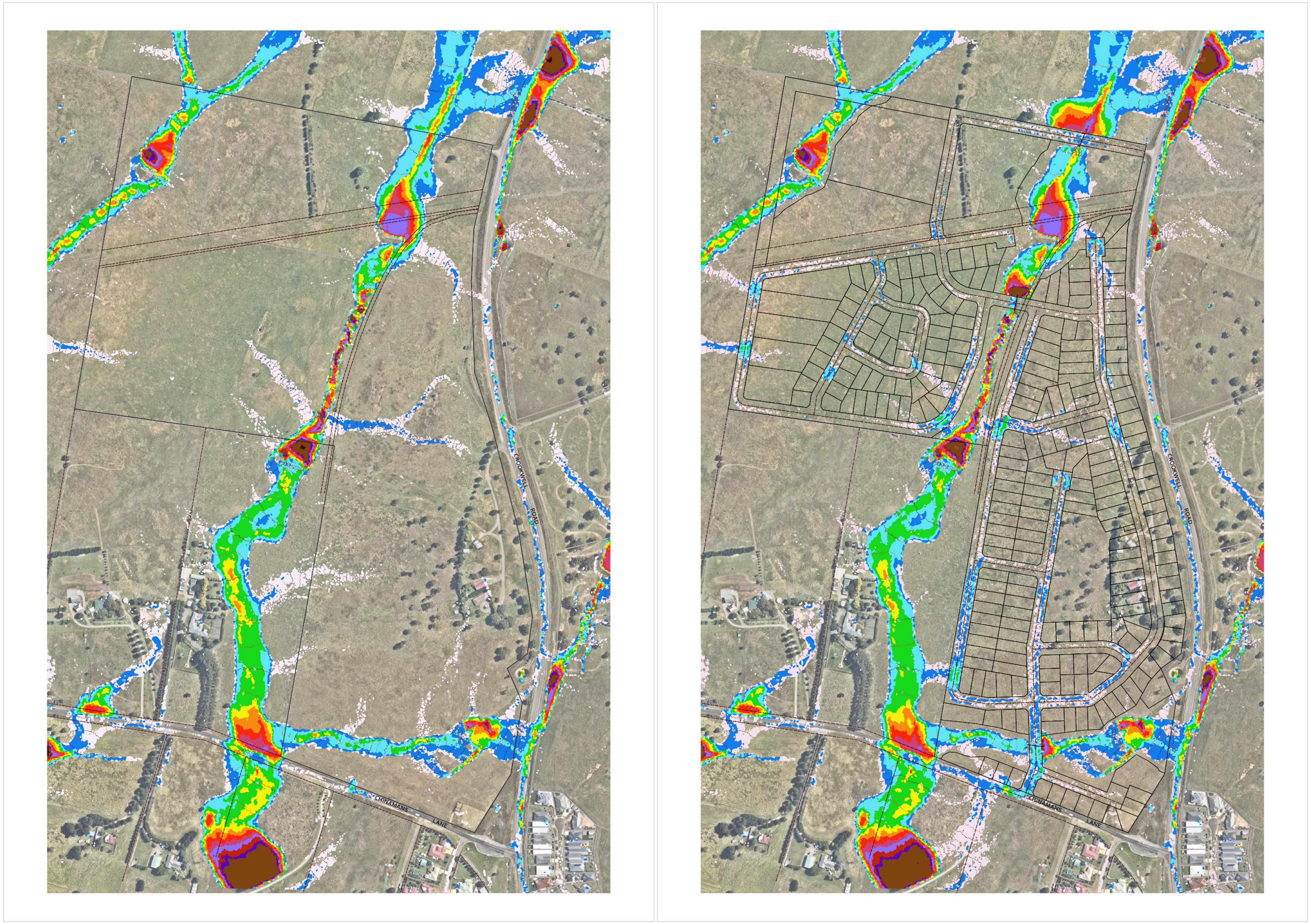

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0.2% AEP
PRE-DEVELOPMENT & POST DEVELOPMENT OVERLAND FLOW WATER DEPTHS & LEVELS

FIGURE: 15

Site boundary

Cadastral boundary

Water Depths (m)

0.025 – 0.050
0.050 – 0.100
0.100 – 0.200
0.200 – 0.300
0.300 – 0.400
0.400 – 0.500
0.500 – 0.600
0.600 – 0.700
0.700 – 0.800
0.800 – 0.900
0.900 – 1.000
1.000 – 1.500
> 1.500

Major water level – 1.0m

Minor water level - 0.5m

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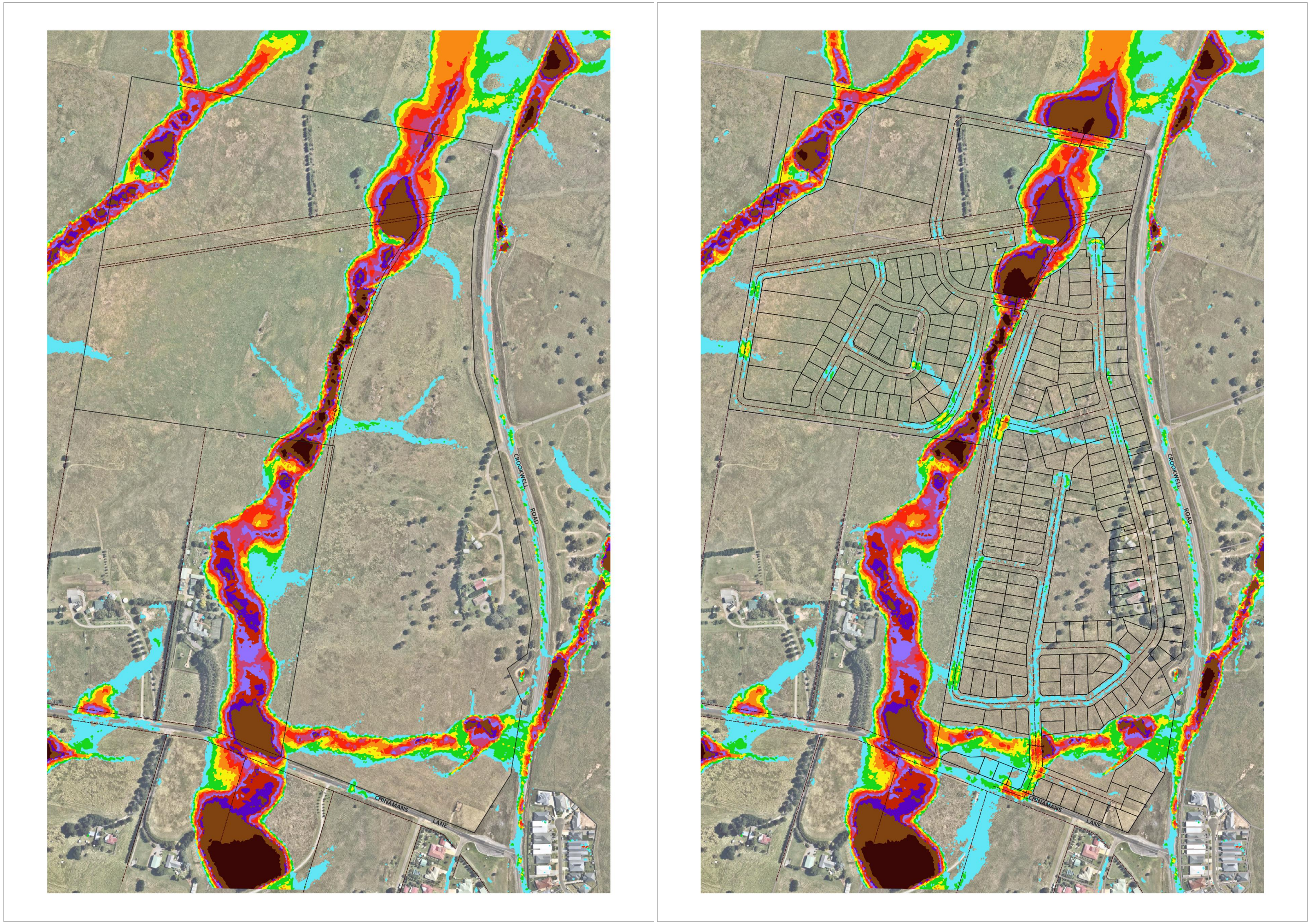

LAND REZONING
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PROBABLE MAXIMUM FLOOD – (DEPTHS >100MM) PRE-DEVELOPMENT & POST DEVELOPMENT OVERLAND FLOW WATER DEPTHS & LEVELS

FIGURE: 16

Site boundary

Cadastral boundary

Water Depths (m)

0.025 – 0.050
0.050 – 0.100
0.100 – 0.200
0.200 – 0.300
0.300 – 0.400
0.400 – 0.500
0.500 – 0.600
0.600 – 0.700
0.700 – 0.800
0.800 – 0.900
0.900 – 1.000
1.000 – 1.500
> 1.500

Major water level – 1.0m

Minor water level - 0.5m

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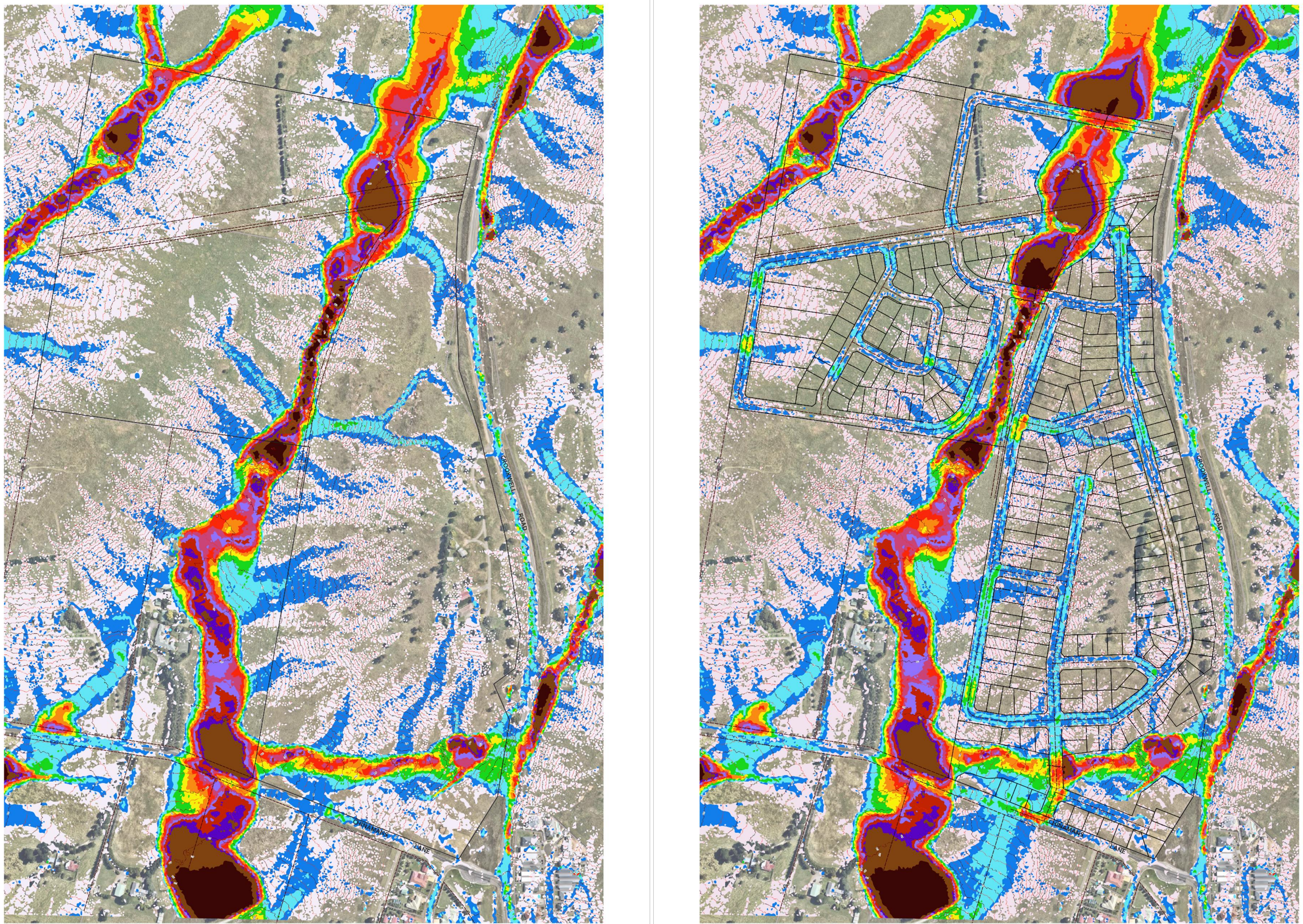

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PROBABLE MAXIMUM FLOOD – (DEPTHS >25MM) PRE-DEVELOPMENT & POST DEVELOPMENT OVERLAND FLOW WATER DEPTHS & LEVELS

FIGURE: 17

Site boundary

Cadastral boundary

Water Depths (m)

0.025 – 0.050
0.050 – 0.100
0.100 – 0.200
0.200 – 0.300
0.300 – 0.400
0.400 – 0.500
0.500 – 0.600
0.600 – 0.700
0.700 – 0.800
0.800 – 0.900
0.900 – 1.000
1.000 – 1.500
> 1.500

Major water level – 1.0m

Minor water level - 0.5m

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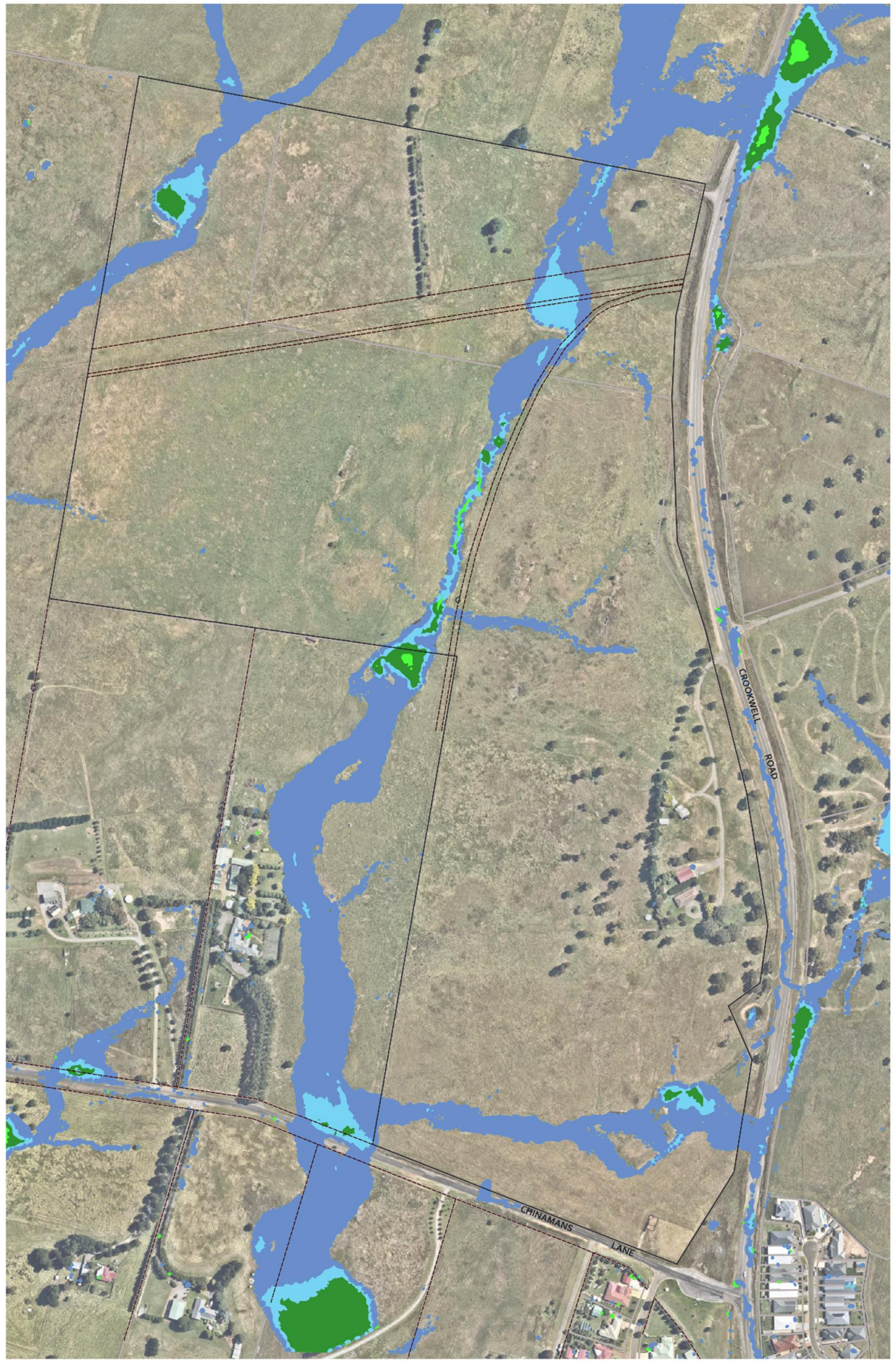

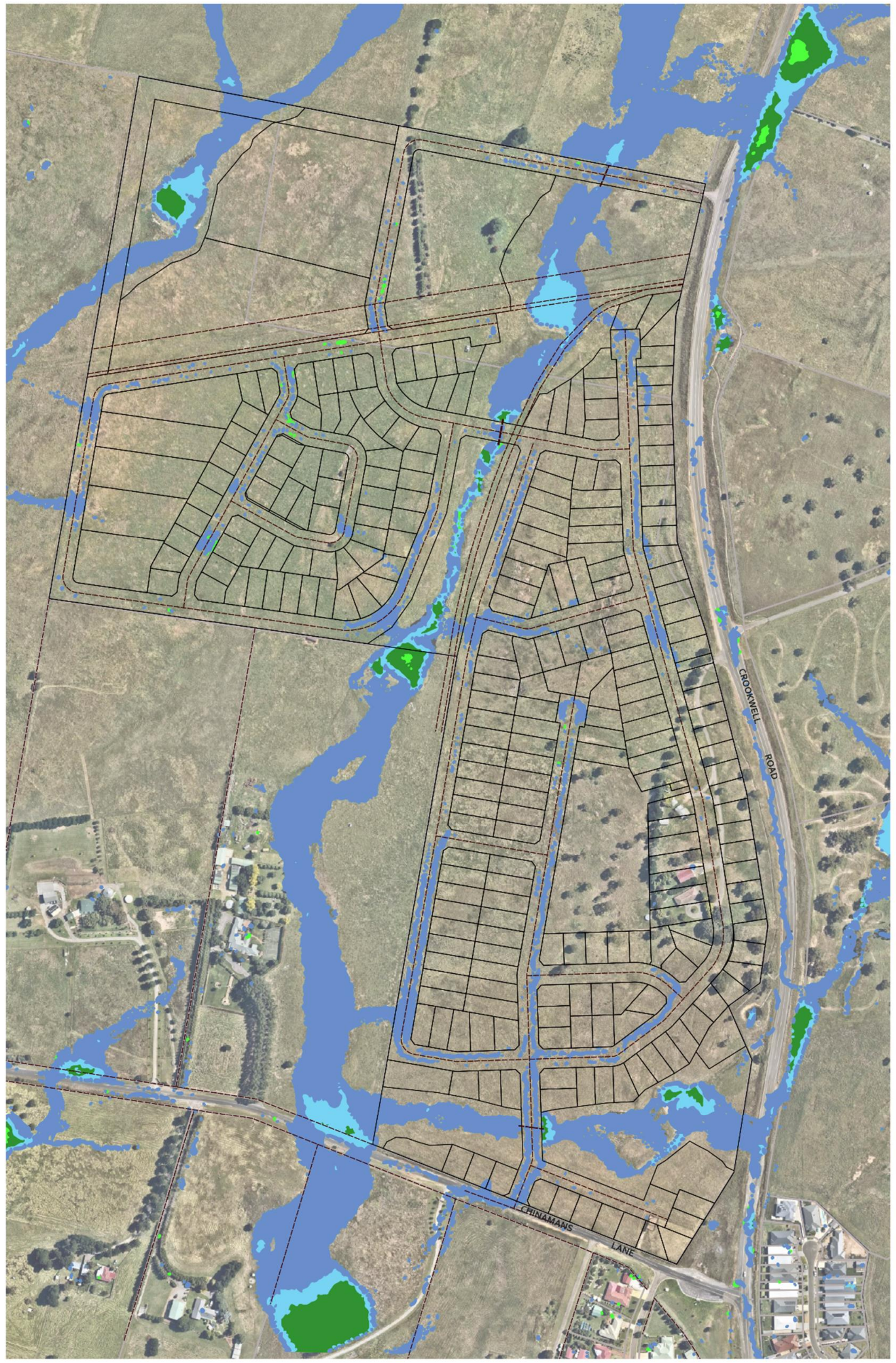

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10% AEP
PRE-DEVELOPMENT & POST DEVELOPMENT FLOOD HAZARD CATEGORY

FIGURE: 18

Site boundary

Cadastral boundary

Hazard Category

H1
(Generally safe for vehicles, people & buildings)

H2
(Unsafe for small vehicles)

H3
(Unsafe for vehicles, children & the elderly)

H4
(Unsafe for vehicles & people)

H5
(Unsafe for vehicles & people. All buildings subject to structural damage)

H6
(Unsafe for vehicles & people. All building types considered vulnerable to failure)

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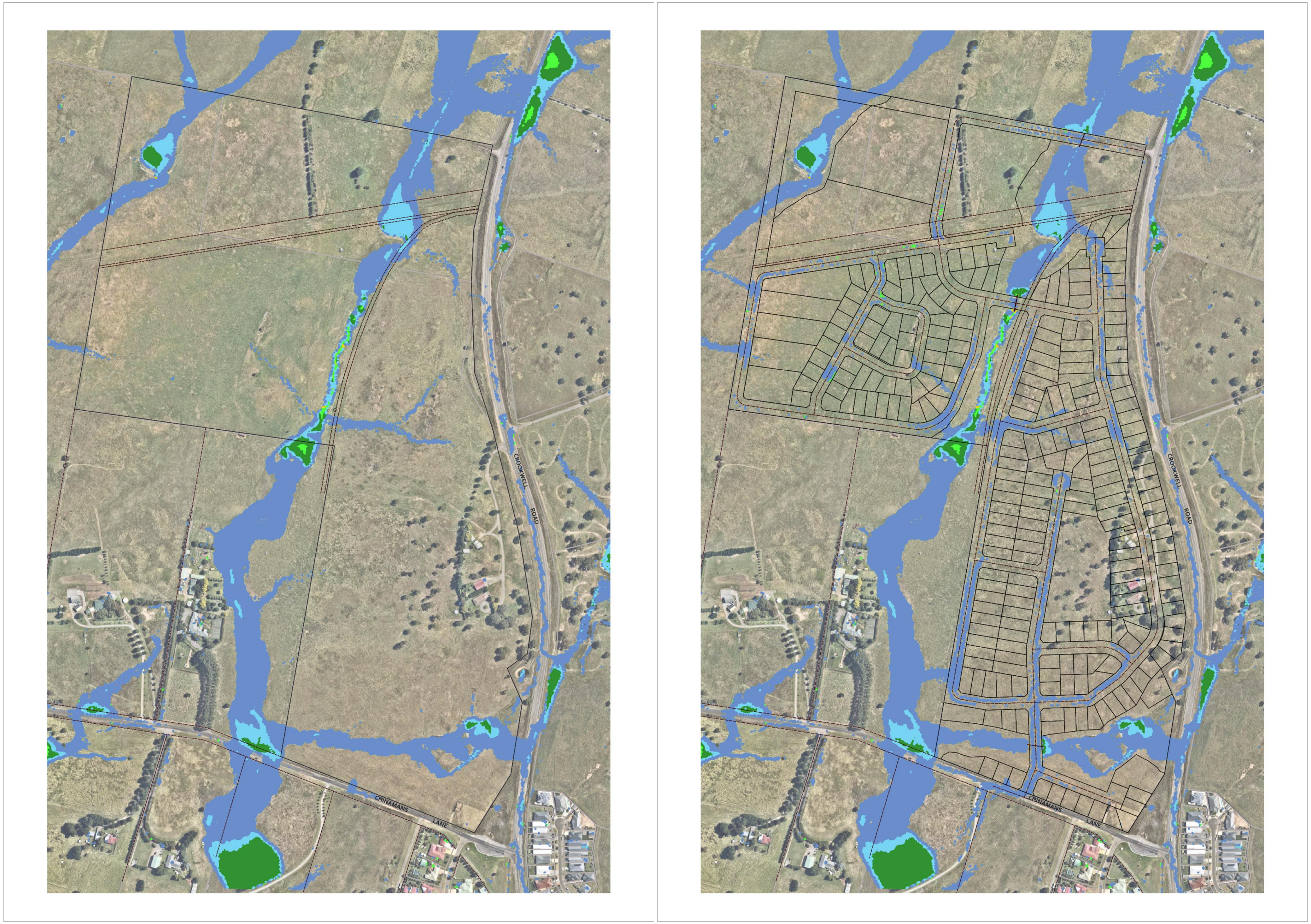

LAND REZONING
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5% AEP
PRE-DEVELOPMENT & POST DEVELOPMENT FLOOD HAZARD CATEGORY

FIGURE: 19

Site boundary

Cadastral boundary

Hazard Category

H1 (Generally safe for vehicles, people & buildings)

H2 (Unsafe for small vehicles)

H3 (Unsafe for vehicles, children & the elderly)

H4 (Unsafe for vehicles & people)

H5 (Unsafe for vehicles & people. All buildings subject to structural damage)

H6 (Unsafe for vehicles & people. All building types considered vulnerable to failure)

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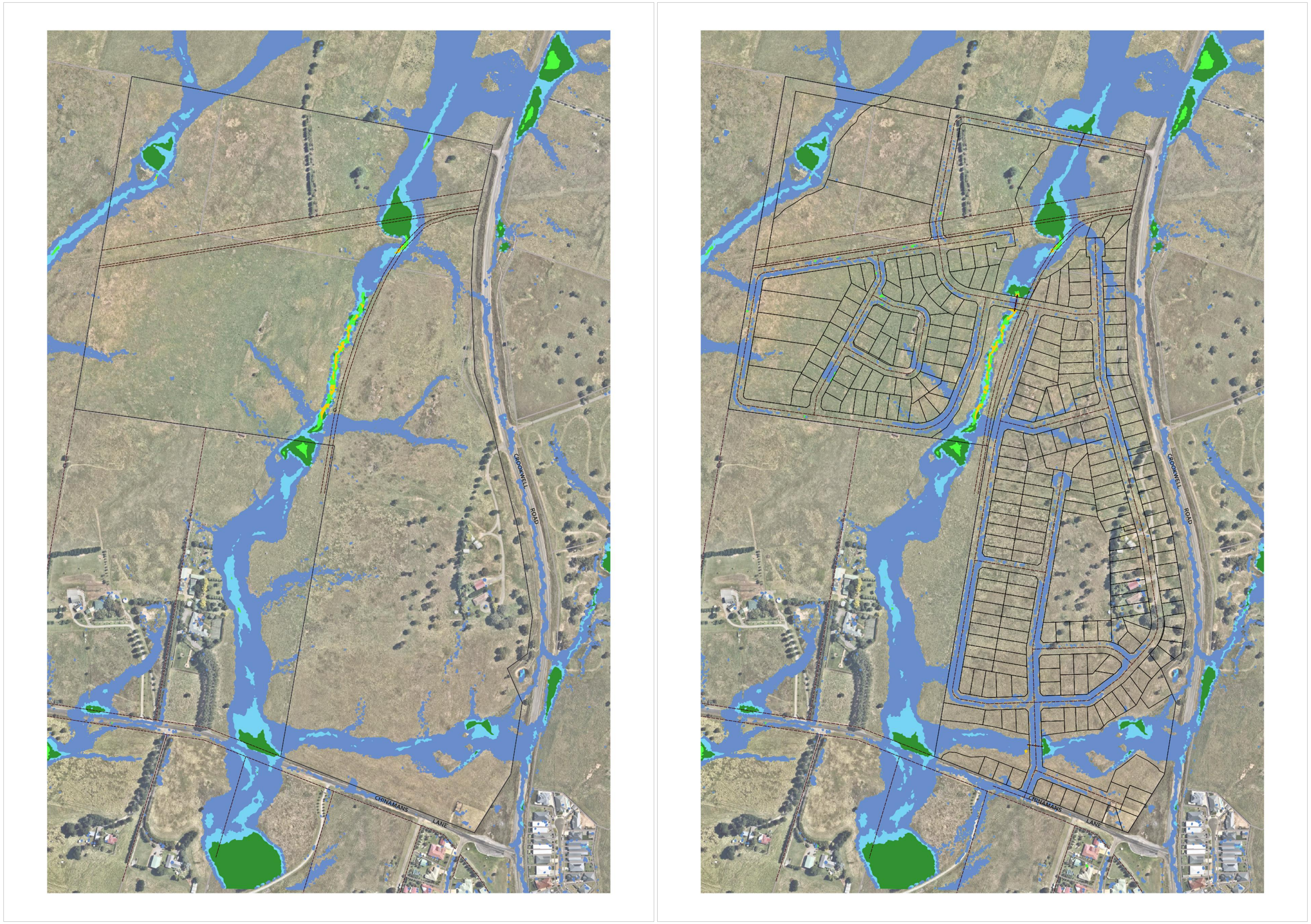

LAND REZONING
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1% AEP
PRE-DEVELOPMENT & POST DEVELOPMENT FLOOD HAZARD CATEGORY

FIGURE: 20

Site boundary

Cadastral boundary

Hazard Category

H1
(Generally safe for vehicles, people & buildings)

H2
(Unsafe for small vehicles)

H3
(Unsafe for vehicles, children & the elderly)

H4
(Unsafe for vehicles & people)

H5
(Unsafe for vehicles & people. All buildings subject to structural damage)

H6
(Unsafe for vehicles & people. All building types considered vulnerable to failure)

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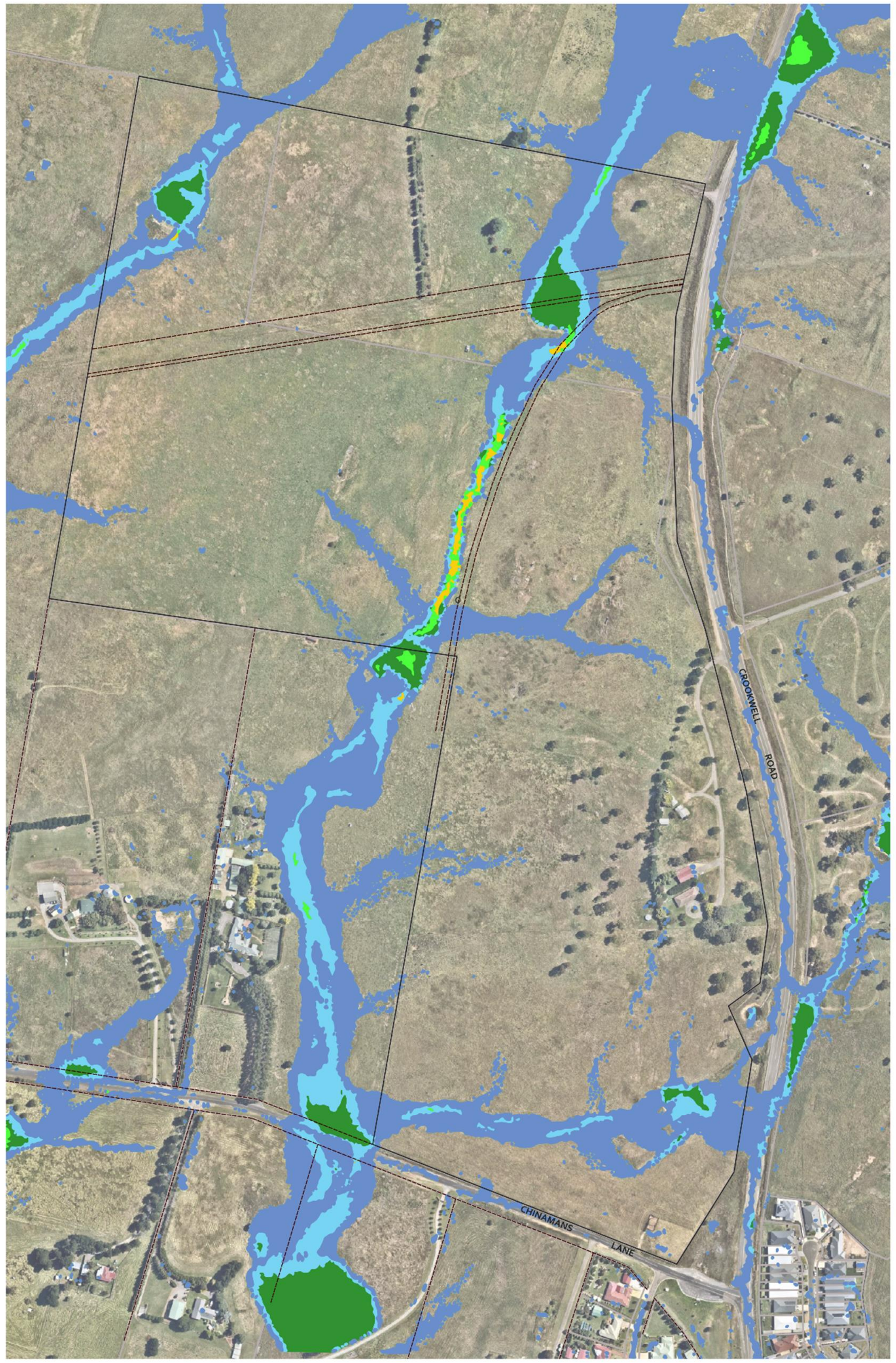

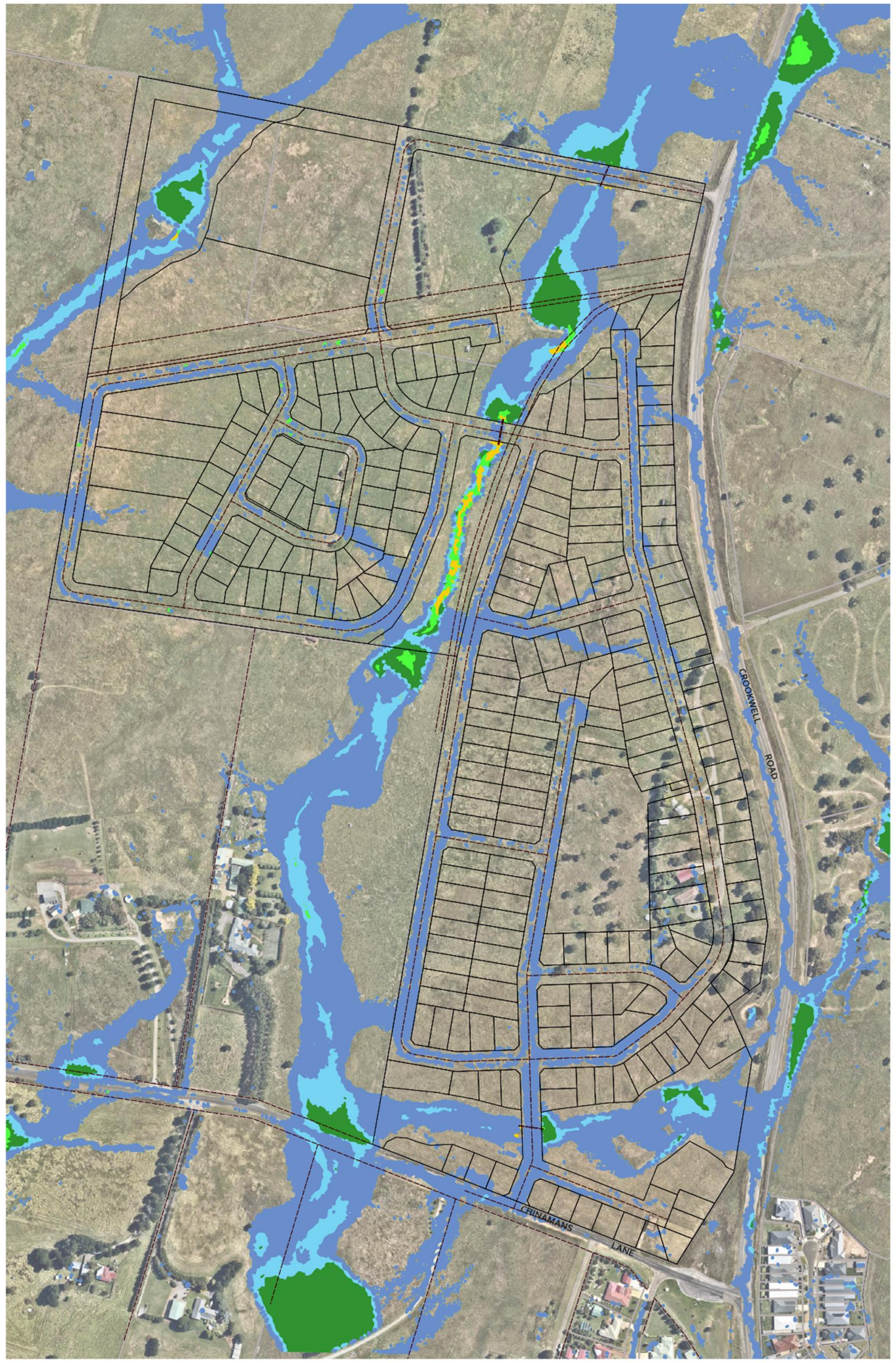

LAND REZONING
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0.5% AEP
PRE-DEVELOPMENT & POST DEVELOPMENT FLOOD HAZARD CATEGORY

FIGURE: 21

Site boundary

Cadastral boundary

Hazard Category

H1
(Generally safe for vehicles, people & buildings)

H2
(Unsafe for small vehicles)

H3
(Unsafe for vehicles, children & the elderly)

H4
(Unsafe for vehicles & people)

H5
(Unsafe for vehicles & people. All buildings subject to structural damage)

H6
(Unsafe for vehicles & people. All building types considered vulnerable to failure)

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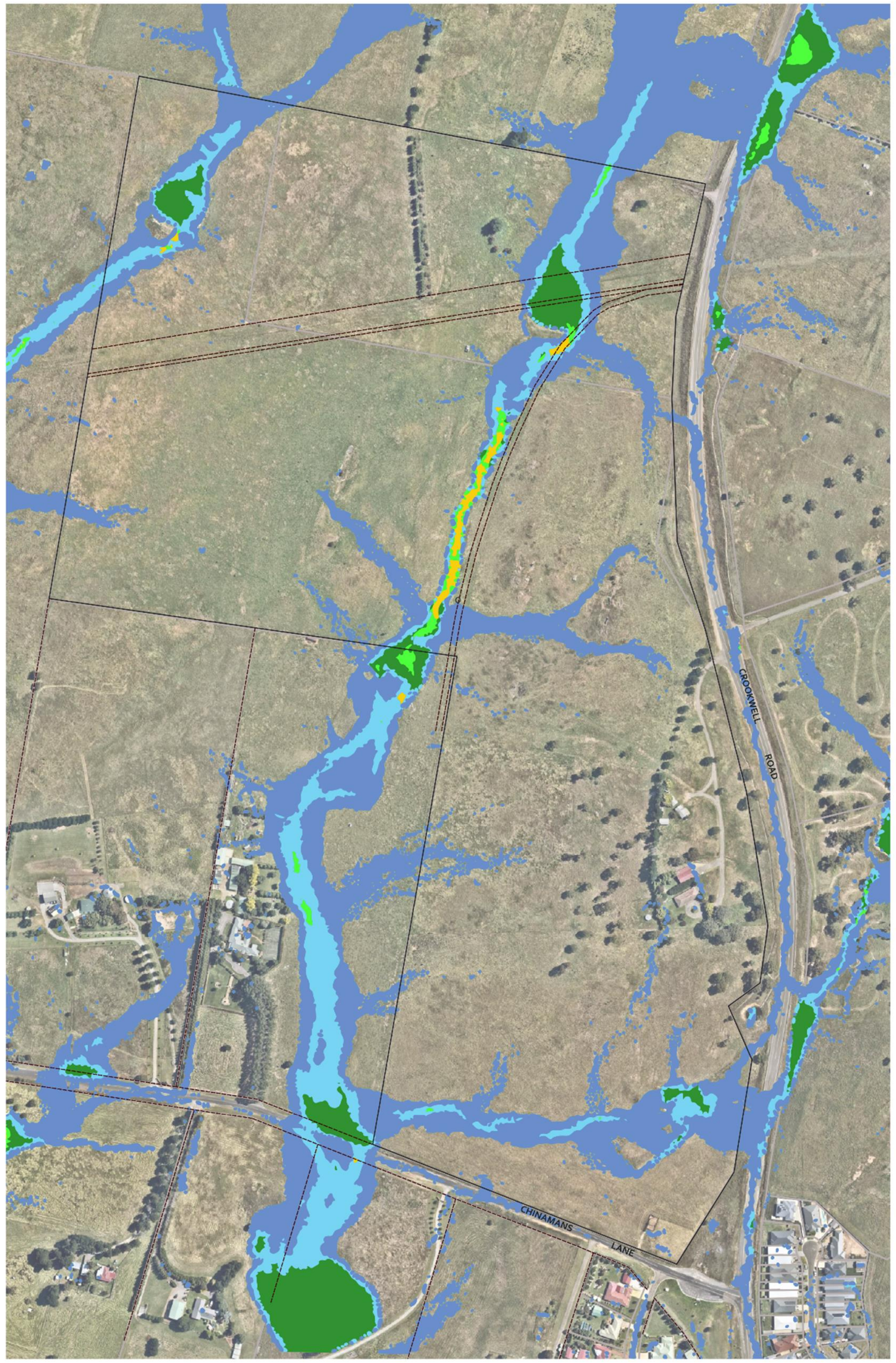

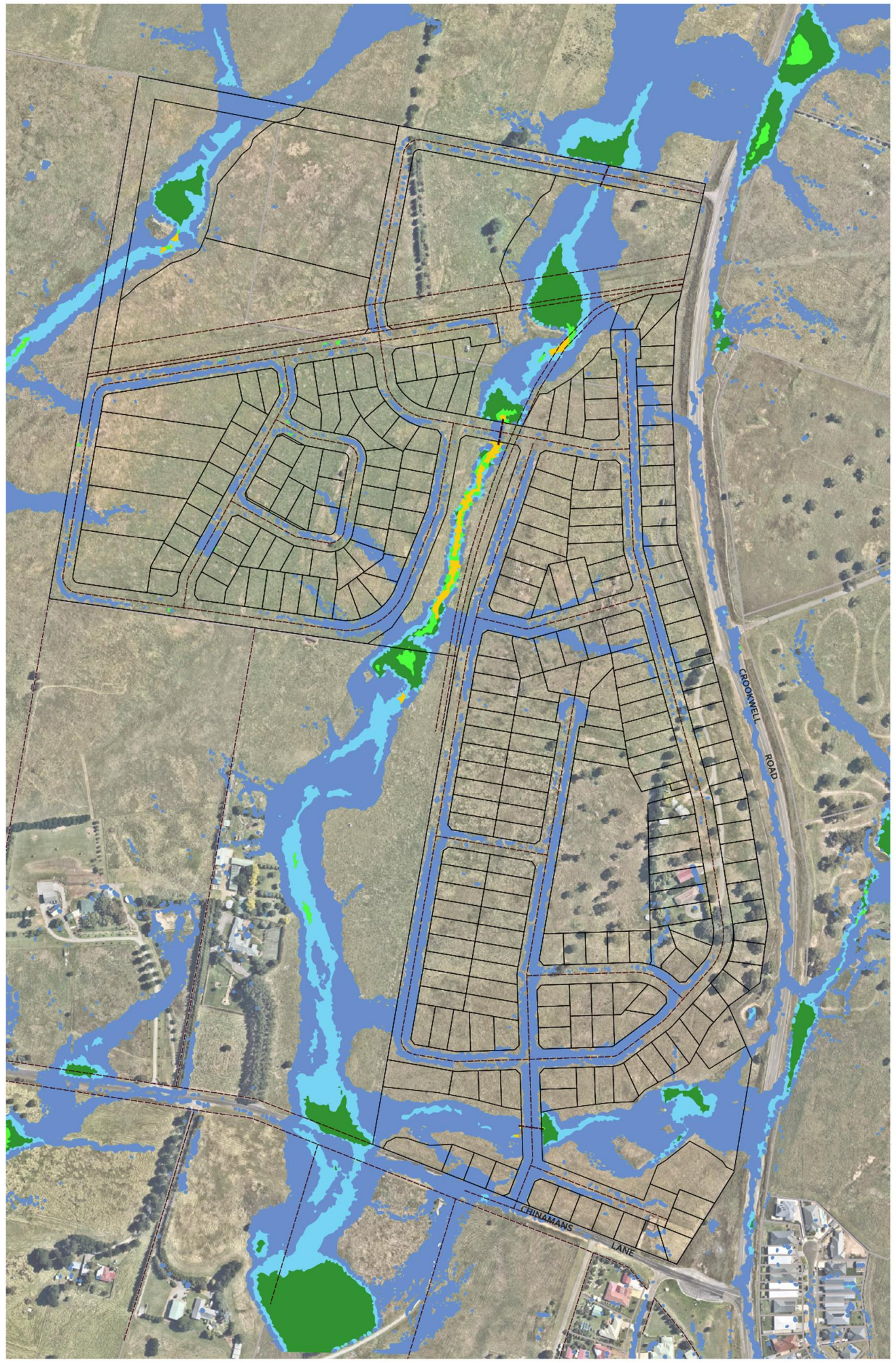

LAND REZONING
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0.2% AEP
PRE-DEVELOPMENT & POST DEVELOPMENT FLOOD HAZARD CATEGORY

FIGURE: 22

Site boundary

Cadastral boundary

Hazard Category

H1
(Generally safe for vehicles, people & buildings)

H2
(Unsafe for small vehicles)

H3
(Unsafe for vehicles, children & the elderly)

H4
(Unsafe for vehicles & people)

H5
(Unsafe for vehicles & people. All buildings subject to structural damage)

H6
(Unsafe for vehicles & people. All building types considered vulnerable to failure)

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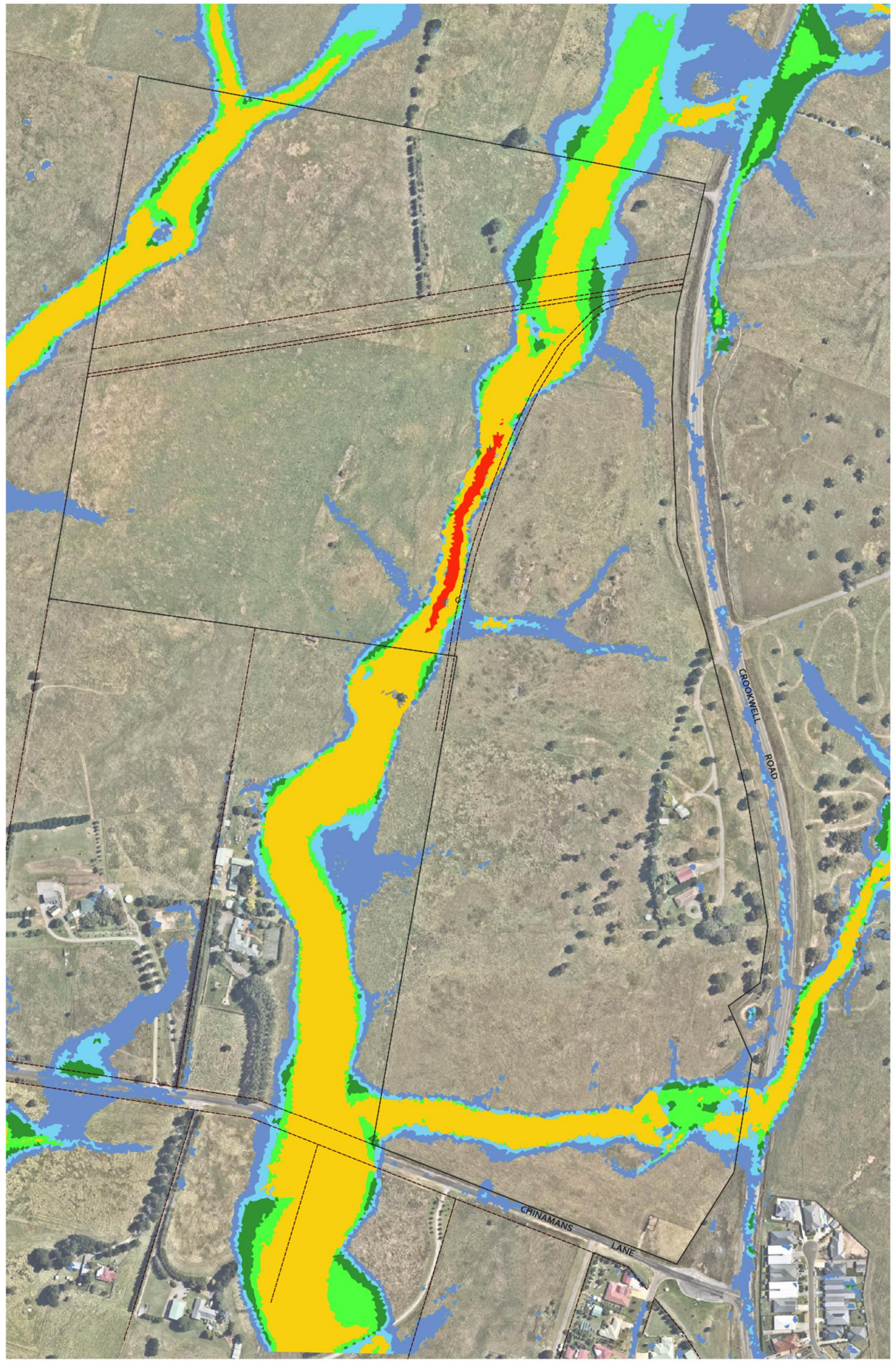

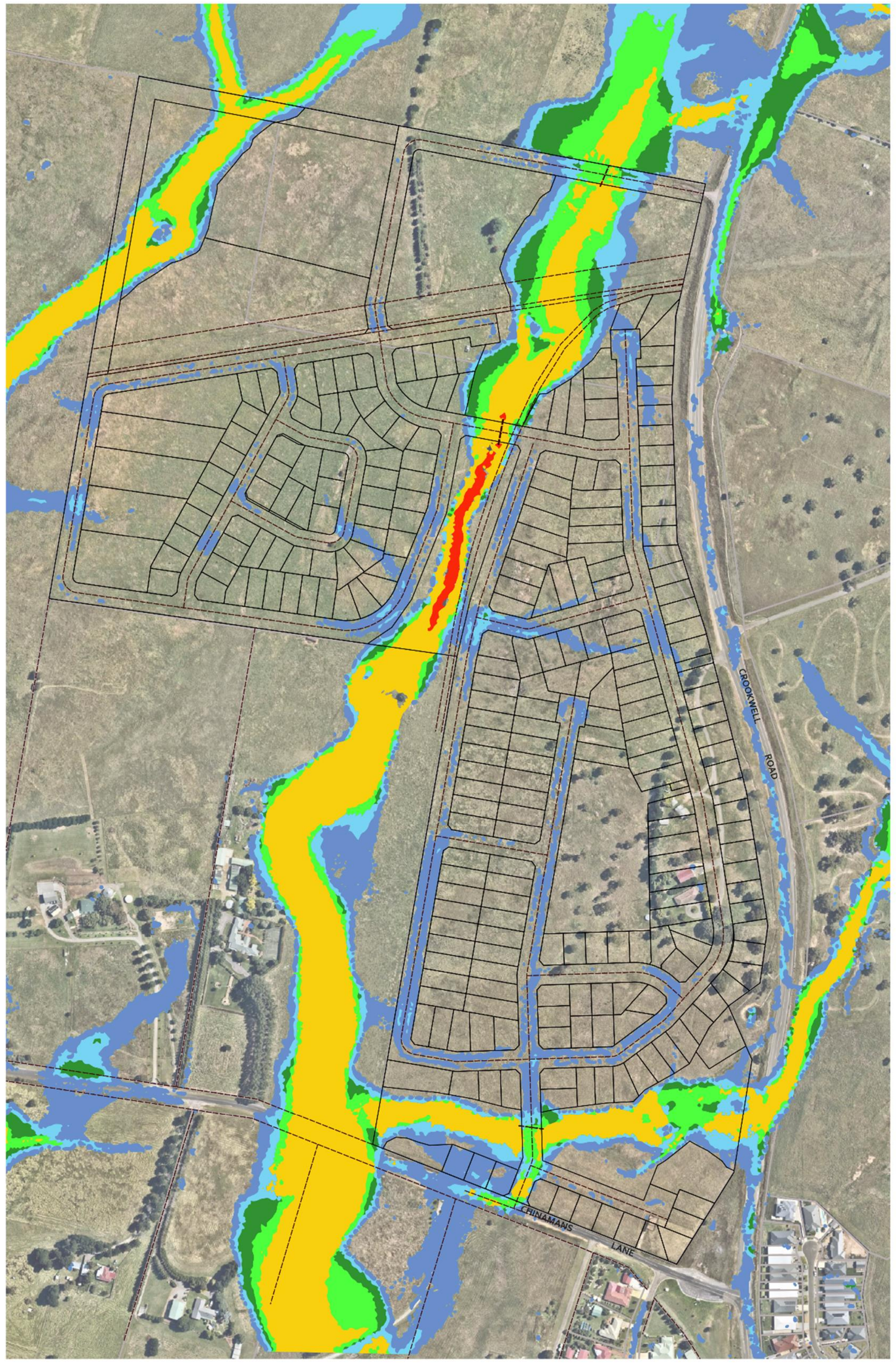

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GOULBURN. NSW. 2580

PROBABLE MAXIMUM FLOOD - (DEPTHS >100MM) PRE-DEVELOPMENT & POST DEVELOPMENT FLOOD HAZARD CATEGORY

FIGURE: 23

Site boundary

Cadastral boundary

Hazard Category

H1
(Generally safe for vehicles, people & buildings)

H2
(Unsafe for small vehicles)

H3
(Unsafe for vehicles, children & the elderly)

H4
(Unsafe for vehicles & people)

H5
(Unsafe for vehicles & people. All buildings subject to structural damage)

H6
(Unsafe for vehicles & people. All building types considered vulnerable to failure)

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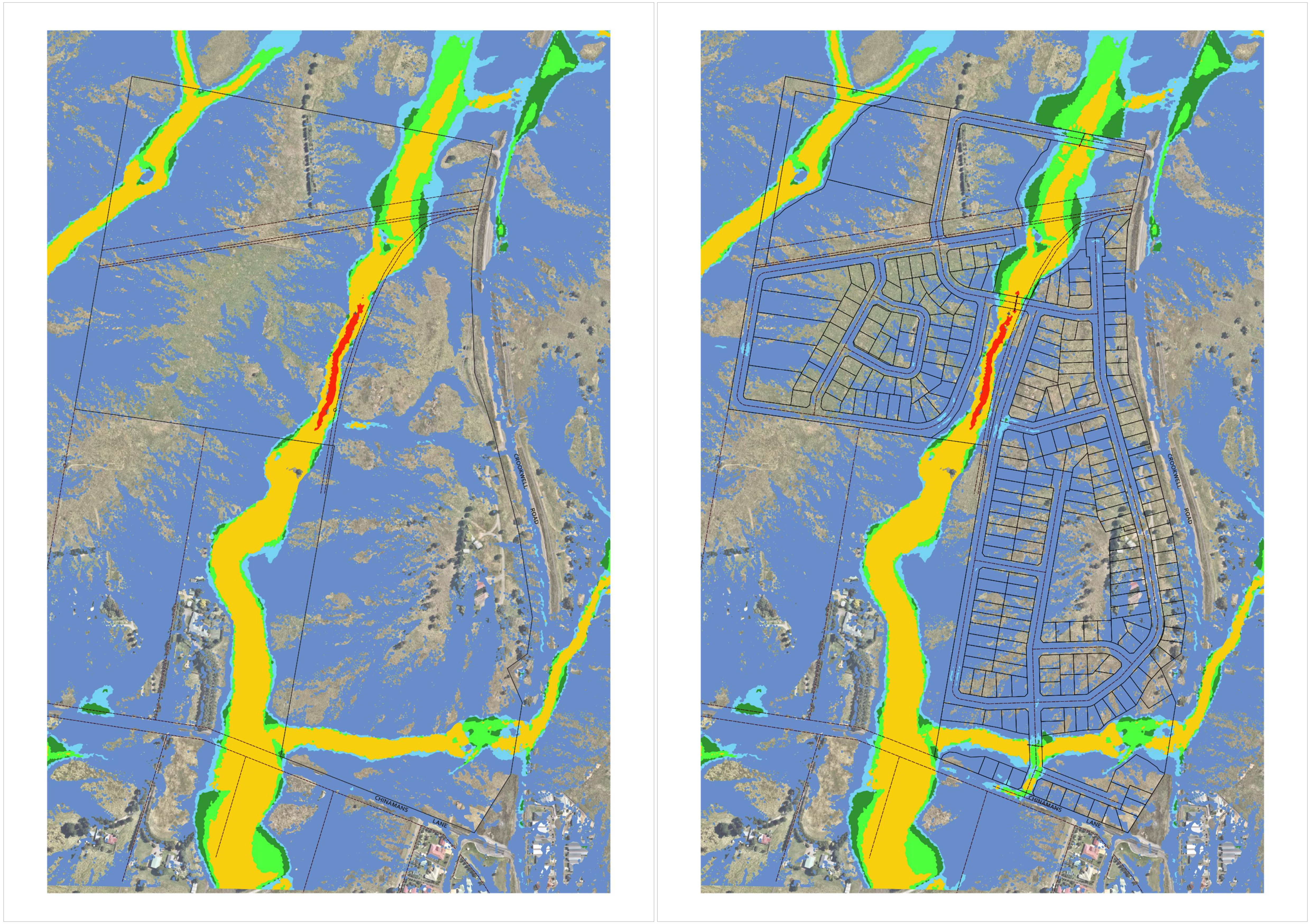

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PROBABLE MAXIMUM FLOOD – (DEPTHS >25MM) PRE-DEVELOPMENT & POST DEVELOPMENT FLOOD HAZARD CATEGORY

FIGURE: 24

Site boundary

Cadastral boundary

Hazard Category

H1
(Generally safe for vehicles, people & buildings)

H2
(Unsafe for small vehicles)

H3
(Unsafe for vehicles, children & the elderly)

H4
(Unsafe for vehicles & people)

H5
(Unsafe for vehicles & people. All buildings subject to structural damage)

H6
(Unsafe for vehicles & people. All building types considered vulnerable to failure)

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APPENDIX A

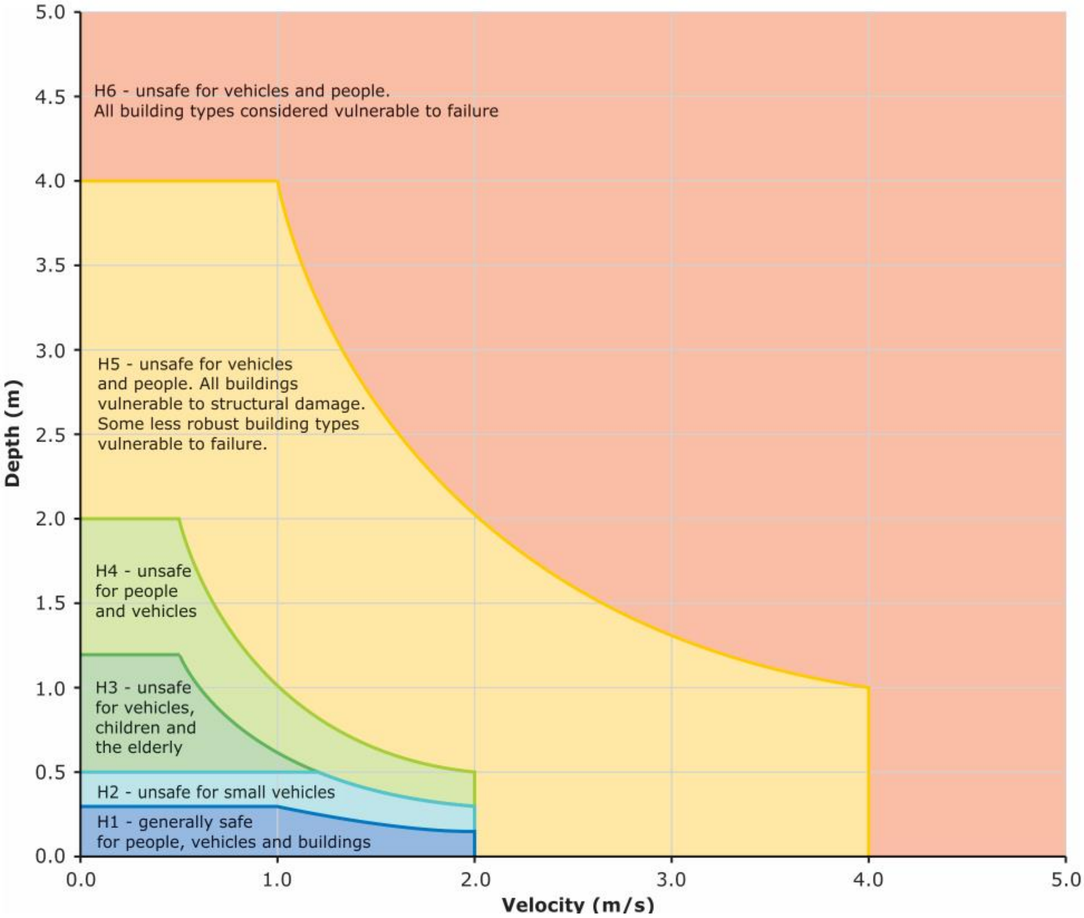

Table 6.7.3. Combined Hazard Curves - Vulnerability Thresholds (Smith et al., 2014)

Hazard Vulnerability Classification	Description
H1	Generally safe for vehicles, people and buildings.
H2	Unsafe for small vehicles.
H3	Unsafe for vehicles. children and the elderly.
H4	Unsafe for vehicles and people.
H5	Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure.

Table 6.7.4. Combined Hazard Curves - Vulnerability Thresholds Classification Limits (Smith et al., 2014)

Hazard Vulnerability Classification	Classification Limit (D and V in combination)	Limiting Still Water Depth (D)	Limiting Velocity (V)
H1	D*V ≤ 0.3	0.3	2.0
H2	D*V ≤ 0.6	0.5	2.0
H3	D*V ≤ 0.6	1.2	2.0
H4	D*V ≤ 1.0	2.0	2.0
H5	D*V ≤ 4.0	4.0	4.0
H6	D*V > 4.0	-	-

Figure 25. Hazard risk curves and classification tables from Chapter 7, Book 6 of AR&R2019.

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