SARFIIP – Katarapko Floodplain Hydraulic Modelling – Natural, Current and Basin Plan Flow Scenarios

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Government of South Australia
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SARFIIP – Katarapko Floodplain Hydraulic Modelling

Natural, Current and Basin Plan Flow Scenarios

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Summary

The following report presents the hydraulic modelling work undertaken to understand the hydrological regime (both inundated area and hydraulic variability) of Katarapko Floodplain for a range of conditions:

- natural, without structures on the floodplain or development influences on flow in the River Murray
- current, the hydrological regime expected based on pre-Basin Plan (2009) conditions
- future, with a range of Basin Plan water recovery scenarios considered (2400, 2750 and 3200GL/year).

The hydraulic modelling results indicate that:

- The frequency of inundation of the floodplain for a given flow is significantly reduced under baseline (existing) conditions compared to without development conditions.
- Without development conditions show the majority of velocities are contained in the fast category with relatively even distributions of velocities throughout the other categories (between very slow to moderate-fast class).
- For all Basin Plan flow regimes, events corresponding to a flow of 40 000 ML/d have the largest proportion of the reaches in the very slow velocity class. For events with a flow of 50 000 ML/d or greater the velocity distribution is not dissimilar to natural conditions (albeit with a slightly small proportion of the reach in the fast velocity class).
- Comparison of inundation extents, frequencies and velocity distributions within the floodplain between without development floodplain conditions and baseline conditions indicates that that additional flows delivered to the Murray–Darling Basin through the Basin Plan alone cannot be expected to achieve full ecological benefits (as indicated by inundation extent and velocity distributions) without additional measures being implemented, such as via man-made embankment removals and infrastructure solutions.

1 Background

Katarapko Floodplain is an anabranch of the River Murray located in the vicinity of Loxton, South Australia. Its main inlets are located upstream of Lock 4, with return flows re-entering the River Murray on the downstream side of Lock 4 through Katarapko Creek. A number of structures and banks have been constructed over the years internal and external to the floodplain, which have modified the natural hydraulics of the system and resulted in a general degradation of the ecological condition of the floodplain and associated wetlands. Figure 1.1 shows the main creeks and structures associated with the floodplain.

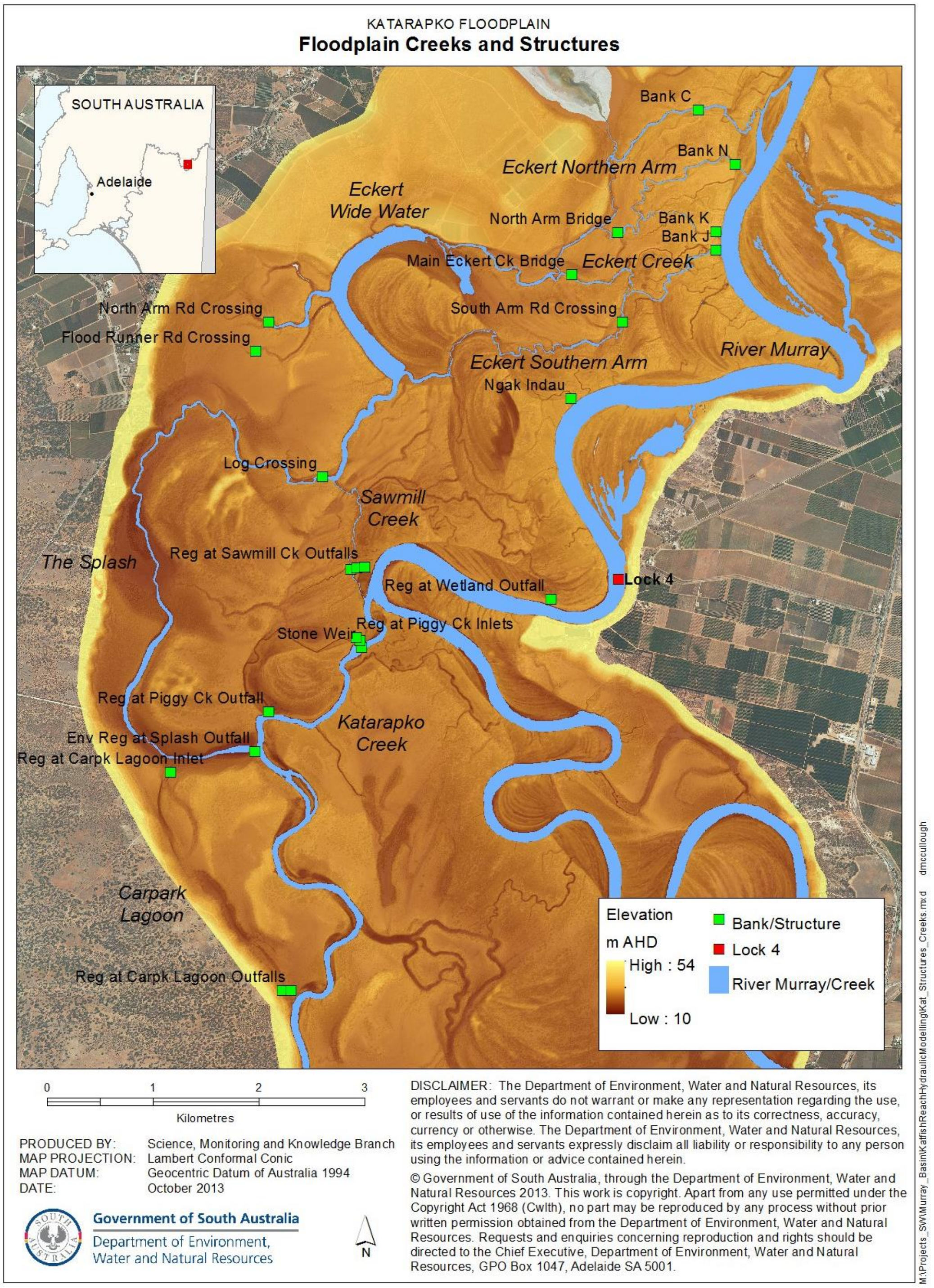

Figure 1.1 Katarapko Floodplain creeks and structures.

Owing to the general degradation of the floodplain condition in comparison to that under natural conditions, the South Australian Riverland Floodplains Integrated Infrastructure Program (SARFIIP) has been initiated to improve the flexibility of managing the system via new infrastructure and operational solutions. The following report presents the hydraulic modelling work undertaken to understand the hydrological regime (both inundated area and hydraulic variability) of the Katarapko Floodplain for a range of conditions:

- natural, without structures on the floodplain or development influences on flow in the River Murray
- current, the hydrological regime expected based on pre-Basin Plan (2009) conditions
- future, with a range of Basin Plan water recovery scenarios considered.

2 Hydraulic Model

The numerical hydrodynamic models were originally produced and calibrated by Water Technology using the MIKE FLOOD modelling platform that combines the dynamic coupling of the one-dimensional MIKE 11 river model and MIKE 21 two dimensional model system. Details of the original MIKE FLOOD model configuration are presented in Water Technology (2010). The MIKE FLOOD model was further refined and re-calibrated in 2014 (McCullough, 2014) and again in 2015 (McCullough, 2015) within the SMK branch of DEWNR to address the updates implemented by the DEWNR.

To represent the current conditions of the Katarapko Floodplain, the following branches are specified in the model as 1D representations (refer to Figure 1.1 for locations of creeks and structures):

- River Murray (between Locks 3 to 5)
- Main Eckert Creek
- Eckert Creek Northern Arm and Southern Arm
- The Splash
- Sawmill Creek
- Katarapko Creek
- Piggy Creek
- Ngak Indau Wetland inlet
- Wetland 1541
- Bank A creek

Structures represented in the model are as follows:

- Lock 4
- Banks J, K and N inlet regulators
- Log crossing regulator
- Piggy Creek inlet and outlet structures
- Main Eckert Creek bridge and North Arm bridge
- South Arm road crossing regulator
- Sawmill Creek culvert structure
- Katarapko Creek stone weir
- Ngak Indau inlet and outlet structures
- Car Park Lagoon inlet and outlet regulators
- Bank A regulator

The recently calibrated MIKE FLOOD model was used as a basis in this investigation. The details of the recent MIKE FLOOD model are presented in McCullough (2015).

3 Methodology

3.1 Scenarios Modelled

To provide context on the potential benefits that could be restored to Katarapko floodplain through infrastructure, two key states of the floodplain have been considered representing: 1) the baseline infrastructure condition (i.e. existing condition) and 2) without development condition (i.e. near to natural condition). The recent MIKE FLOOD model was used without any modifications to represent the baseline condition, and then all structures and locks were removed from this model to create a model representing the floodplain as near to natural conditions as possible.

A number of Basin Plan water recovery scenarios were considered under baseline condition to assess the impact of different flow regimes on frequency of inundation within Katarapko Floodplain. These water recovery scenarios have been developed by the Murray-Darling Basin Authority (MDBA) since 2010 to represent the changes in the flow regime that can be achieved through the recovery and use of water for the environment under the Basin Plan. The characteristics of the Basin Plan water recovery scenarios are discussed in detail in MDBA (2012a) and MDBA (2012b) for the relaxed constraint (BP3200RC) scenario.

All scenarios that were assessed in this investigation are as follows:

- **Without development Condition**

  Floodplain conditions that are as near to natural conditions as possible and flow regime based on MDBA without development model run that excludes diversions and river infrastructure such as storages

- **Baseline Condition – Current flow regime**

  Existing floodplain condition (structures, locks and operating rules) with flow regime representing pre Basin Plan river development (representative of 2009 conditions) (MDBA, 2012a).

- **Baseline Condition - BP2750**

  Existing floodplain condition (structures, locks and operating rules) with a flow regime based on a water recovery of 2750 GL. This was the updated mode run developed for the SDL Adjustment Mechanism Benchmark (MDBA 2014), which is similar to the BP2800 scenario in MDBA (2012a).

- **Baseline Condition - BP2400**

  Existing floodplain condition (structures, locks and operating rules) with a reduced water recovery of 2400 GL, representing a possible post SDL Adjustment recovery volume

- **Baseline Condition - BP3200RC**

  Existing floodplain condition (structures, locks and operating rules) with an increased water recovery volume of 3200 GL. including relaxed flow delivery constraints within the Murray, representing an upper limited to the inundation regime expected from the Basin Plan (MDBA, 2012b).

3.2 Model Simulations

Each hydraulic model requires boundary conditions to be defined, including upstream flow into the model (i.e. flow upstream of Lock 5) and water level at the outlet of the model (i.e. upstream of Lock 4).

3.2.1 Flow data

Flow rates with average recurrence interval (ARI) of less than 10 years, representing inundation frequencies relevant to flood dependent ecosystems, that meet specific duration of inundation within Katarapko Floodplain were identified for each scenario by applying statistical analysis on daily time series of calculated flow to South Australian (QSA) modelled by MDBA.

The same definition of a successful event as in MDBA (2012a) was adopted here, namely the target duration was met over the period between June 1 and December 31 each year. Smaller events within the period were combined to meet the target duration, provided the length of an individual event was longer than one week. The flow that exceeded the target duration was identified every year over the 114 year MDBA modelled flow period, and then flows meeting different frequencies were calculated and rounded to the nearest 5000 ML/day for each water recovery scenario. Three target durations were considered, 30, 60 and 90 days, which align with different flow indicators.

Flow rates with ARI of less than 10 years for each scenario are summarised in Table 3.1 to Table 3.5.

Table 3.1 Flows (ML/day) with average recurrence interval (ARI) of less than 10 years that meet specific target durations under without development condition

ARI (1 in …)	Duration (days)		
	30	60	90
2	60 000	50 000	45 000
3	80 000	70 000	60 000
4	90 000	75 000	65 000
5	95 000	80 000	70 000
6	100 000	80 000	70 000
7	100 000	85 000	75 000
8	105 000	90 000	75 000
9	110 000	90 000	75 000
10	110 000	95 000	75 000

Table 3.2 Flows (ML/day) with average recurrence interval (ARI) of less than 10 years that meet specific target durations under baseline condition – Current flow regime

ARI (1 in …)	Duration (days)		
	30	60	90
3	45 000	35 000	30 000
4	55 000	45 000	35 000
5	60 000	50 000	40 000
6	65 000	55 000	45 000
7	65 000	60 000	45 000
8	70 000	60 000	50 000
9	70 000	60 000	50 000
10	75 000	65 000	50 000

Table 3.3 Flows (ML/day) with average recurrence interval (ARI) of less than 10 years that meet specific target durations under baseline condition – BP2750

ARI (1 in …)	Duration (days)		
	30	60	90
2	40 000	35 000	30 000
3	55 000	50 000	40 000
4	60 000	55 000	45 000
5	65 000	60 000	50 000
6	70 000	60 000	55 000
7	70 000	65 000	55 000
8	75 000	65 000	60 000
9	85 000	65 000	60 000
10	85 000	70 000	60 000

Table 3.4 Flows (ML/day) with average recurrence interval (ARI) of less than 10 years that meet specific target durations under baseline condition – BP2400

ARI (1 in …)	Duration (days)		
	30	60	90
2	40 000	35 000	25 000
3	55 000	45 000	40 000
4	60 000	55 000	45 000
5	65 000	60 000	50 000
6	70 000	60 000	50 000
7	70 000	60 000	55 000
8	75 000	60 000	55 000
9	75 000	65 000	55 000
10	85 000	65 000	60 000

Table 3.5 Flows (ML/day) with average recurrence interval (ARI) of less than 10 years that meet specific target durations under baseline condition – BP3200RC

ARI (1 in …)	Duration (days)		
	30	60	90
2	40 000	35 000	30 000
3	55 000	50 000	40 000
4	65 000	55 000	45 000
5	70 000	60 000	50 000
6	70 000	65 000	55 000
7	75 000	65 000	60 000
8	75 000	65 000	60 000
9	75 000	70 000	60 000
10	80 000	70 000	60 000

3.2.2 Water level data

Water levels data at Lock 3 and 4 were derived from DEWNR's Hydstra database and the SA Water backwater curves for both without development and baseline conditions.

For without development conditions, as Locks 3 and 4 are removed, an estimate of water level at each flow rate was required at the Lock 3 downstream boundary. These estimates were obtained by interpolating historical water level data captured at the Lock 3 and 4 sites in 1920s immediately preceding lock construction, and relating this data to calculated Flow to South Australia (QSA) representing actual flows based on the maximum monthly stream discharge. Table 3.6 shows interpolated Lock 3 and 4 levels prior to lock construction for a range of identified flow rates under without development condition (i.e. 45 000 ML/day to 110 000 ML/day).

Table 3.6 Interpolated water level at Lock 3 and Lock 4 sites (pre-lock construction) against calculated flow to South Australia (QSA).

QSA (ML/day)	Lock 3 site Water Level (m AHD)	Lock 4 site* Water Level (m AHD)
45 000	8.3	12.5
50 000	8.6	12.6
55 000	8.9	12.7
60 000	9.1	12.8
65 000	9.4	12.9
70 000	9.6	13.0
75 000	9.9	13.1
80 000	10.1	13.2
85 000	10.3	13.2
90 000	10.5	13.3
95 000	10.7	13.4
100 000	10.8	13.4
105 000	11.0	13.5
110 000	11.1	13.6

*Water level data at Lock 4 site was used for model validation only.

A similar approach was used to estimate water level data at Locks 3 and 4 for baseline conditions by focusing on water level data captured after construction of Lock 3 and 4. Table 3.7 shows interpolated Lock 3 and 4 levels for a range of identified flow rates under baseline condition (i.e. 25 000 ML/day to 85 000 ML/day).

Table 3.7 Interpolated water level at Lock 4 and Lock 5 against calculated flow to South Australia (QSA).

QSA (ML/day)	Lock 3 Water Level (m AHD)	Lock 4 Water Level (m AHD)
25 000	9.8	13.20
30 000	9.8	13.20
35 000	9.8	13.20
40 000	9.8	13.20
45 000	9.8	13.38
50 000	9.8	13.55
55 000	9.8	13.85
60 000	9.95	14.15
65 000	10.18	14.25
70 000	10.31	14.31
75 000	10.34	14.36
80 000	10.76	14.55
85 000	10.80	14.58

3.3 Model Validation

The hydraulic models assumed steady-state flow conditions, which signifies that the water levels in the models are allowed sufficient time to equalise under the specified flow rate. The hydraulic model was validated by comparing the simulated water with the observed water levels at three locations, namely Lock 4 upstream and downstream levels, and Lock 3 upstream level. The comparison of observed and modelled water levels under baseline condition is presented in Figure 3.1. Given the steady state assumption, the model would be expected to closer to the upper water levels recorded for each flow, and this can be seen to be the case in Figure 3.1.

Figure 3.1 Observed and modelled water level at Lock 3 and 4.

4 Results

Inundation areas and velocities corresponding to flows with less than 10 years ARI that meet the target duration of 30, 60 and 90 days were derived from the hydraulic models and compared to assess the impact of development on the Katarapko Floodplain.

The following section presents the outputs relating to flood frequency mapping and distribution of velocities for without development conditions and baseline conditions (BP2750). The outputs of the other water recovery scenarios and current flow regime under baseline conditions are presented in the Appendix.

4.1 Inundation Frequency Mapping

The following figures were produced to assess the natural and potential Basin Plan frequency of inundation within Katarapko Floodplain. Each colour presents a unique ARI event in all figures. In general, it can be seen that naturally larger areas of the floodplain were inundated for longer periods more regularly compare to current conditions, and this is still the case even for the most optimistic scenario (e.g. BP3200RC). To allow the different scenarios to be compared more quantitatively, Table 4.1 provides the area inundated for each flow rate.

For example, as shown by the light blue colour in Figure 4.1, under without development conditions, it was estimated that once every three years Katarapko Floodplain was inundated for at least 30 days by flow of around 80 000 ML/day, whereas under baseline conditions (assuming a water recovery target of 2750 GL), a smaller portion of Katarapko Floodplain was estimated to be inundated by a flow of around 55 000 ML/day once every three years for the same duration of 30 days (Figure 4.2). From Table 4.1 it can be seen that these 1 in 3 events correspond to an inundation area of 1724 ha for without development conditions and 767 ha for BP2750.

Similarly, under without development conditions, it was expected that Katarapko Floodplain was inundated once every three years by a flow of around 70 000 ML/day for at least 60 days (Figure 4.3), while under baseline conditions (assuming a water recovery target of 2750 GL), a smaller portion of Katarapko Floodplain was estimated to be inundated by flow of around 50 000 ML/day once every three years for a similar duration of 60 days (Figure 4.4).

In addition, referring to the light green colour in Figure 4.5 and Figure 4.6, under without development conditions it was expected that Katarapko Floodplain was inundated once every five years by a flow of around 70 000 ML/day for at least 90 days, however under baseline conditions (assuming a water recovery target of 2750 GL) a smaller portion of Katarapko Floodplain was estimated to be inundated by a flow of around 50 000 ML/day once every five years for a similar duration of 90 days.

Table 4.1 Area inundated within Katarapko Floodplain for each flow rate

QSA (ML/day)	Area Inundated (Ha)	
	baseline Condition	without development Condition
25 000	96	Not Modelled
30 000	138	Not Modelled
35 000	186	Not Modelled
40 000	236	215
45 000	321	289
50 000	515	433
55 000	767	688
60 000	1091	985
65 000	1286	1235
70 000	1458	1447
75 000	1588	1589
80 000	1717	1724
85 000	1798	1809
90 000	Not Modelled	1878
95 000	Not Modelled	1938
100 000	Not Modelled	1996
105 000	Not Modelled	2064
110 000	Not Modelled	2136

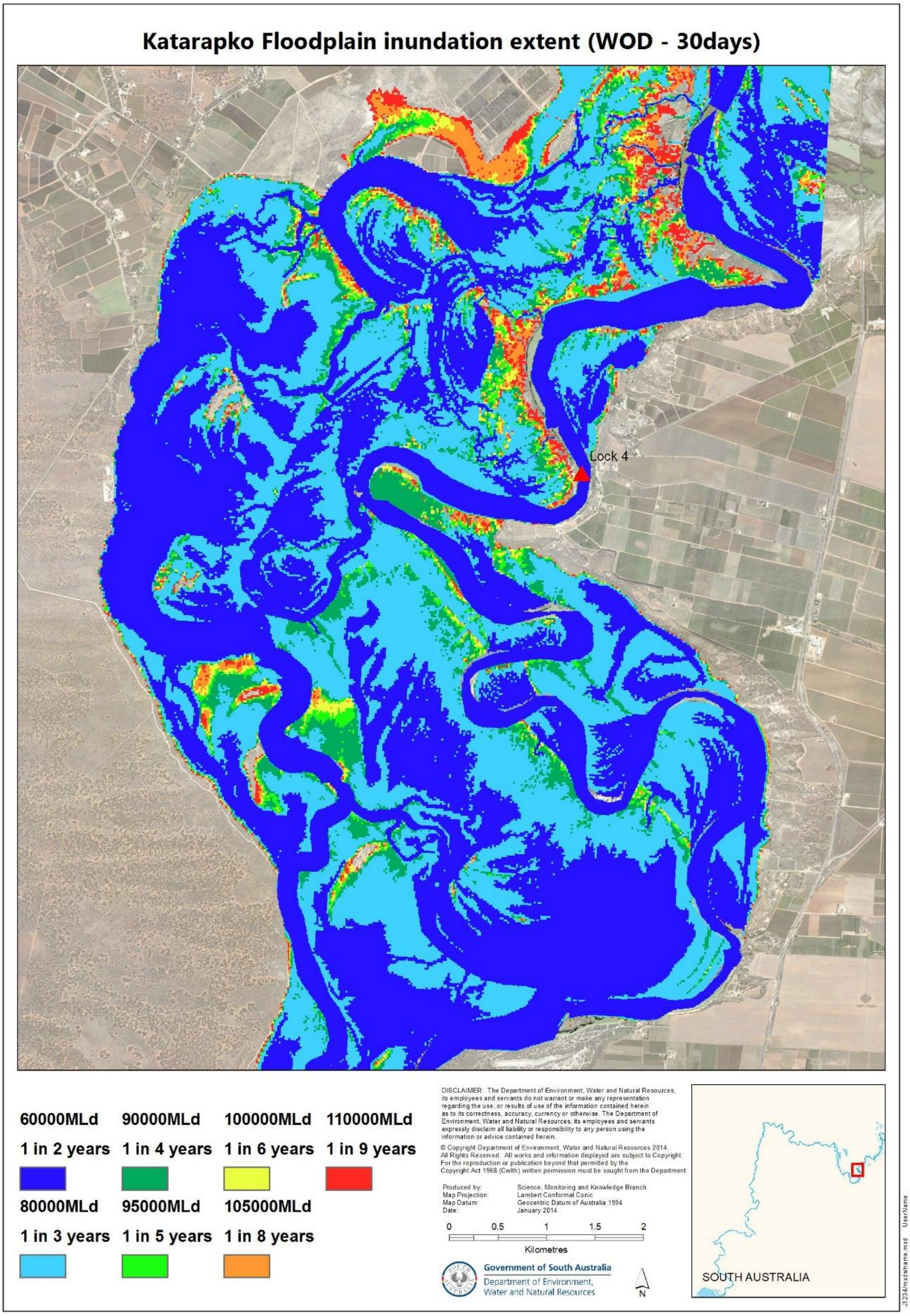

Figure 4.1 Katarapko Floodplain inundation extent – without development (30 days)

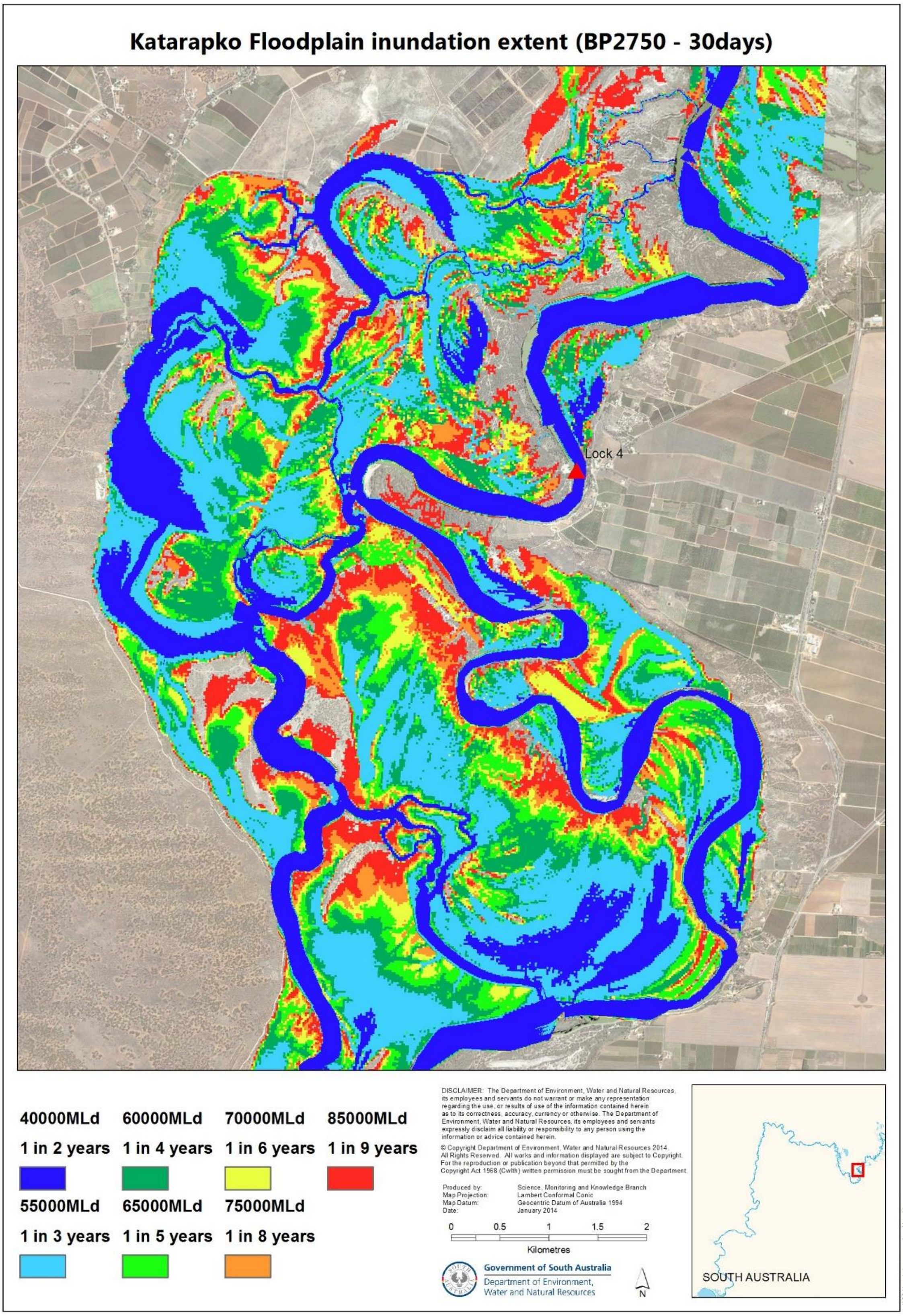

Figure 4.2 Katarapko Floodplain inundation extent – BP2750 (30 days)

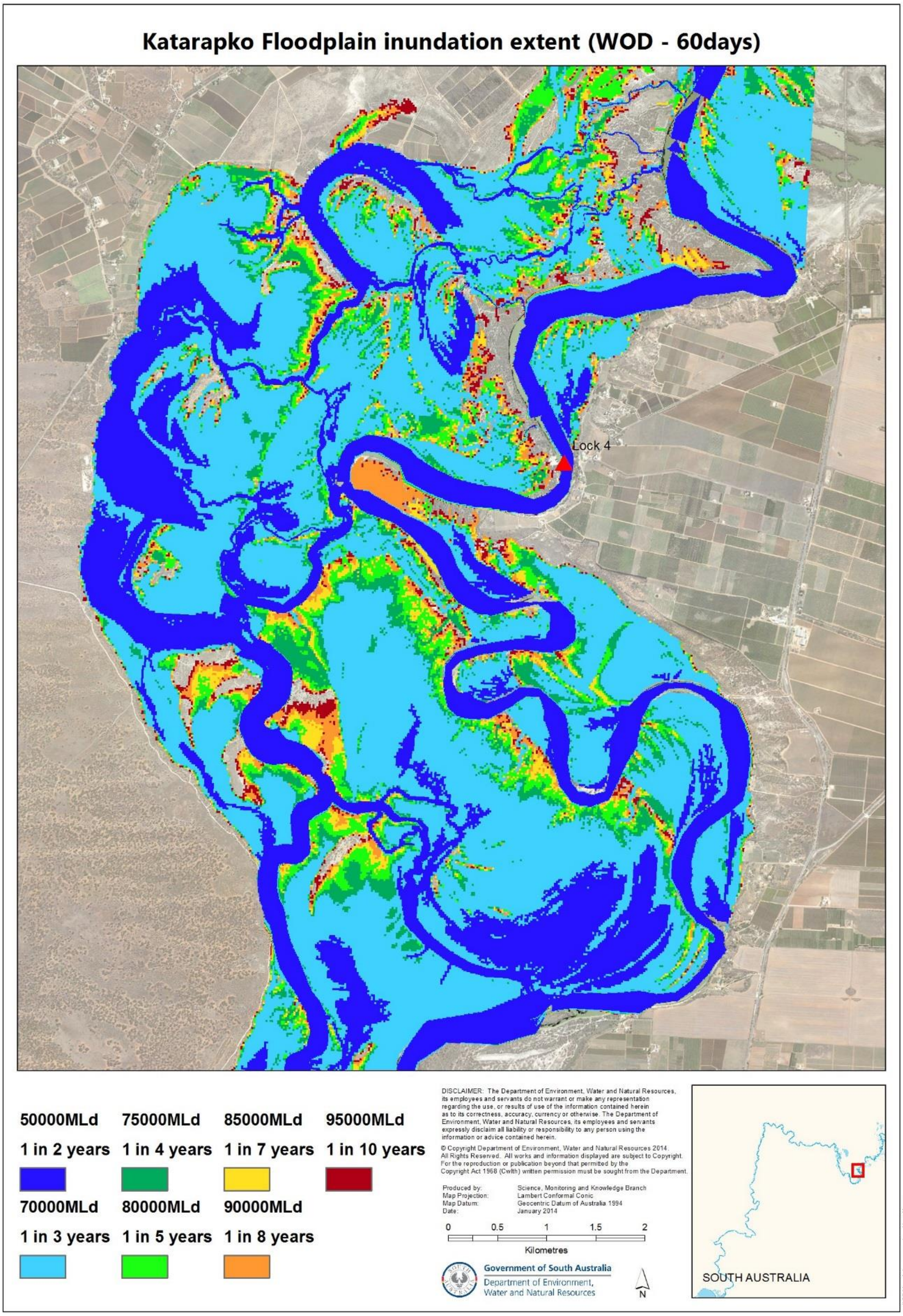

Figure 4.3 Katarapko Floodplain inundation extent – WOD (60 days)

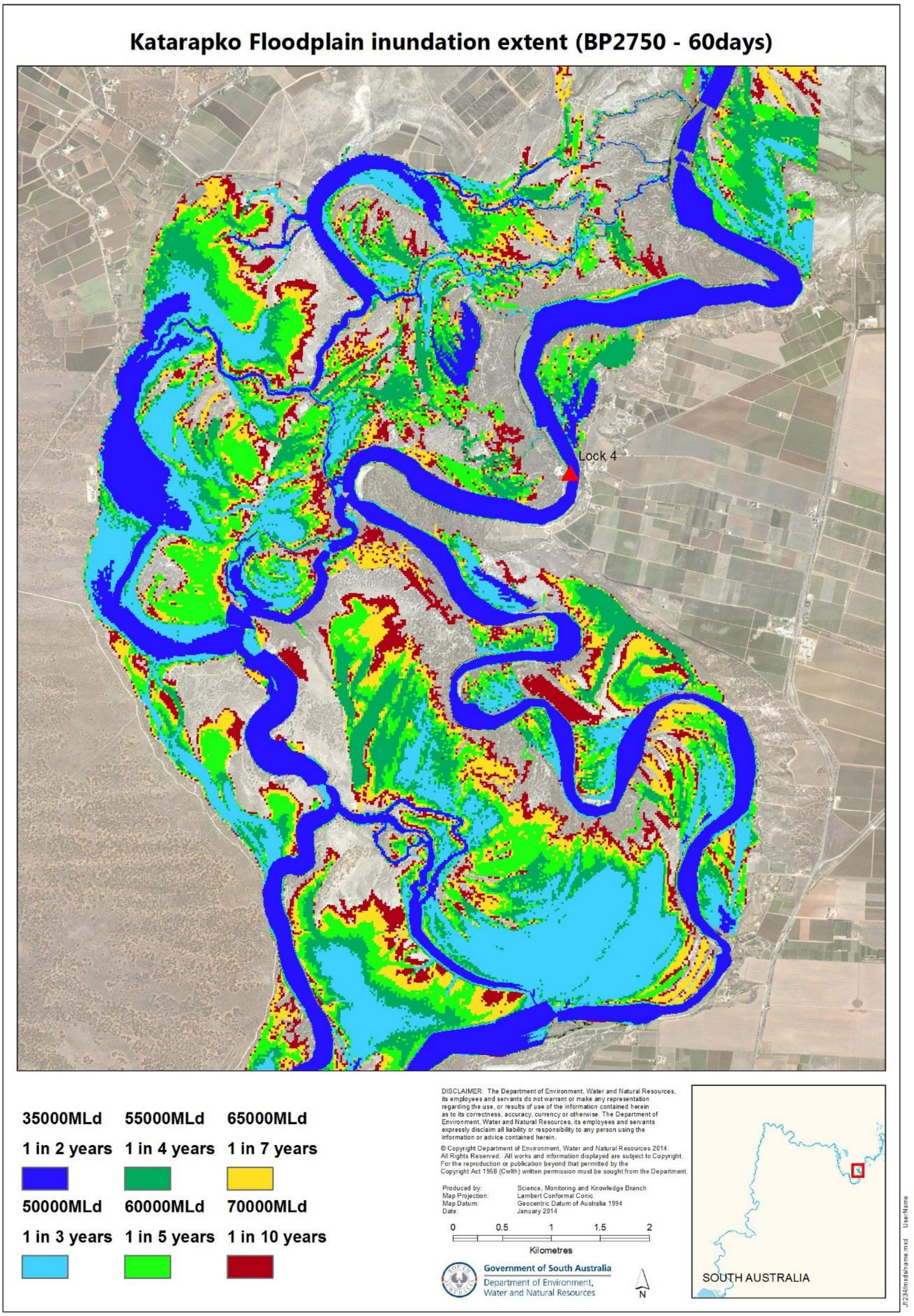

Figure 4.4 Katarapko Floodplain inundation extent – BP2750 (60 days)

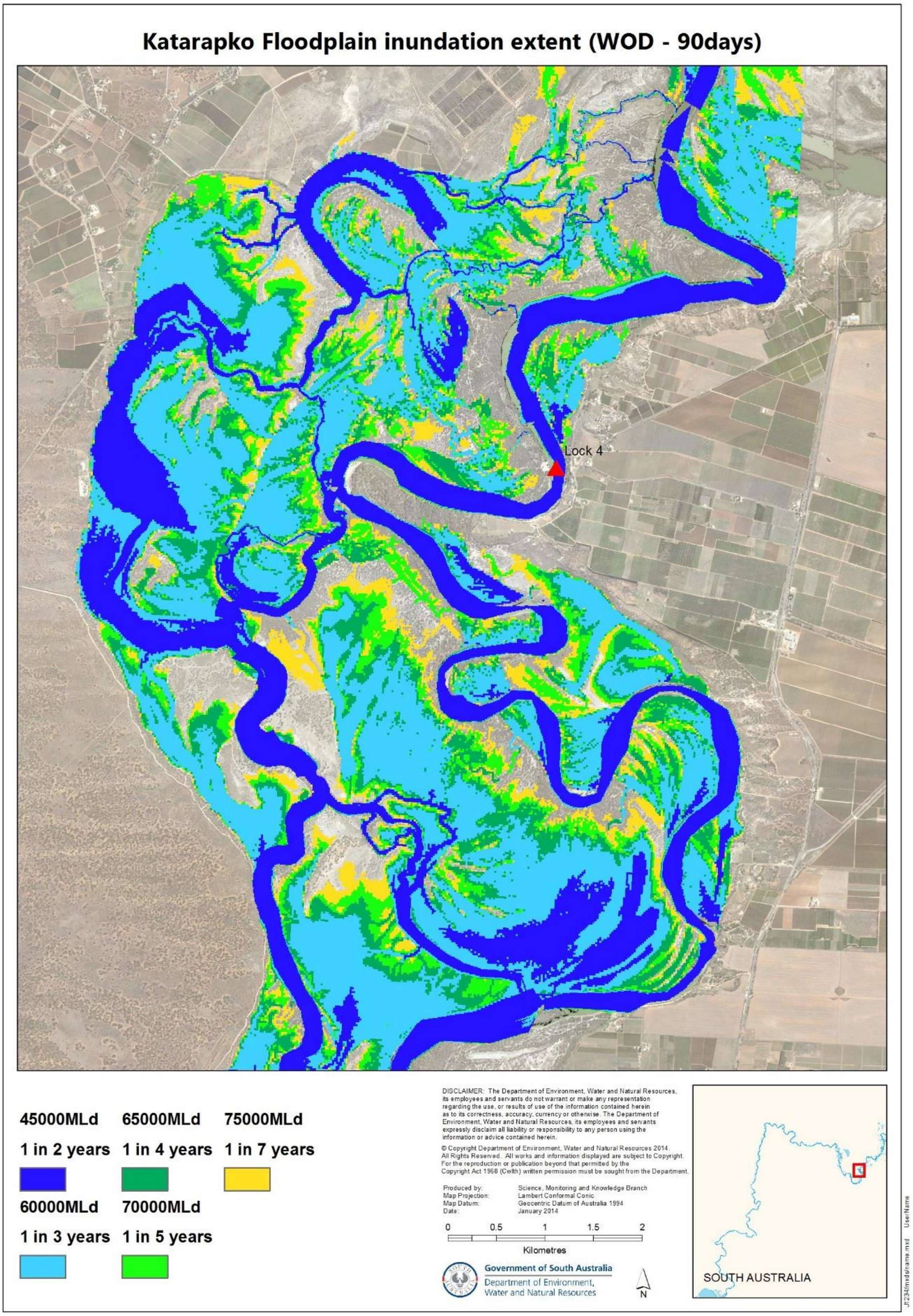

Figure 4.5 Katarapko Floodplain inundation extent – WOD (90 days)

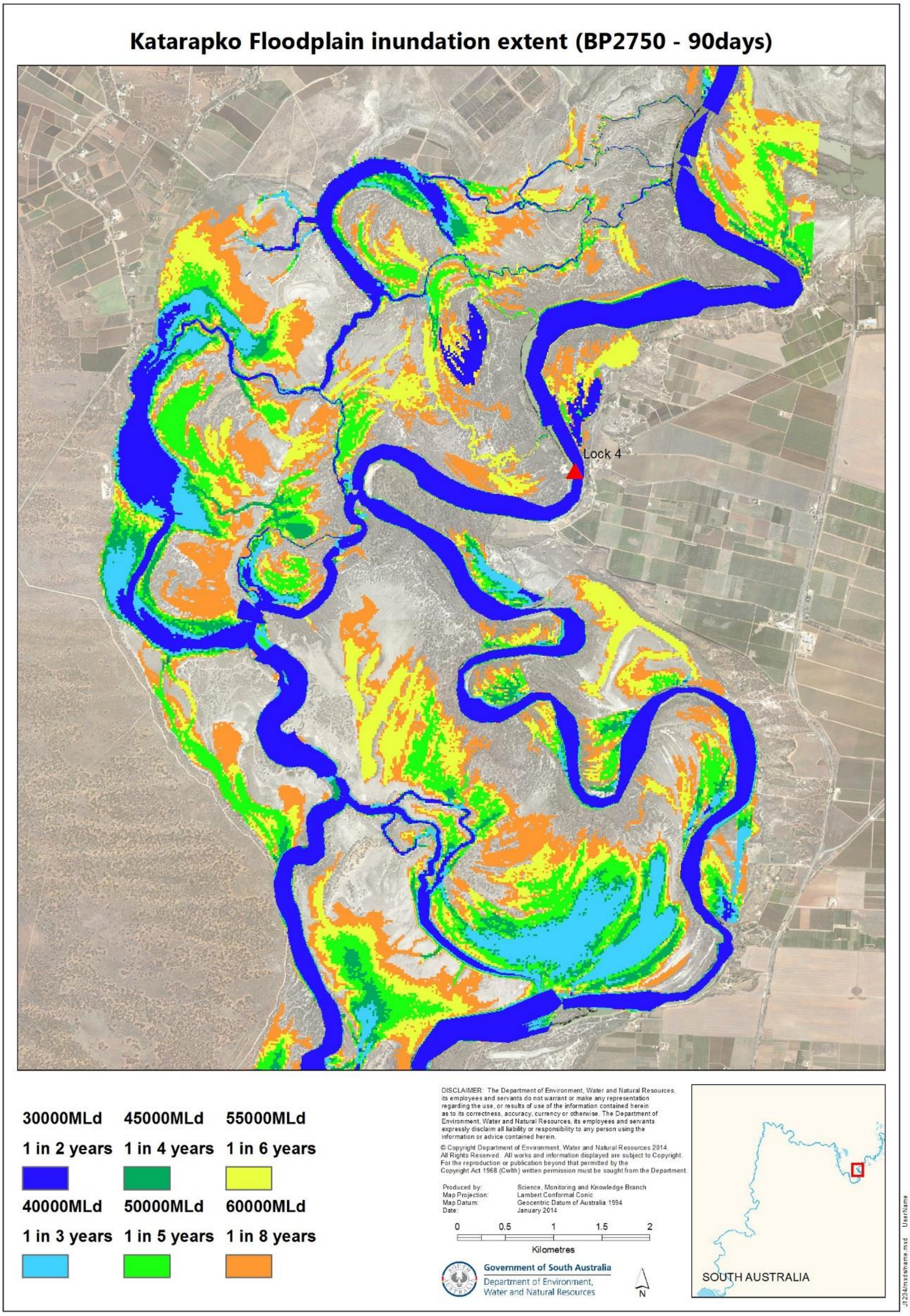

Figure 4.6 Katarapko Floodplain inundation extent – BP2750 (90 days)

4.2 Distribution of Velocity

The outputs of velocities were derived from the creeks and channels within the floodplain represented by the MIKE 11 portion of the models (the floodplain itself (modelled in MIKE 21) and the river Murray channel were not included). Modelled velocity values corresponding to each flow rate were extracted from cross sections in 100 m intervals along the channel lengths within Katarapko Floodplain, and then the distribution of all modelled values were calculated for the following velocity classes;

- 0 – 0.05 m/s (very slow)
- 0.05 – 0.10 m/s (slow)
- 0.10 – 0.15 m/s (slow–moderate)
- 0.15 – 0.20 m/s (moderate)
- 0.20 – 0.25 m/s (moderate–fast)
- >0.25 m/s (fast)

The following figures were produced to understand the differences between current, Basin Plan and natural conditions on the distribution of velocity within Katarapko Floodplain. Similar to flood frequency mapping results, each colour presents a unique ARI event in all figures.

For flows below 85 000 ML/d, the water level downstream of Katarapko at Lock 3 is lower under natural conditions compared to current conditions with the lock in place (Table 3.6 and Table 3.7), and as such a larger proportion of the reaches were modelled to have higher velocities, with the distribution across velocity classes being more even. Under current conditions, for lower flows (below 40 000 ML/d) there is a large proportion of the creeks in the very slow class since Lock 3 holds the water level downstream of Katarapko constant at these flows.

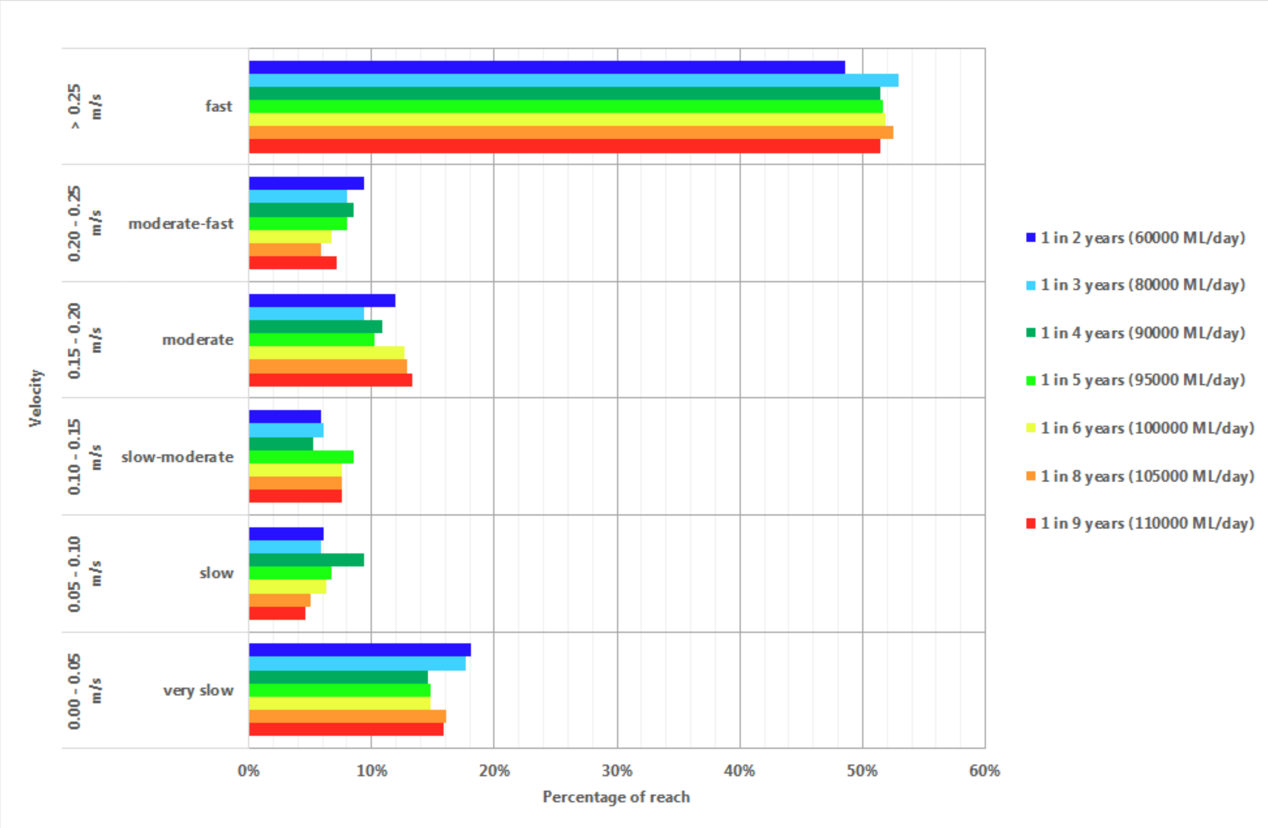

Figure 4.7 Distribution of velocity within Katarapko Floodplain - WOD (30 days)

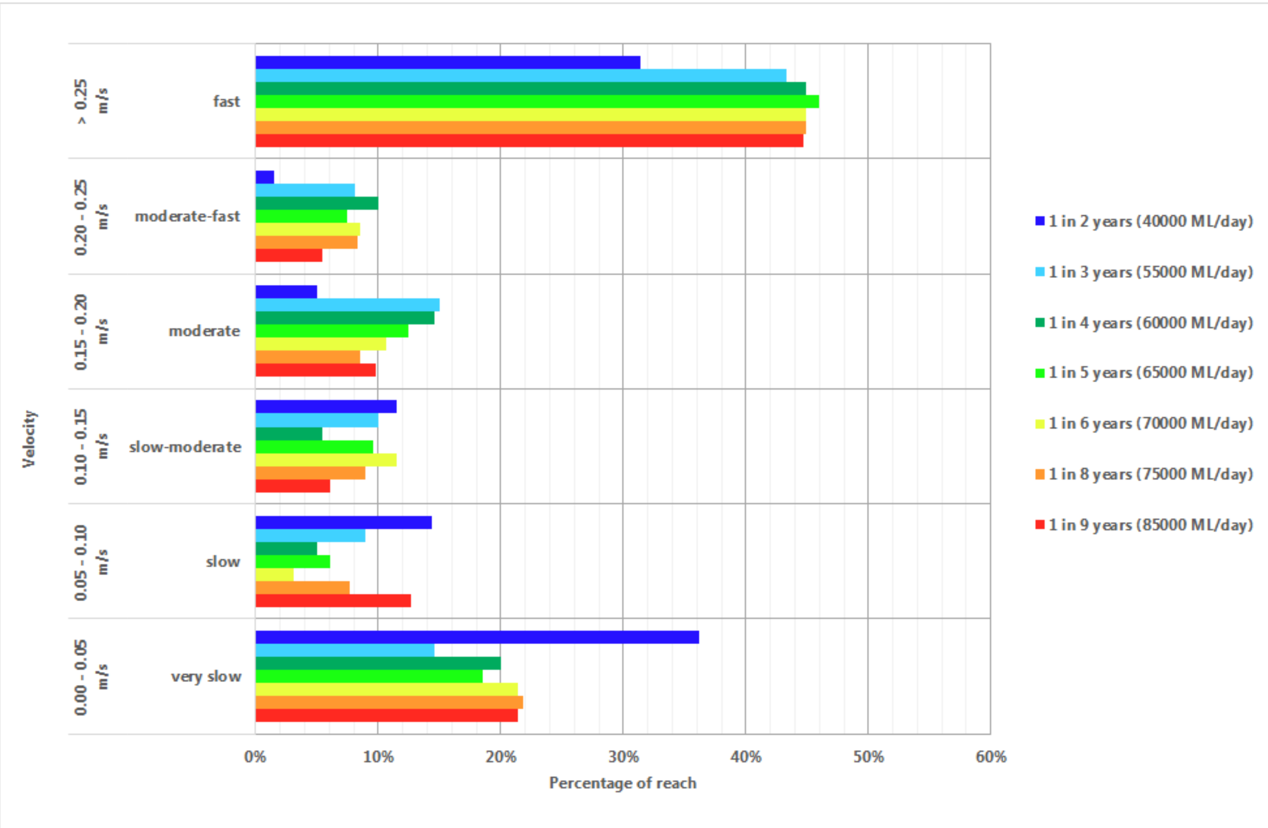

Figure 4.8 Distribution of velocity within Katarapko Floodplain – BP2750 (30 days)

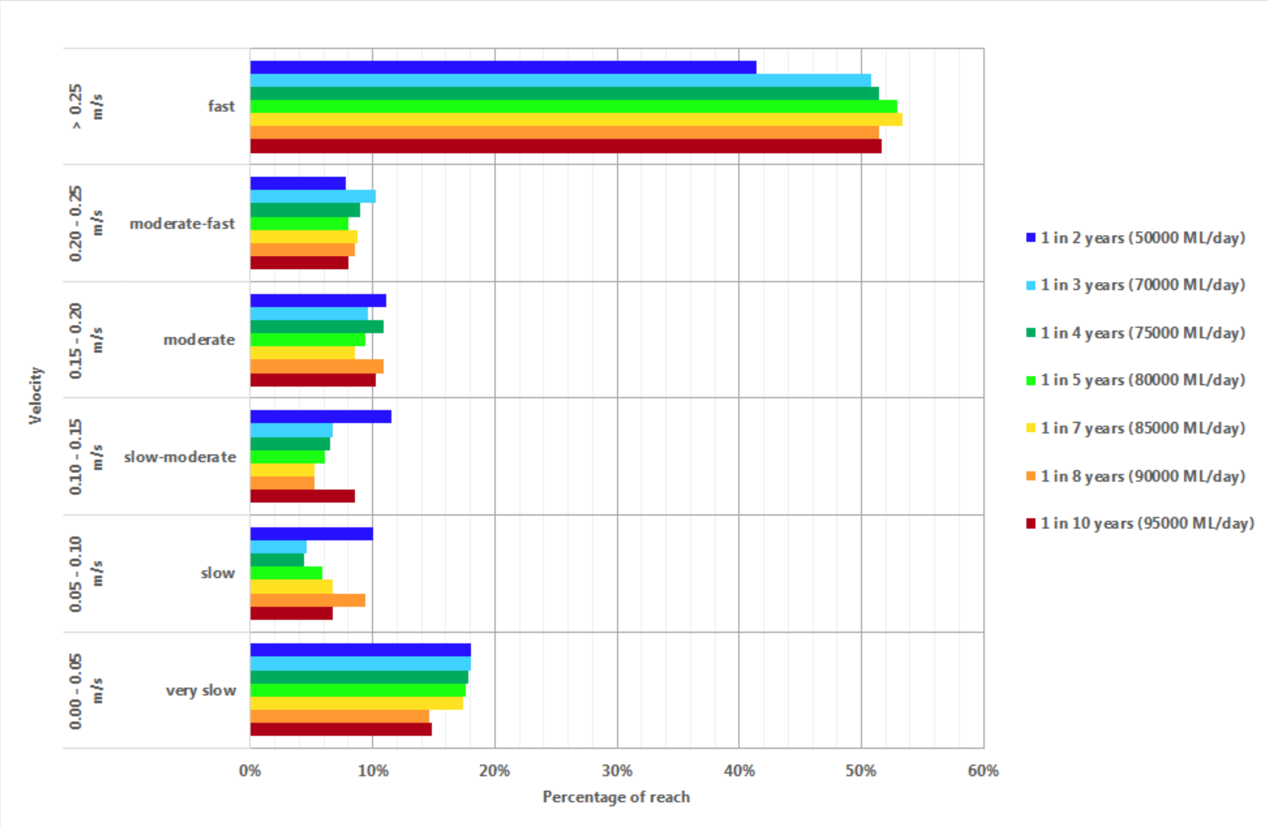

Figure 4.9 Distribution of velocity within Katarapko Floodplain – WOD (60 days)

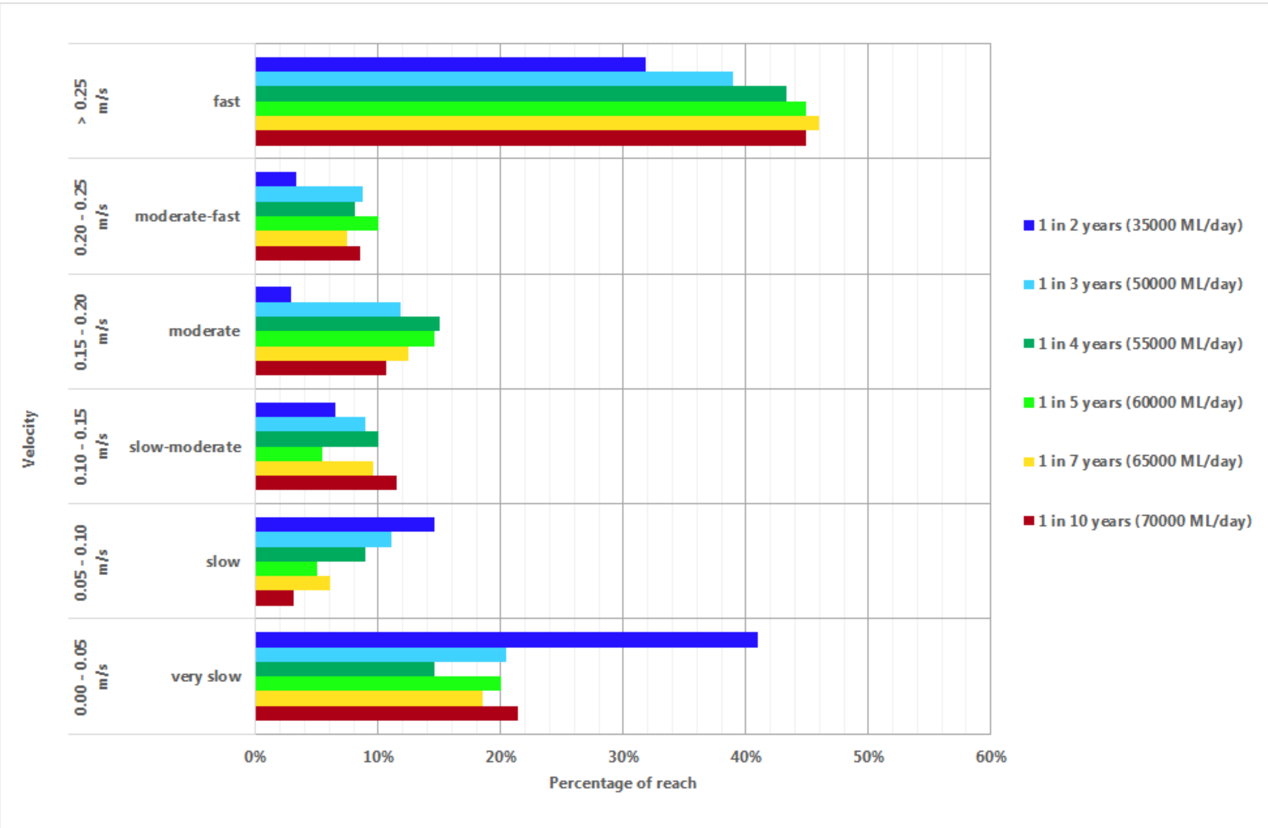

Figure 4.10 Distribution of velocity within Katarapko Floodplain – BP2750 (60 days)

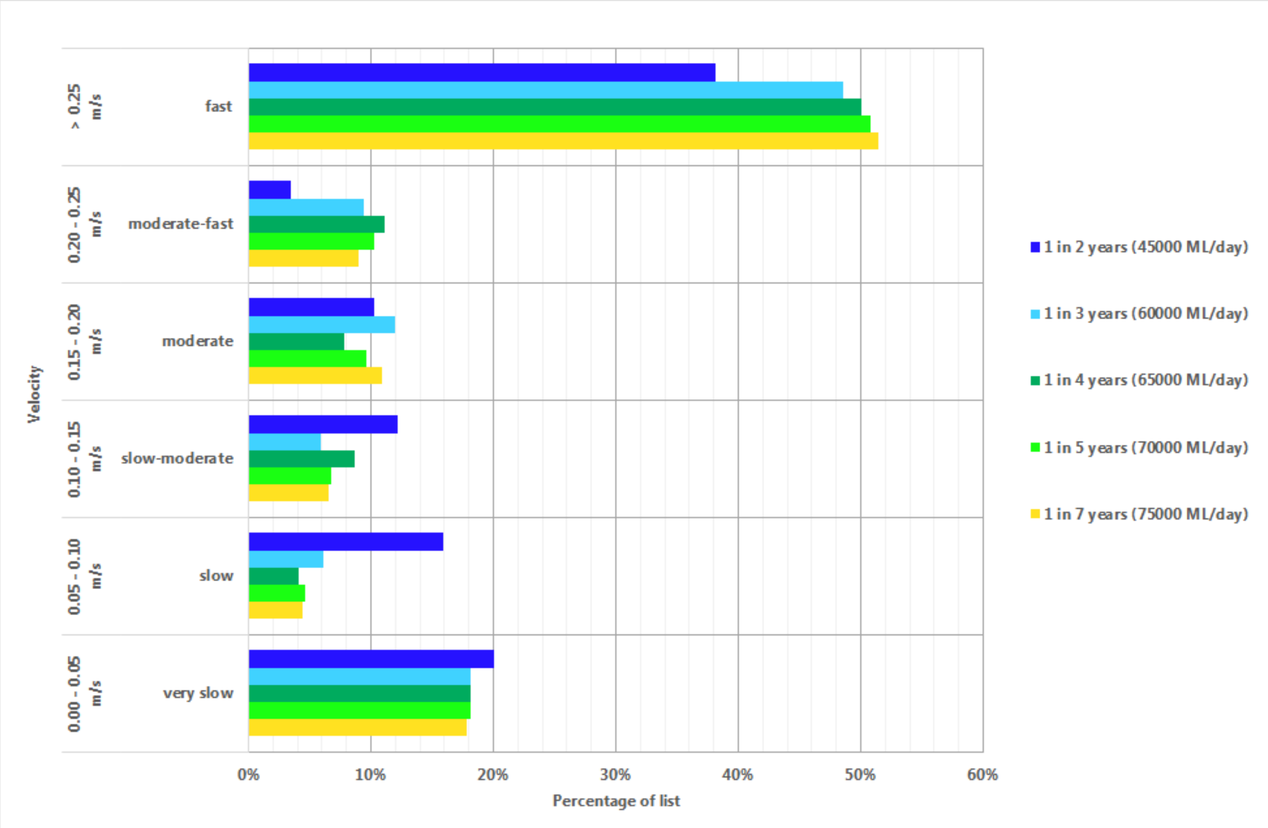

Figure 4.11 Distribution of velocity within Katarapko Floodplain – WOD (90 days)

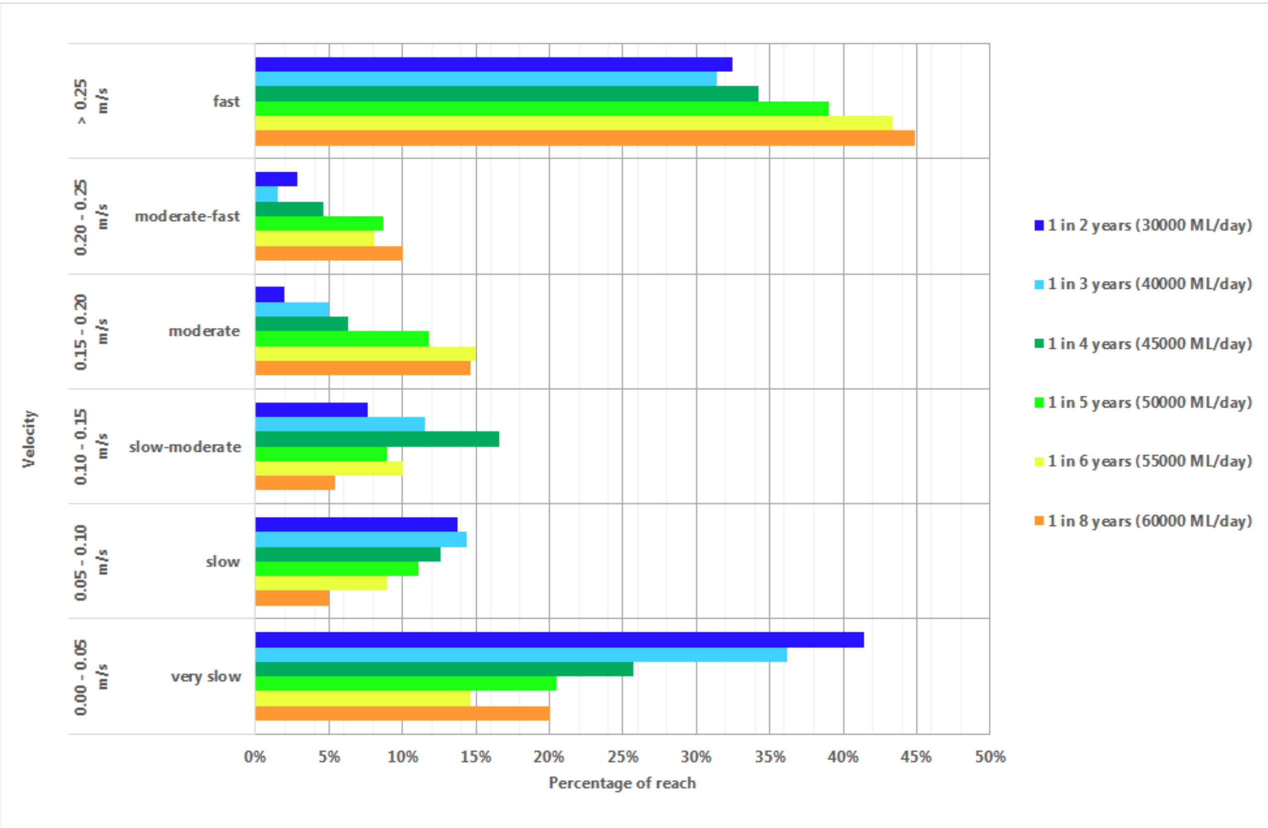

Figure 4.12 Distribution of velocity within Katarapko Floodplain – BP2750 (90 days)

The following points summarise the findings from the modelling results:

- The frequency of inundation of the floodplain for a given flow is significantly reduced in the baseline (existing) conditions compared to the without development conditions.
- Without development conditions show the majority of velocities are contained in the fast category with relatively even distributions of velocities throughout the other categories (between very slow to moderate-fast class).
- For Baseline flow regimes from current up to 3200RC Basin Plan conditions, events corresponding to a flow of 40 000 ML/d have the largest proportion of the reaches in the very slow velocity class. For events with a flow of 50 000 ML/d or greater the velocity distribution is not dissimilar to natural conditions (albeit with a slightly small proportion of the reach in the fast velocity class).
- Comparison of inundation extents, frequencies and velocity distributions within the floodplain between without development floodplain conditions and baseline conditions indicates that that additional flows delivered to the Murray–Darling Basin through the Basin Plan alone cannot be expected to achieve full ecological benefits without additional measures being implemented, such as via man-made embankment removals and infrastructure solutions.

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6 Appendix

The outputs flood frequency mapping and distribution of velocities for following scenarios are presented in this section;

- Baseline Condition – Current flow regime (30 days)
- Baseline Condition – Current flow regime (60 days)
- Baseline Condition – Current flow regime (90 days)
- Baseline Condition - BP2400 (30 days)
- Baseline Condition - BP2400 (60 days)
- Baseline Condition - BP2400 (90 days)
- Baseline Condition - BP3200RC (30 days)
- Baseline Condition - BP3200RC (60 days)
- Baseline Condition - BP3200RC (90 days)

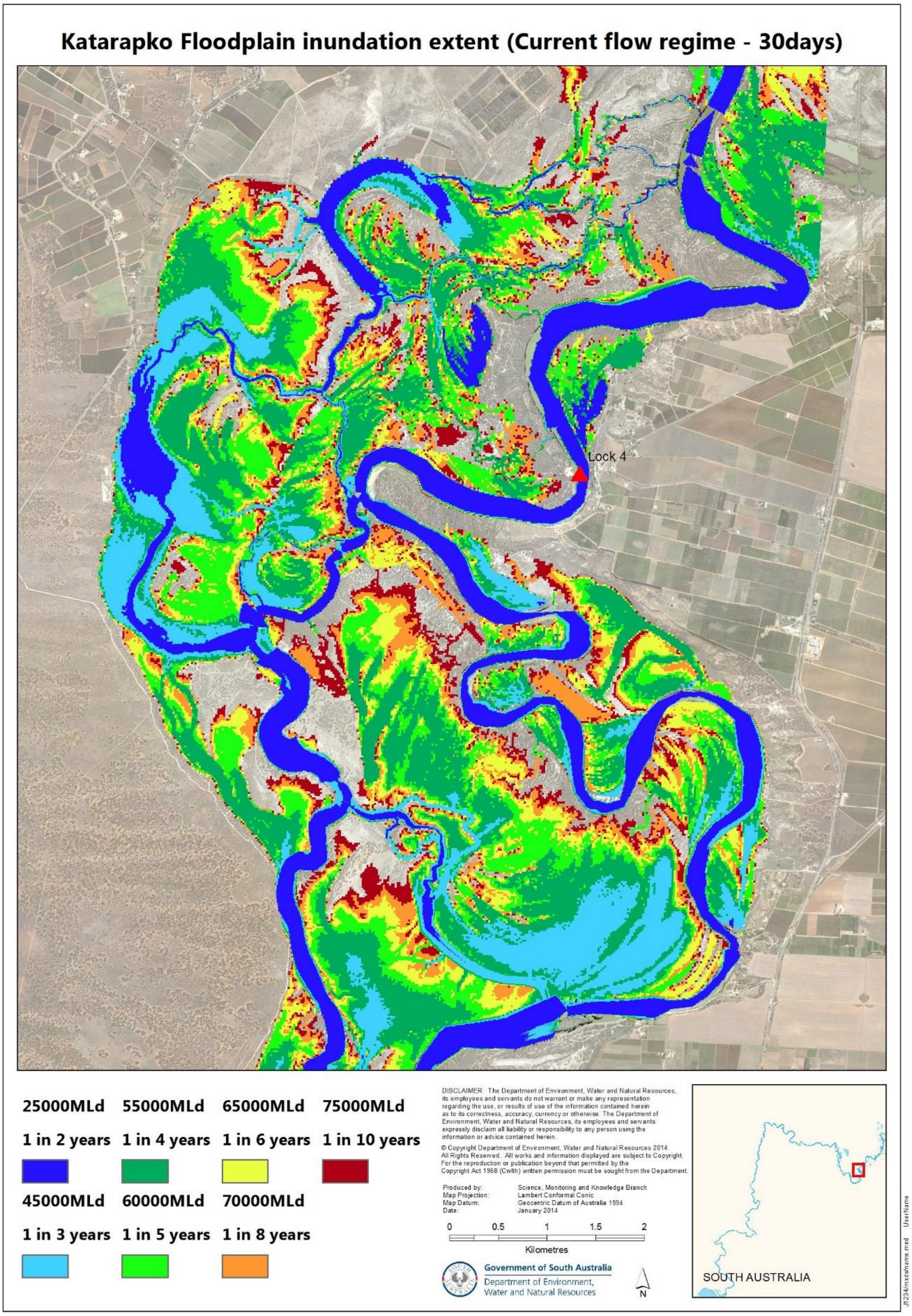

Figure 6.1 Katarapko Floodplain inundation extent – Current flow regime (30 days)

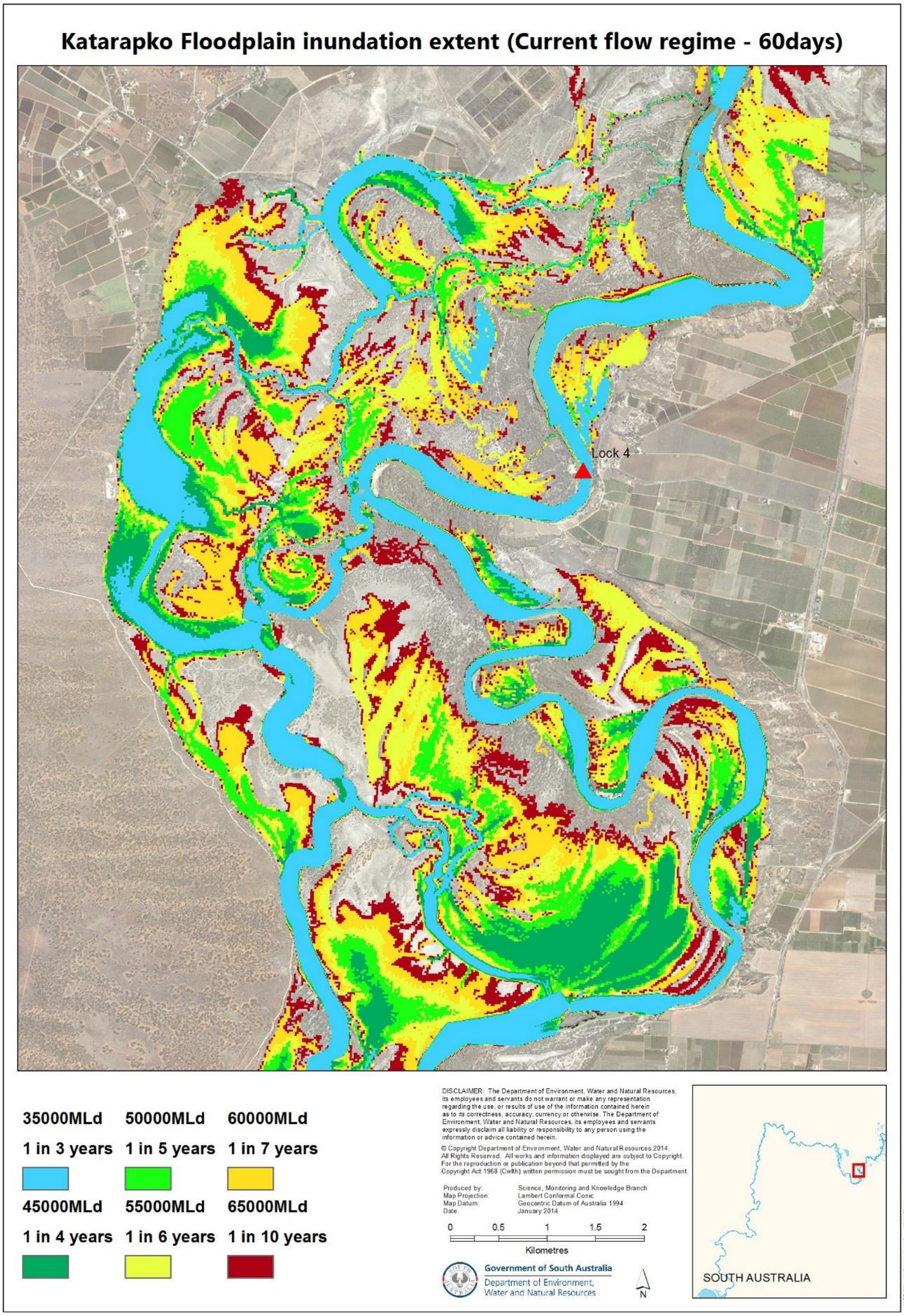

Figure 6.2 Katarapko Floodplain inundation extent – Current flow regime (60 days)

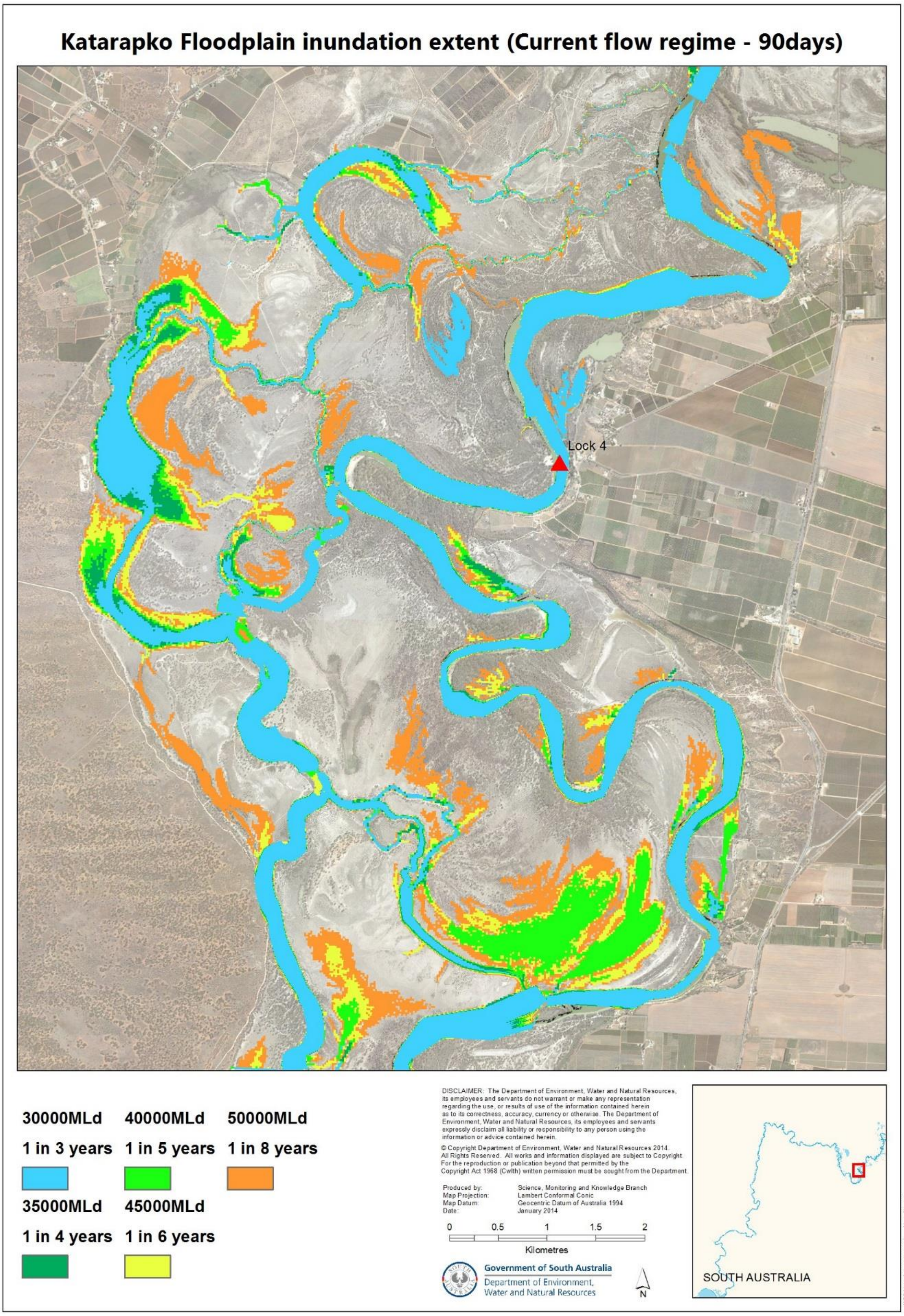

Figure 6.3 Katarapko Floodplain inundation extent – Current flow regime (90 days)

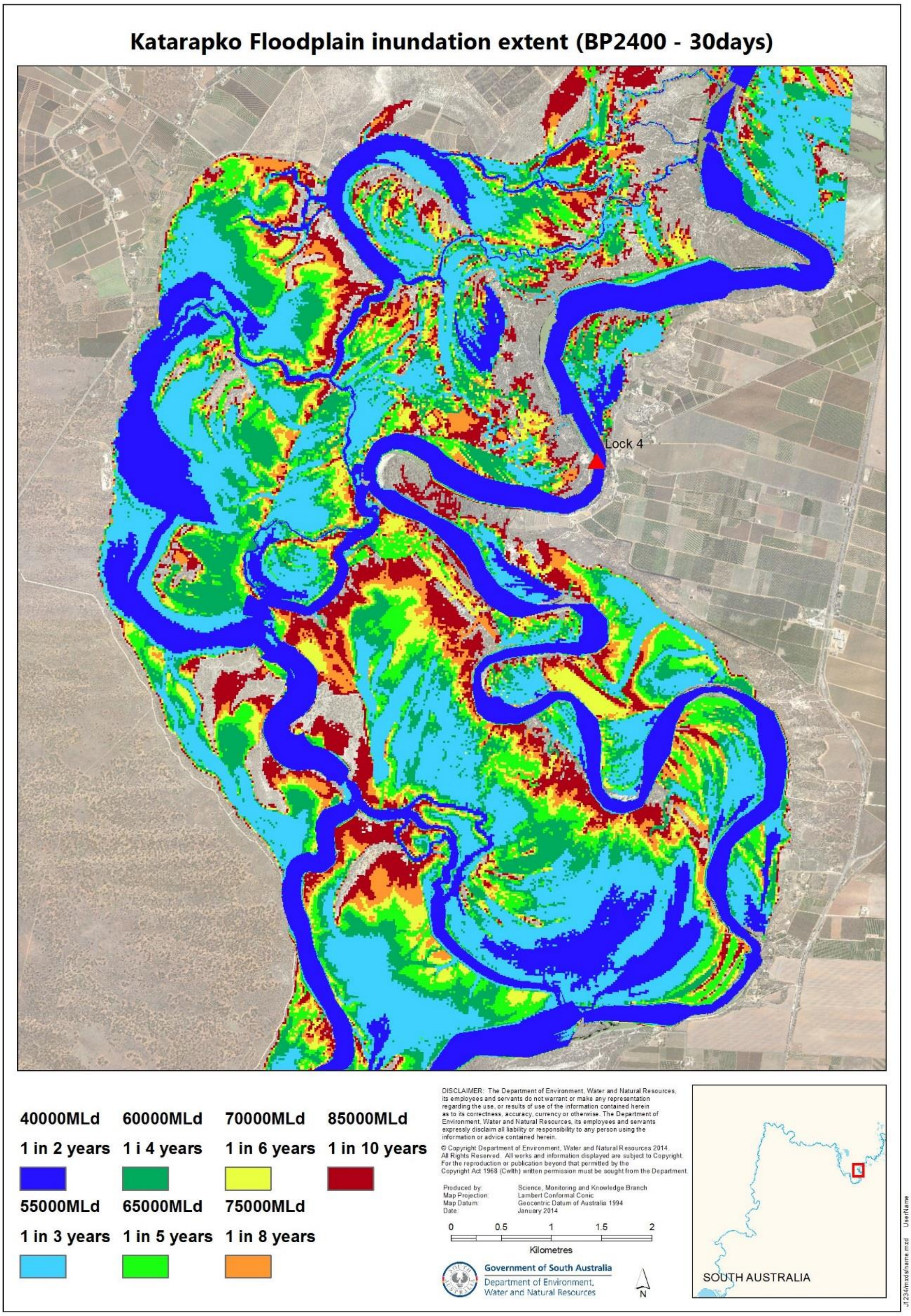

Figure 6.4 Katarapko Floodplain inundation extent – BP2400 (30 days)

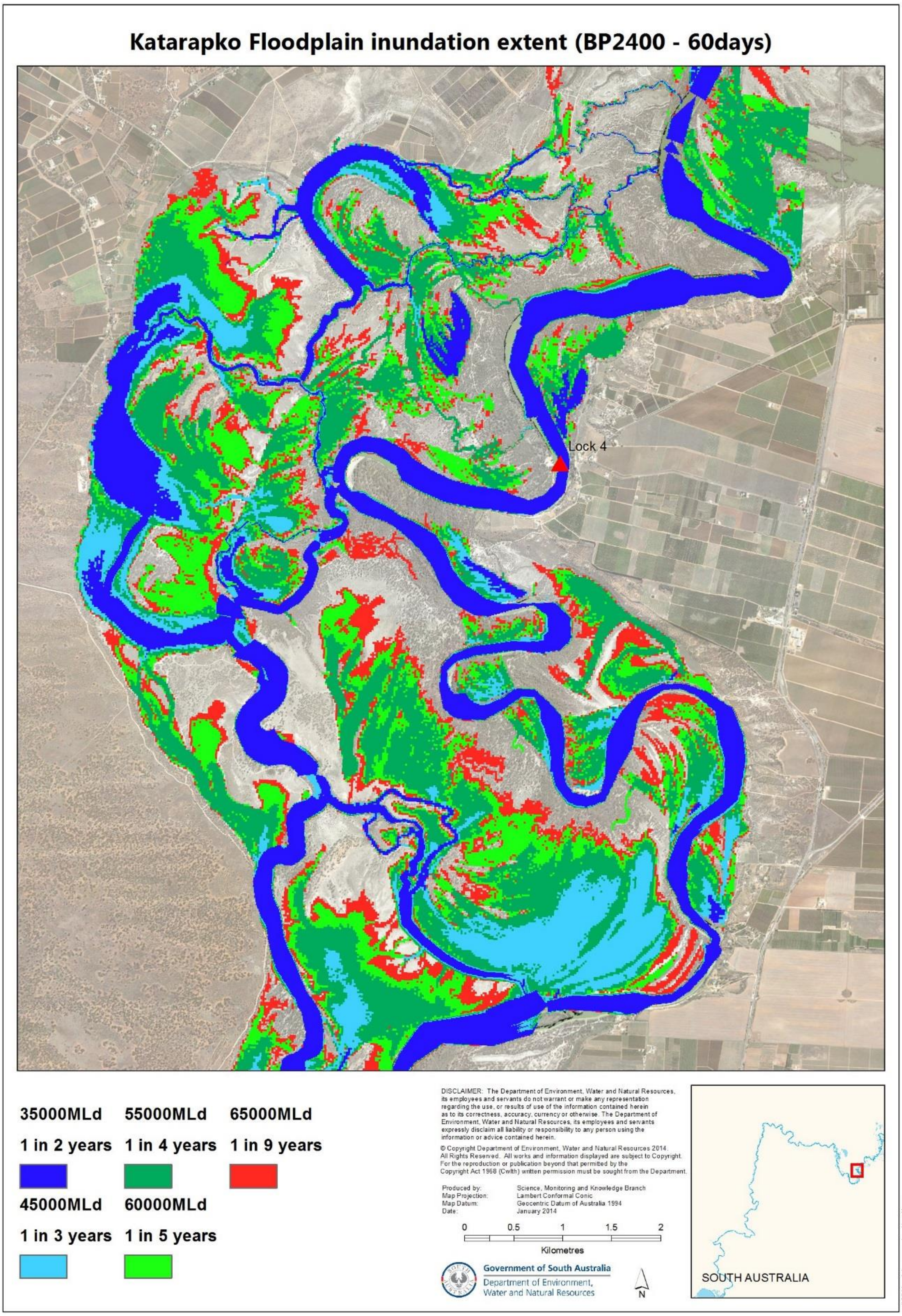

Figure 6.5 Katarapko Floodplain inundation extent – BP2400 (60 days)

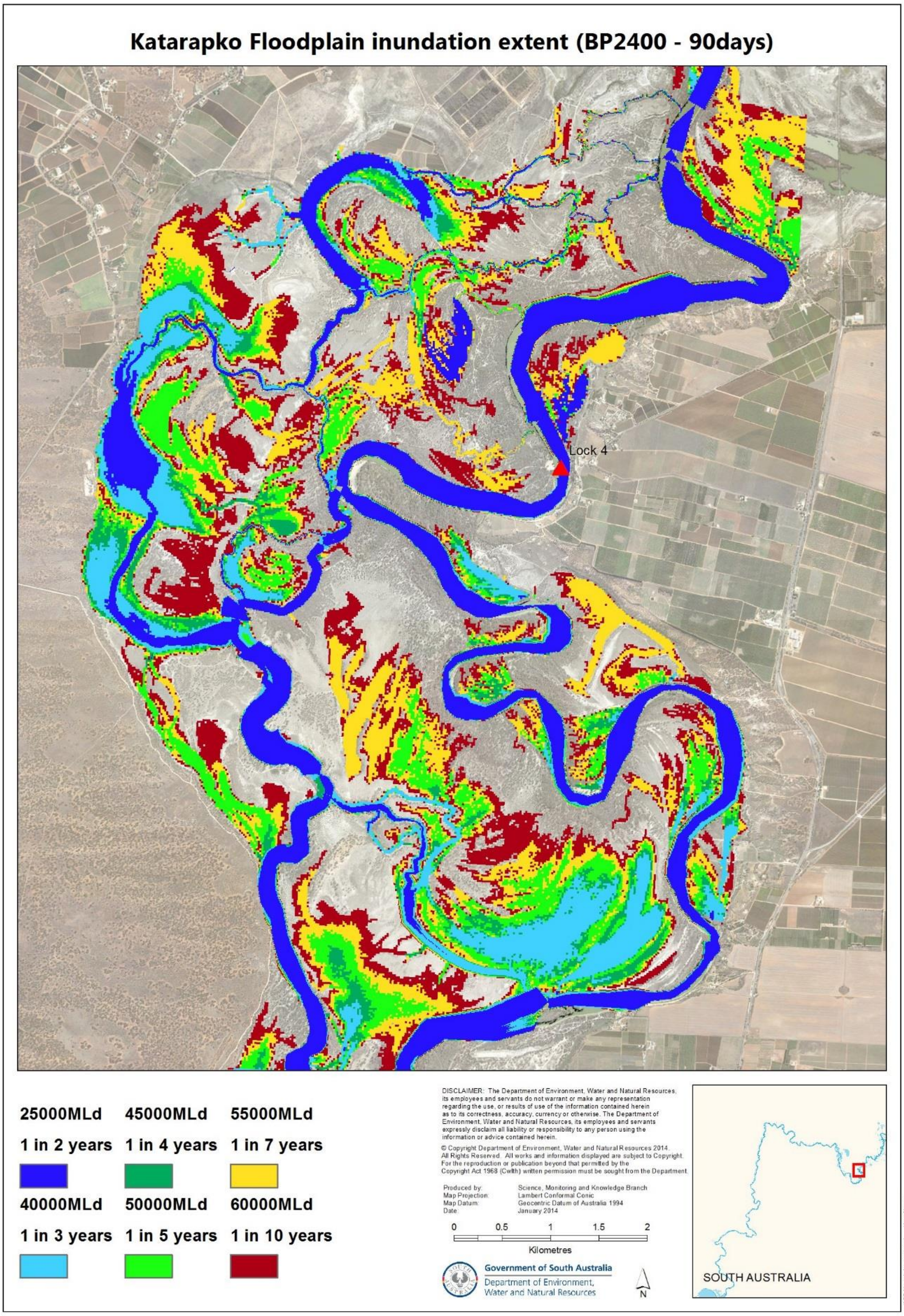

Figure 6.6 Katarapko Floodplain inundation extent – BP2400 (90 days)

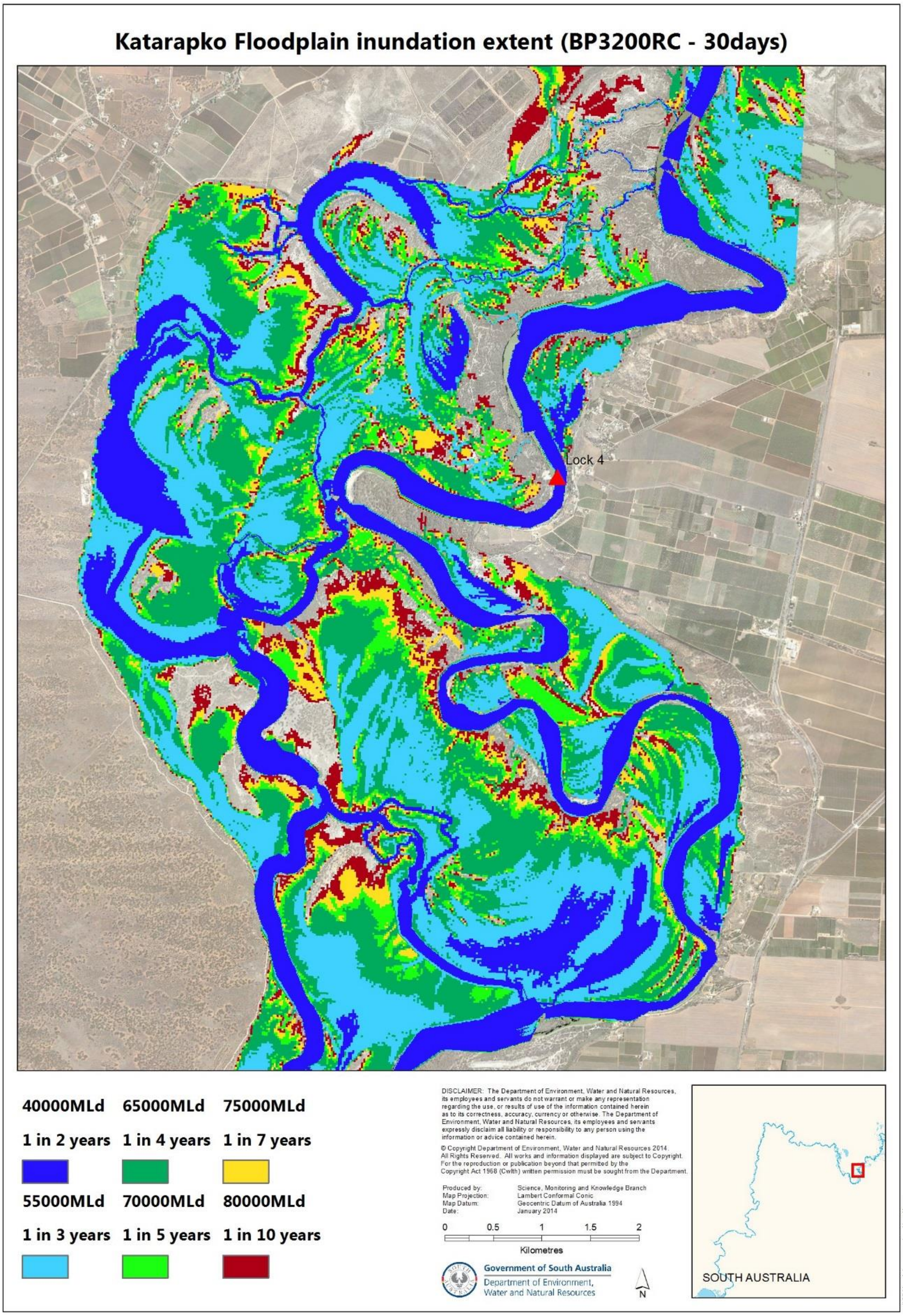

Figure 6.7 Katarapko Floodplain inundation extent – BP3200RC (30 days)

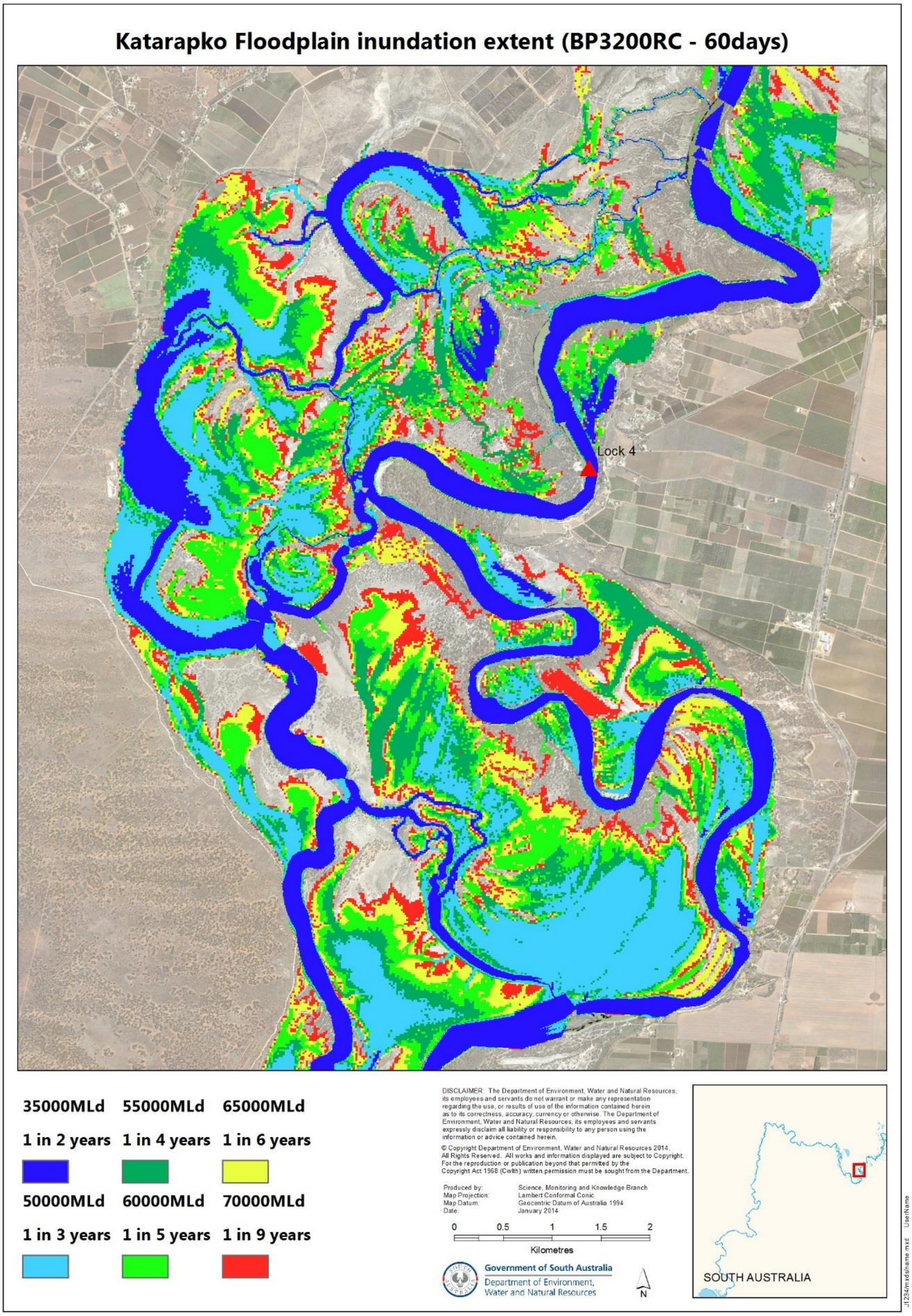

Figure 6.8 Katarapko Floodplain inundation extent – BP3200RC (60 days)

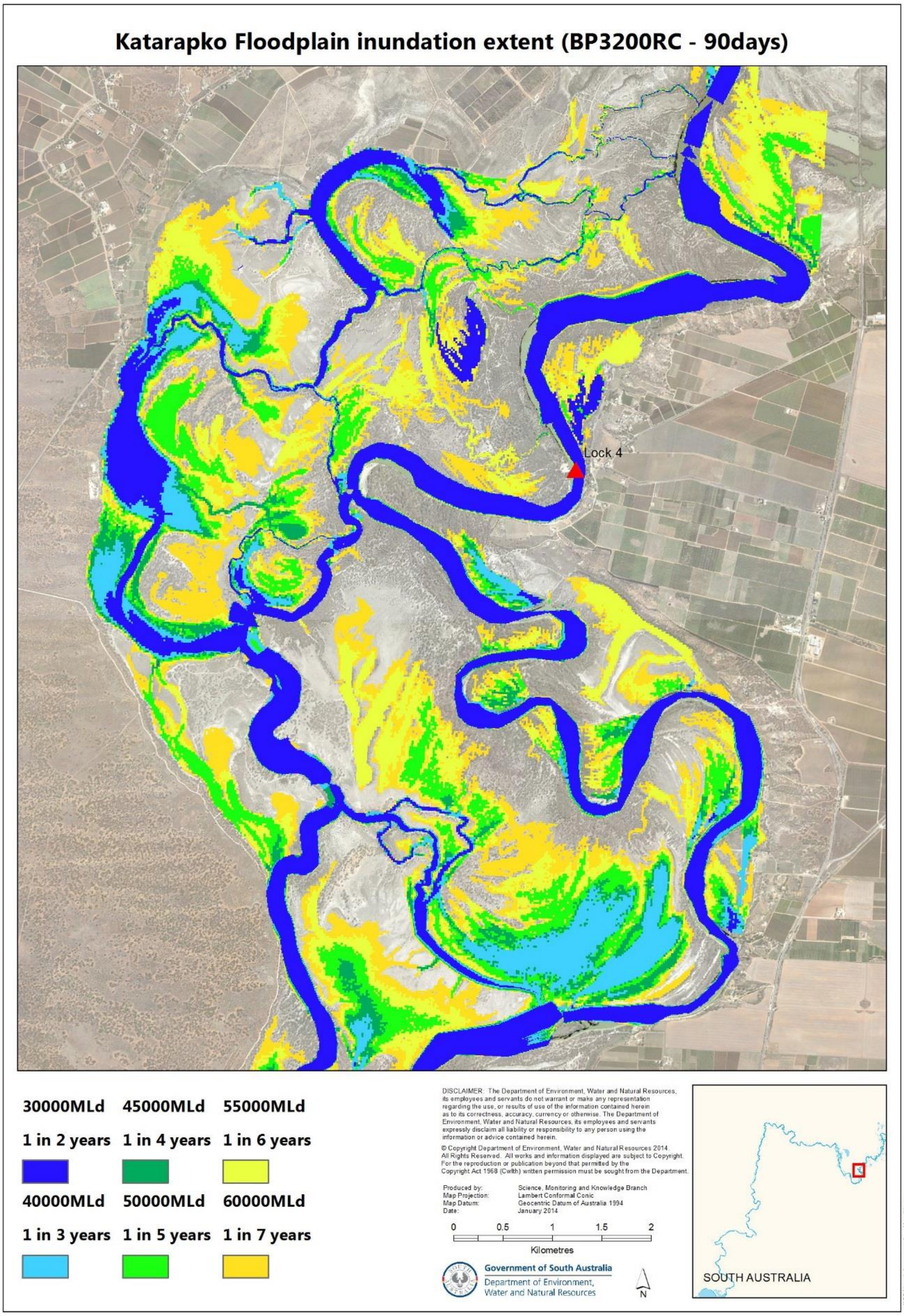

Figure 6.9 Katarapko Floodplain inundation extent – BP3200RC (90 days)

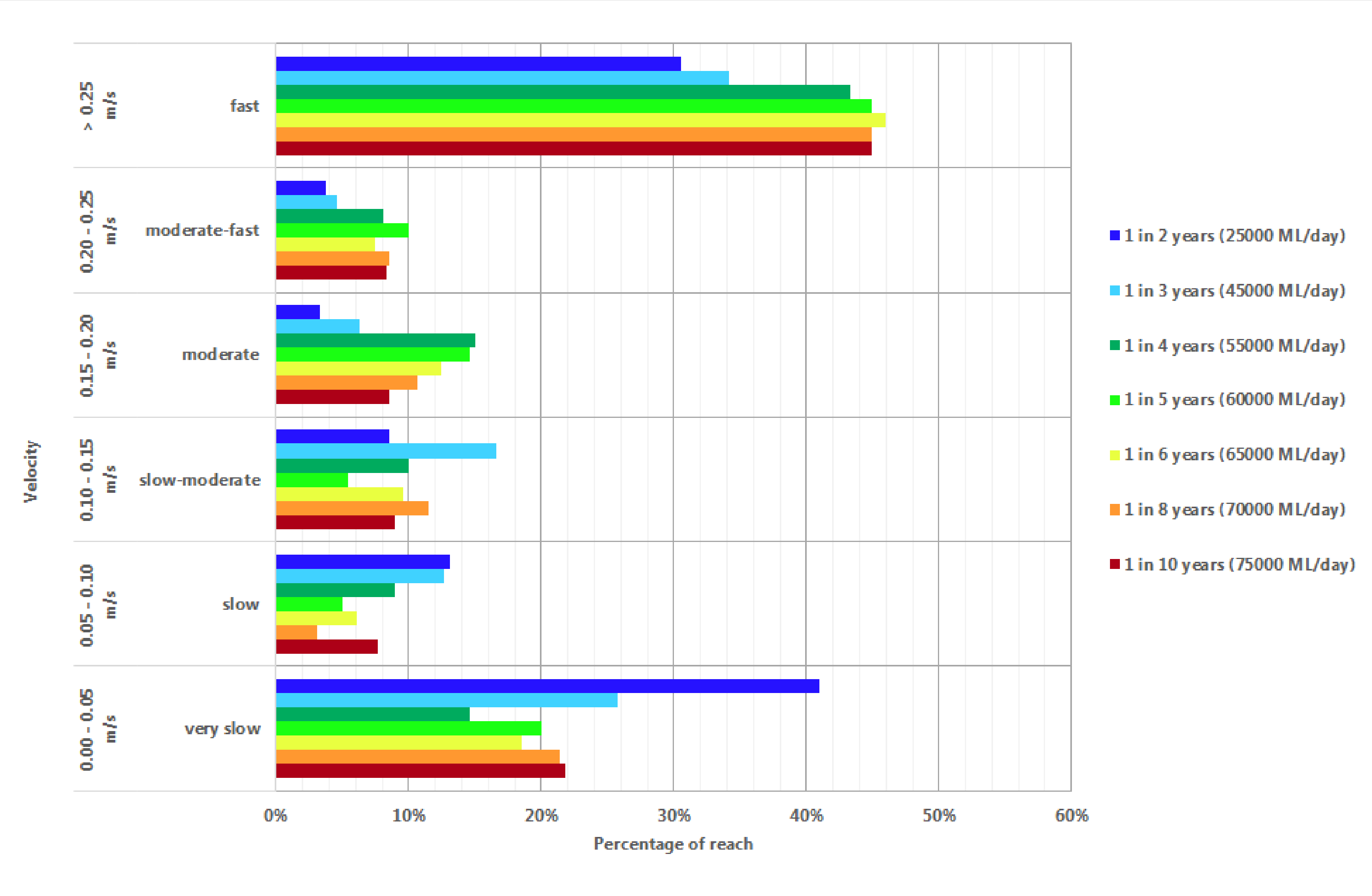

Figure 6.10 Distribution of velocity within Katarapko Floodplain – Current flow regime (30 days)

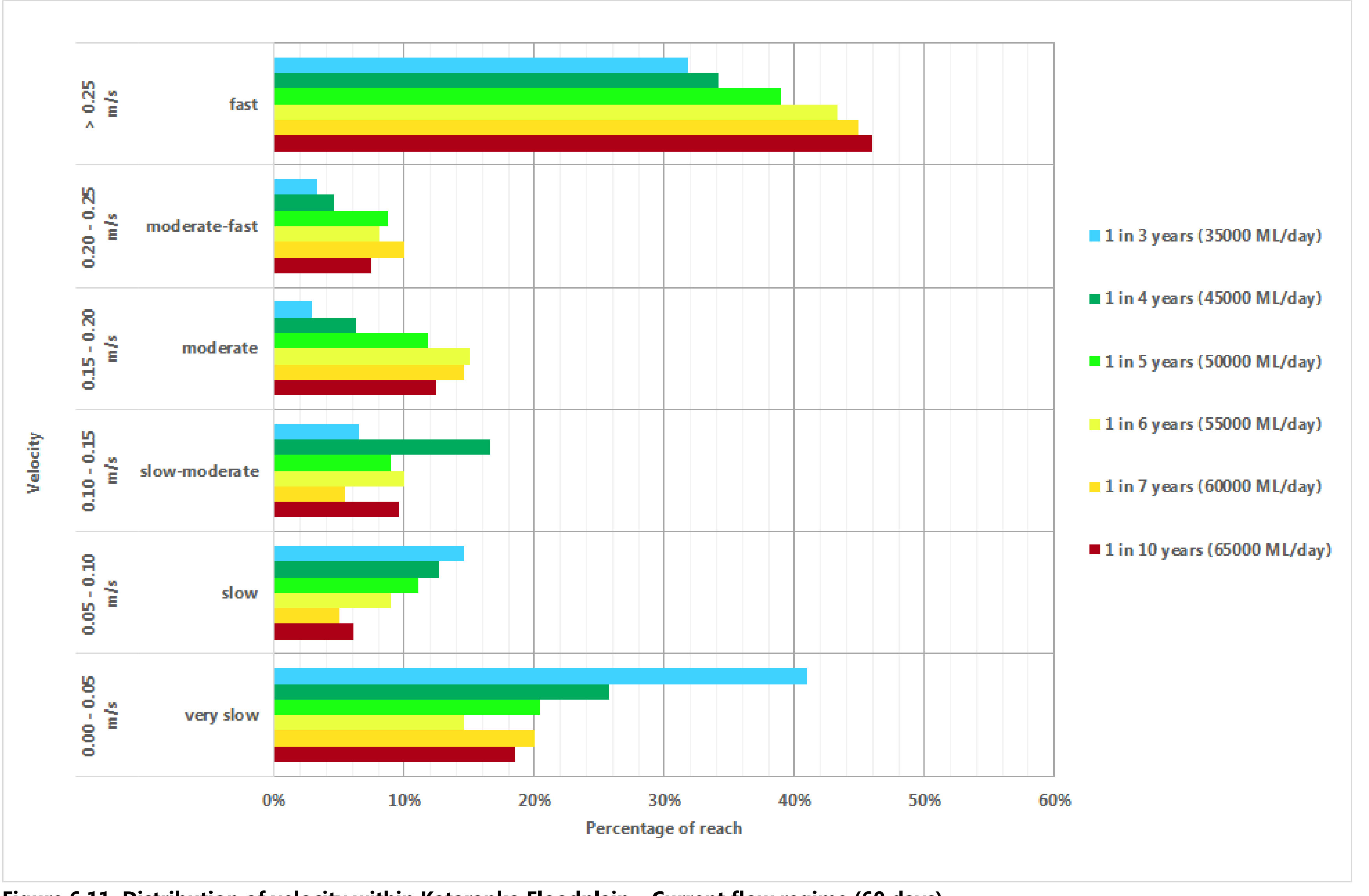

Figure 6.11 Distribution of velocity within Katarapko Floodplain – Current flow regime (60 days)

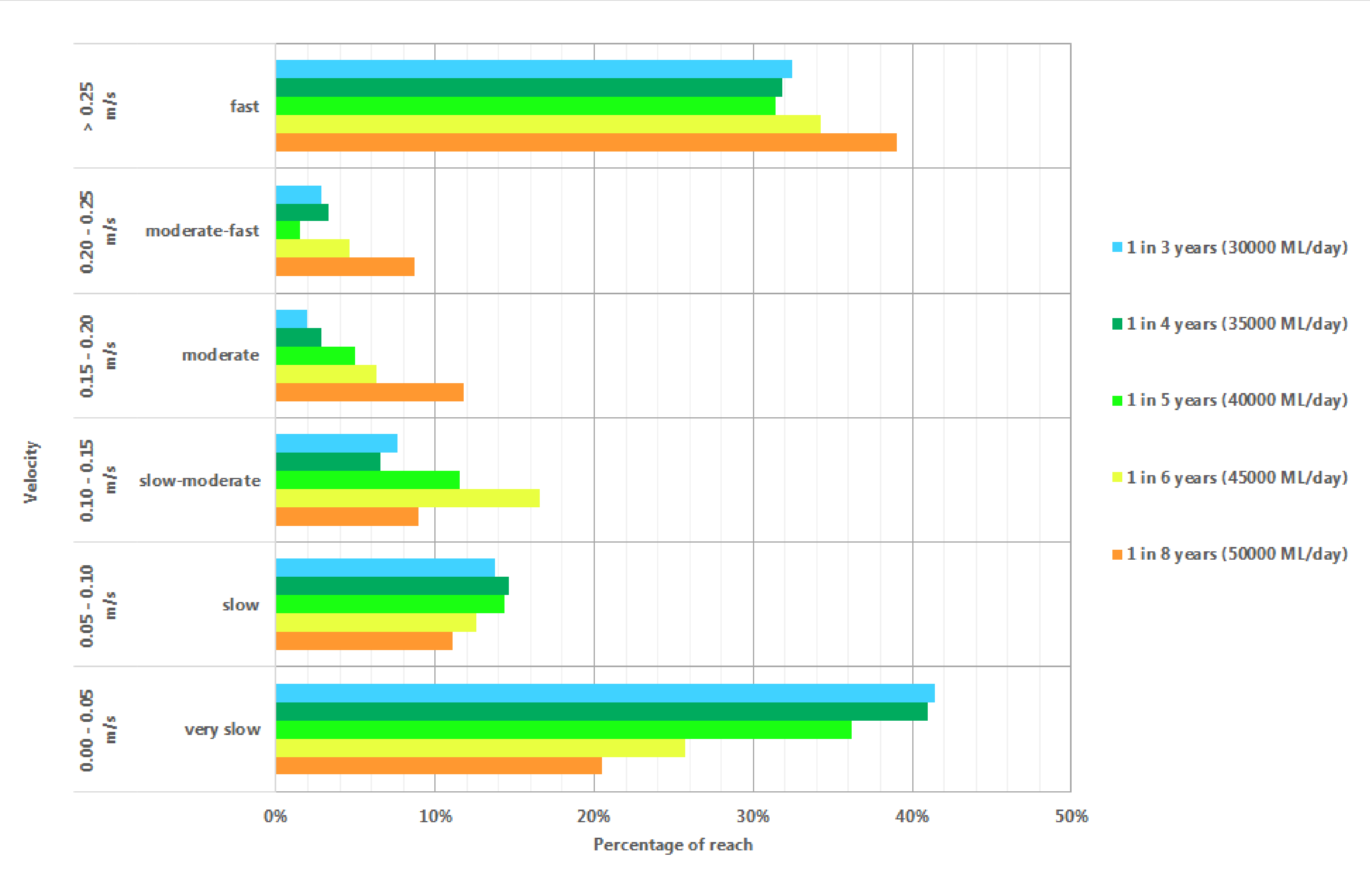

Figure 6.12 Distribution of velocity within Katarapko Floodplain – Current flow regime (90 days)

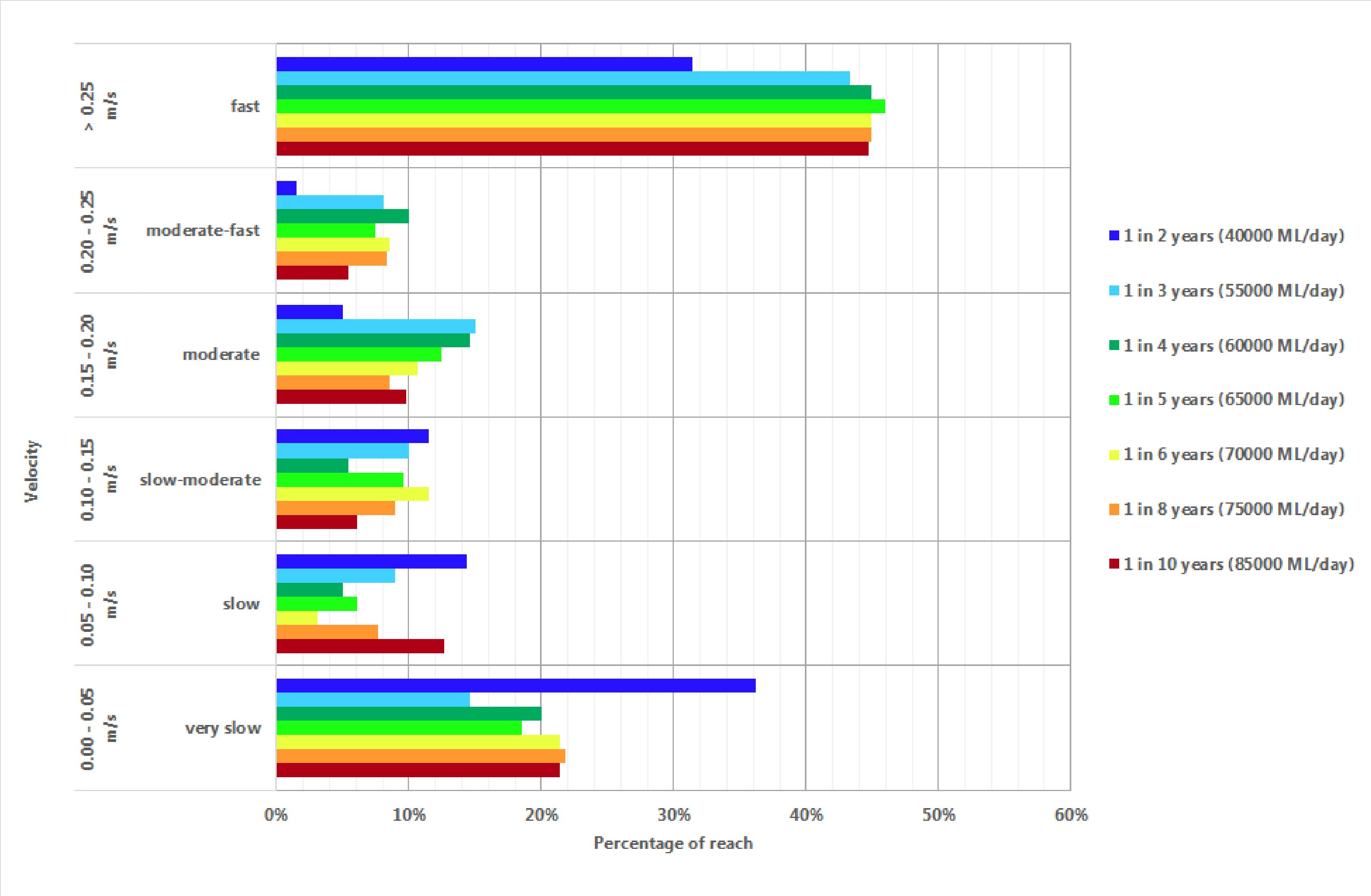

Figure 6.13 Distribution of velocity within Katarapko Floodplain – BP2400 (30 days)

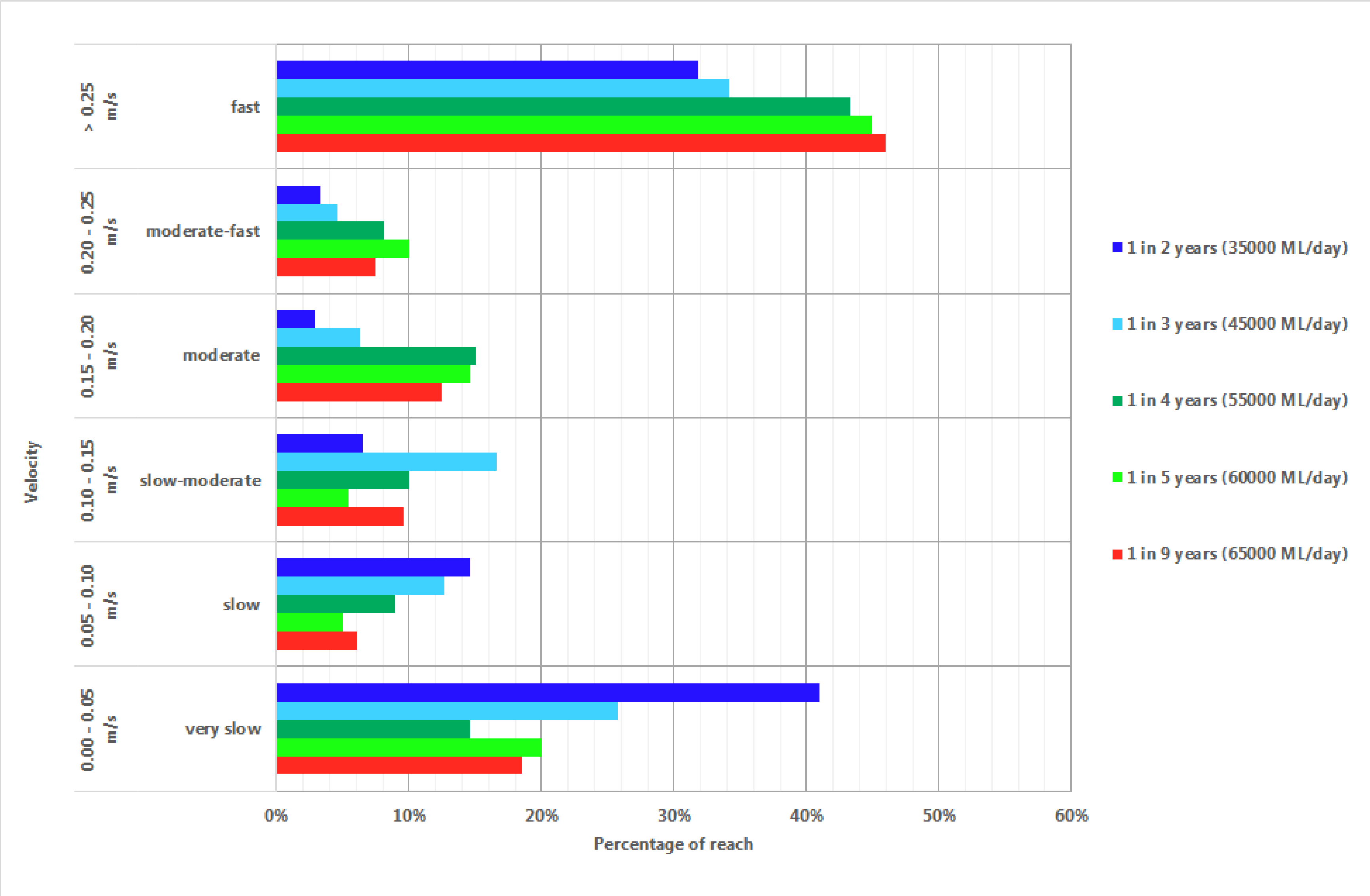

Figure 6.14 Distribution of velocity within Katarapko Floodplain – BP2400 (60 days)

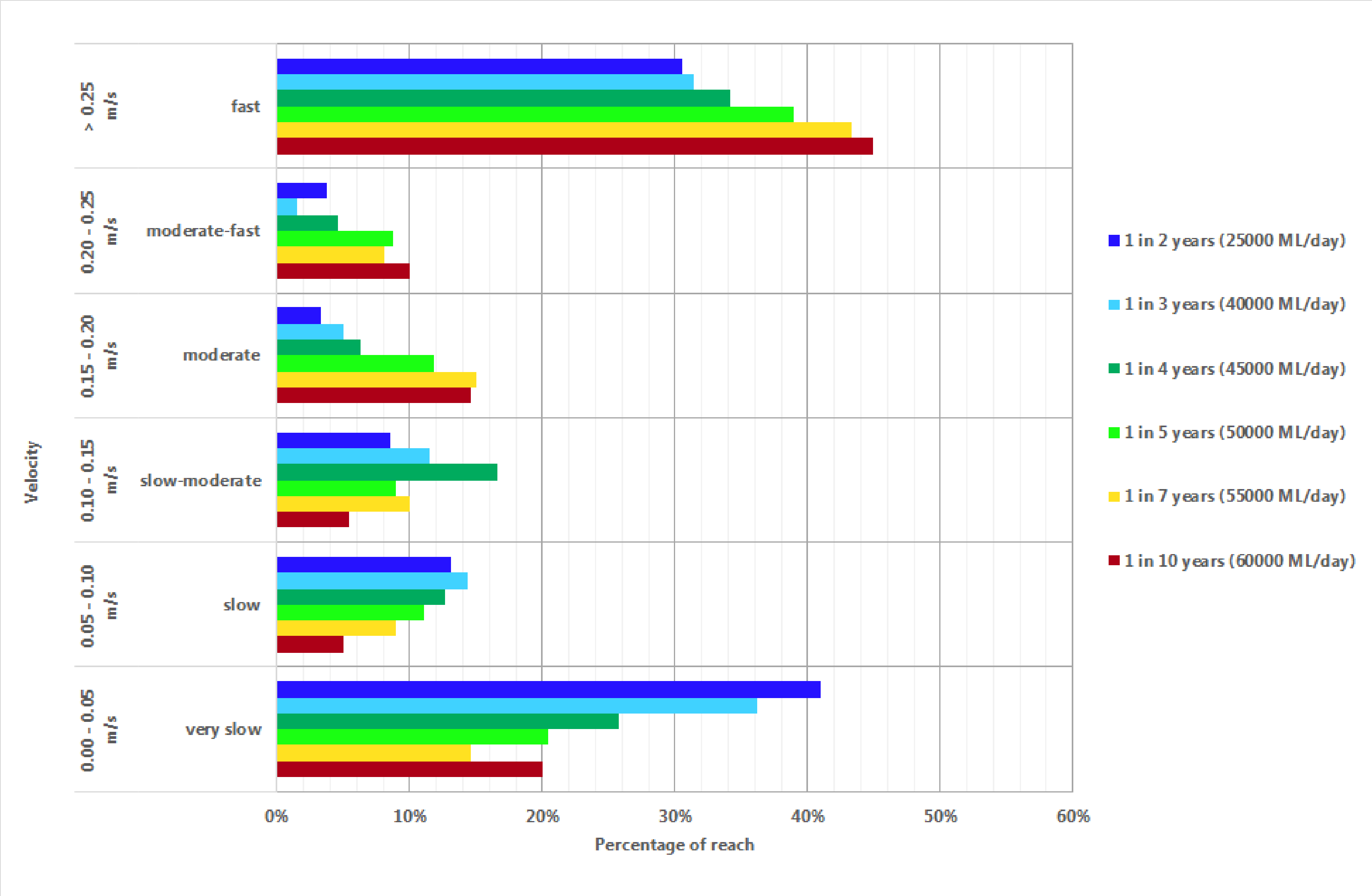

Figure 6.15 Distribution of velocity within Katarapko Floodplain – BP2400 (90 days)

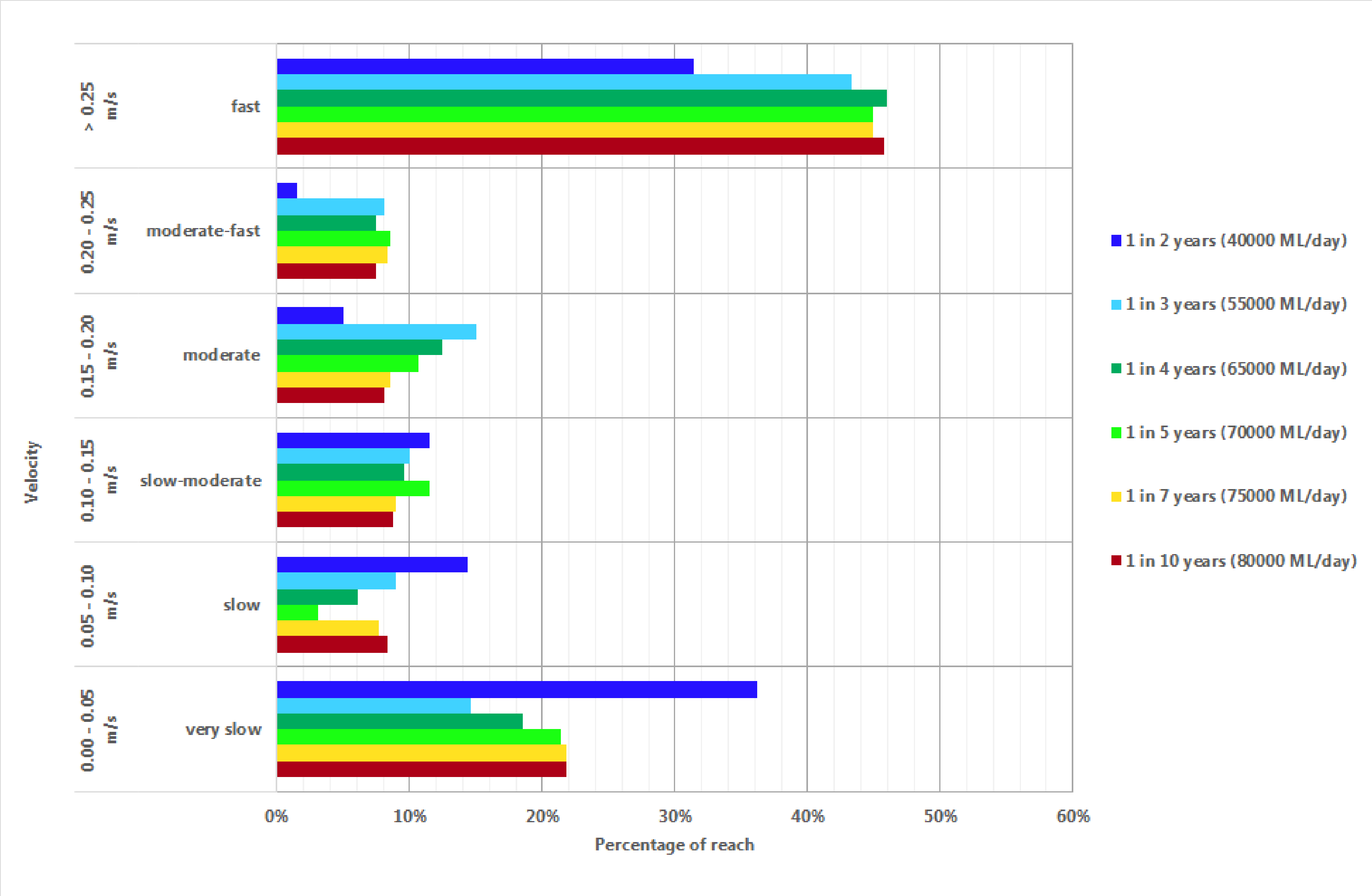

Figure 6.16 Distribution of velocity within Katarapko Floodplain – BP3200RC (30 days)

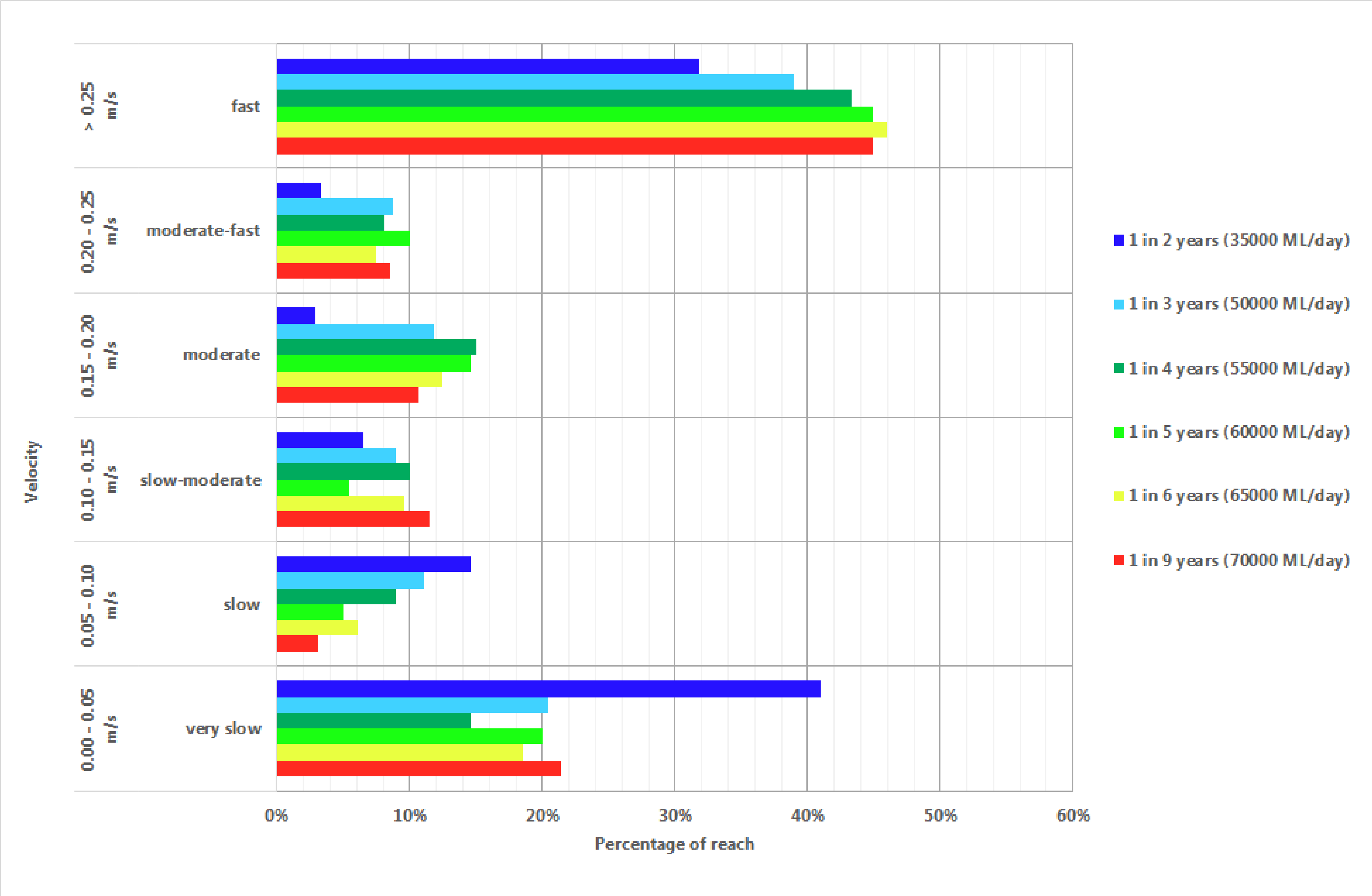

Figure 6.17 Distribution of velocity within Katarapko Floodplain – BP3200RC (60 days)

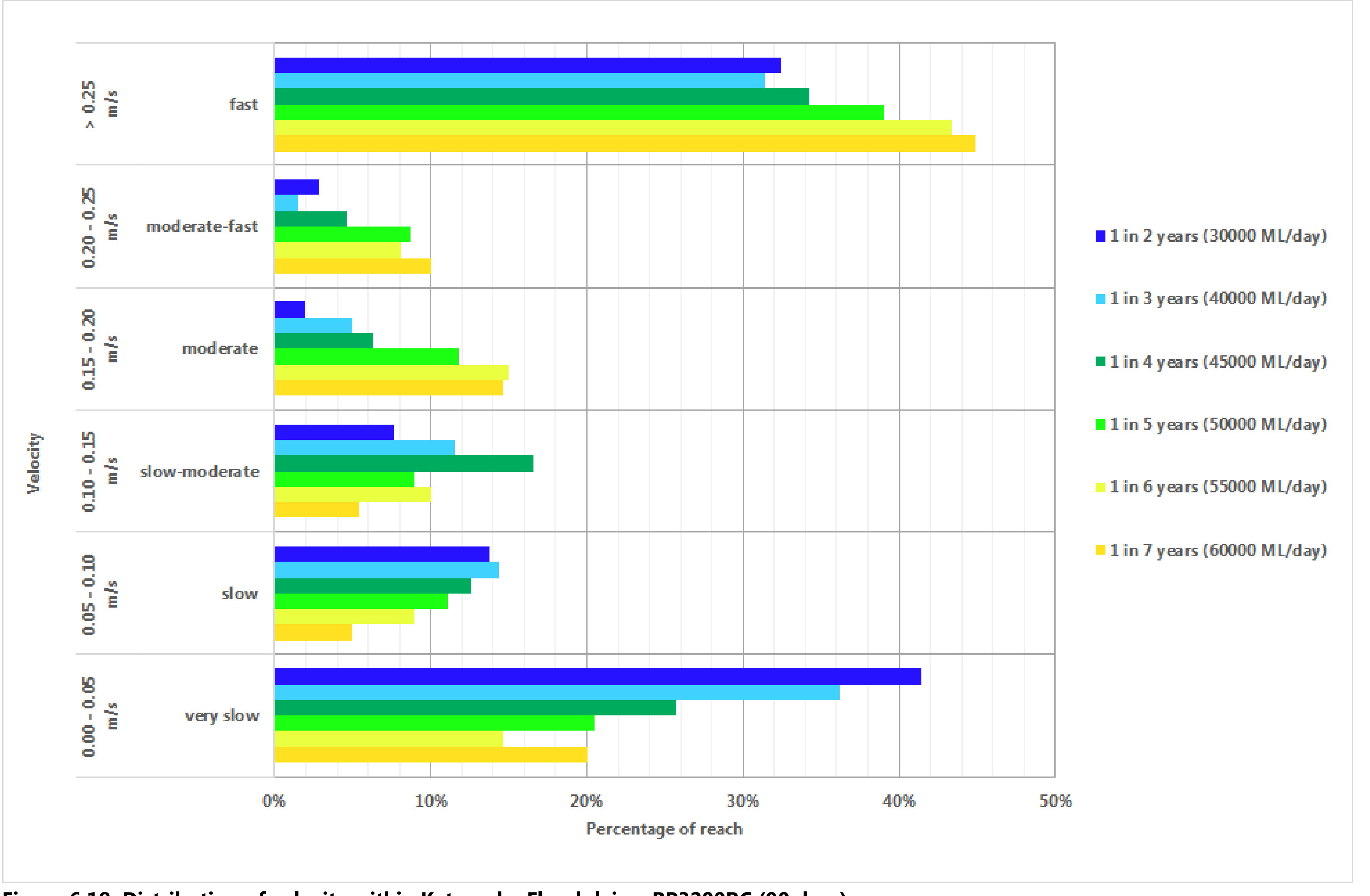

Figure 6.18 Distribution of velocity within Katarapko Floodplain – BP3200RC (90 days)

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