# 5 South Pine River Geomorphic Processes

An understanding of the geomorphic processes which drive change within the tidal reaches of the South Pine River is essential for the development of an effective management strategy.

The geomorphic processes which influence the ongoing migration of the South Pine River have been reviewed following assessment of the existing (and historical) erosion trends based on:

- Literature review findings;
- Site inspections;
- Historic landuse change review;
- Historic aerial photography and ground survey analysis; and
- Hydraulic Assessment of erosion potential.

## 5.1 Historical Erosion Assessments (Past Studies)

Previous reports have assessed the bank erosion along select reaches of the South Pine River. A summary of the findings of these previous studies is given below.

### 5.1.1 Saxton et al (2010)

Saxon *et al* assessed the historic rate of channel migration and future ongoing erosion potential for a reach of the South Pine River focused on the potential impacts on Energex infrastructure. The study extent was limited to the river reach downstream of Gympie Road to the approximate location of the Pine Rivers Private Hospital, shown in Figure 5-1.

Saxon et al used the following assessment techniques to inform their findings and subsequent recommendations:

- Historic aerial photography to assess historic migration rates; and
- Hydraulic modelling of the channel to identify sites of high erosion potential.
- The study found:
- Migration rates have increased over the past 118 years, most likely causes are:
  - Changes in upstream catchment condition as a result of clearing;
  - Gravel extraction;
  - Removal of riparian bank vegetation; and the
  - Increased frequency of bankfull discharge events.
- Channel migration rates have increased significantly since 2002 in sections downstream of the old meander loop (Section C) with a potential maximum shift in orthogonal length of 10-30m over the next 50 years, shown in Figure 5-2.

- Channel planform upstream of the cut-off (Section C) has been stable over the past 118 years and the significant lateral migration of this section of the study reach is unlikely over the next 50 years under current conditions.
- Lateral migration of the channel is likely to continue downstream of the meander cutoff (Section C). The probable migration direction is on an off-axis trajectory, which is not considered a significant risk to existing and proposed Energex infrastructure over the next 60 years.

The study recommended the following:

- Revegetation of channel banks;
- Additional modelling; and
- Permanent access points for infrastructure maintenance are recommended to be located within the upstream arm of the old meander loop, preferably at an existing disturbed site that has manageable bank slope angles that can be revegetated and stabilised.

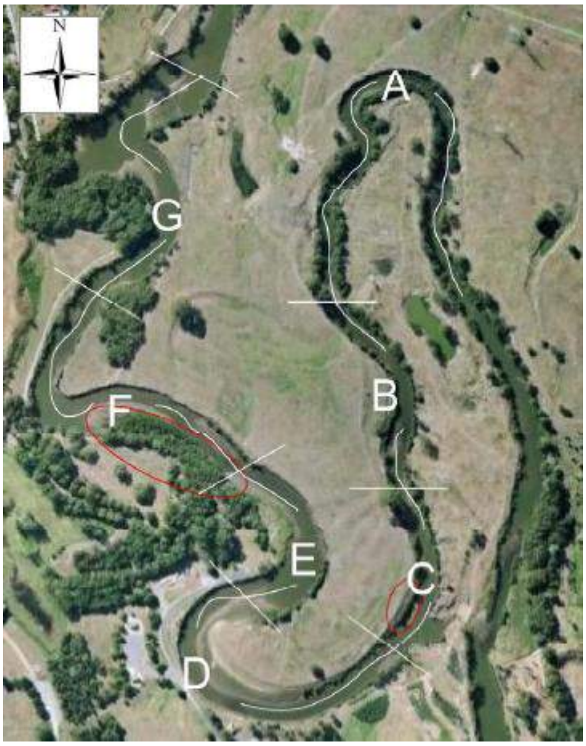
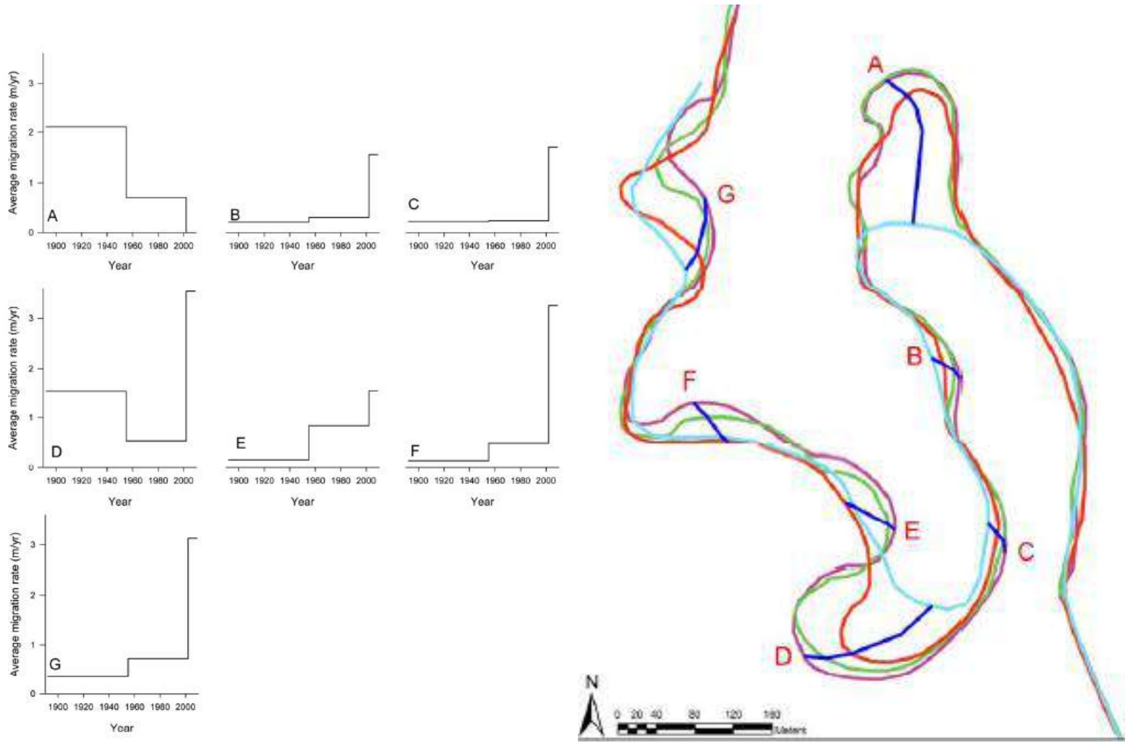



**Figure 5-1 Saxton *et al* (2010) Study Area**




*Longest orthogonals (dark blue) identified for shifts between channel centrelines dating to1892 (light blue), 1955 (red), 2002 (green) and 2009 (purple).*

**Figure 5-2 Saxton *et al* (2010) Historic Channel Migration Rate Results**

### 5.1.2 Aurecon (2010)

Aurecon investigated engineering techniques for riverbank rehabilitation and protection for a portion of the South Pine River bordering the Pine River Park which is actively eroding[8]. The primary aim of the project was to develop and implement a solution that will stabilise and rehabilitate the riverbank, simultaneously reducing riverbank erosion rates and encourage the re-establishment of marine and riparian vegetation.

The Aurecon study included the following elements:

- Assessment of historic channel migration trends;
- Review of environmental factors likely to cause the erosion;
- Geotechnical assessment;
- Hydraulic assessment; and
- Recommendation of a preferred management option.

Findings from the Aurecon study include:

Environmental Factors and Historic Channel Migration Trends

[8] Correlating to Section D from the Saxton *et al* (2010) study

- The South Pine River catchment is highly modified (not representative of its natural state). Key catchment changes since the mid 1900's which have impacted the South Pine River flow regime include:
  - Land clearing for dairy and cattle farming;
  - Loss of riparian vegetation;
  - Sand dredging and gravel extraction; and
  - Urban development.
- Bank erosion at Pine Rivers Park is the result of:
  - Regular tidal movements in the river causing erosion at the toe of the river bank. Erosion at the toe then leads to failure of the lower bank and in turn causes failure of the upper bank; and
  - High flow velocities associated with catchment flood events.
- Rate of migration estimates support those reported by Saxton et al (2010).

Geotechnical Assessment

- The riverbank is cut into Quarternary Alluvium consisting of a basal bed of gravel and sandy gravel overlain by beds of gravelly sand/sandy gravel with fines under a surface layer of clay and/or silt.
- The surface clay layer and the clay fines within the intermediate gravelly sand/sandy gravel layer display dispersive tendencies, particularly once saturated and/or mechanically disturbed.
- Fretting and undercutting caused by clay dispersion is a contributing factor to the progressive collapse of the riverbank.
- Slope stability modelling showed that the existing bank profile has factors of safety lower than the normally accepted values.
- A re-shaped bank profile with a slope of 1V:3H was recommended to provide adequate short and long term factors of safety.
- It was also recommended that the re-shaped bank profile be taken down to the river bed level.
- The dispersive effects of the clay may be controlled by the placement of a geofabric layer over the reshaped bank.

Hydraulic Assessment

- The reach of Pine Rivers Park is subject to constant tidal movement which is a significant contributing factor to bank erosion:
  - Peak velocities of up to 2.3 m/s at the outer bank are predicted during major flow events;
  - In light of the above, a "hard" engineering solution is essential to provide protection to the lower bank. Rock riprap armouring is considered a suitable protection method for the lower bank; and

- “Facing” rock class is recommended to be provided to a depth of 0.5 m and with d50 = 0.3 (ie 50% of rock should have diameter 0.3 m). It is noted that adopting this class of rock provides minimal factor of safety against the calculated velocities. (“Facing” rock riprap is designed to withstand velocities in the range of 2.0 to 2.6 m/s).

- The proposed development is predicted to have negligible impact on both water levels and velocities.

**Preferred Management Option**

- Revegetation of the upper bank and establishment of a riparian corridor;
- Bank battering/terracing;
- Jute matting on the upper bank;
- Geofabric layer on the lower bank;
- Rock riprap protection at the toe of the bank; and
- Revegetation on the lower bank.

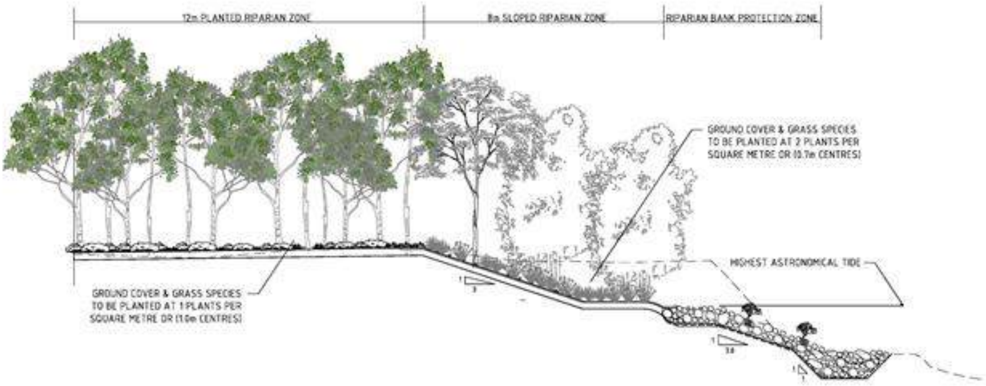



**Figure 5-3 Aurecon (2010) Recommended Mitigation (Cross-section)**

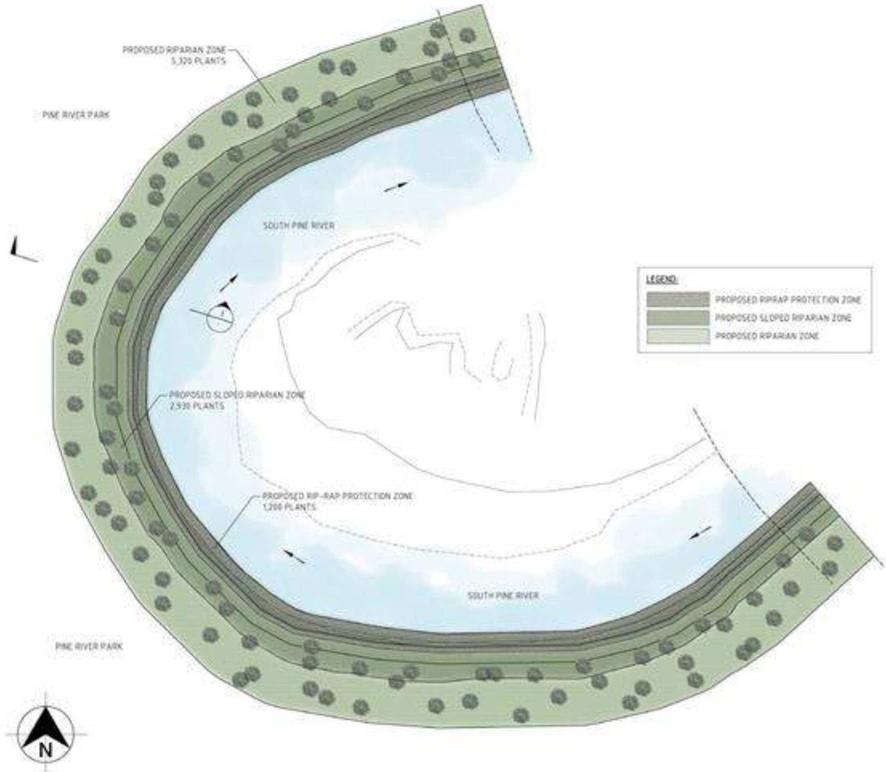



**Figure 5-4 Aurecon (2010) Recommended Mitigation (Plan View)**

### 5.1.3 Alluvium Consulting (2011)

Alluvium Consulting (2011) assessed options for stabilising a reach of South Pine River to the east of the Pine Rivers Park, shown in Figure 5-5.

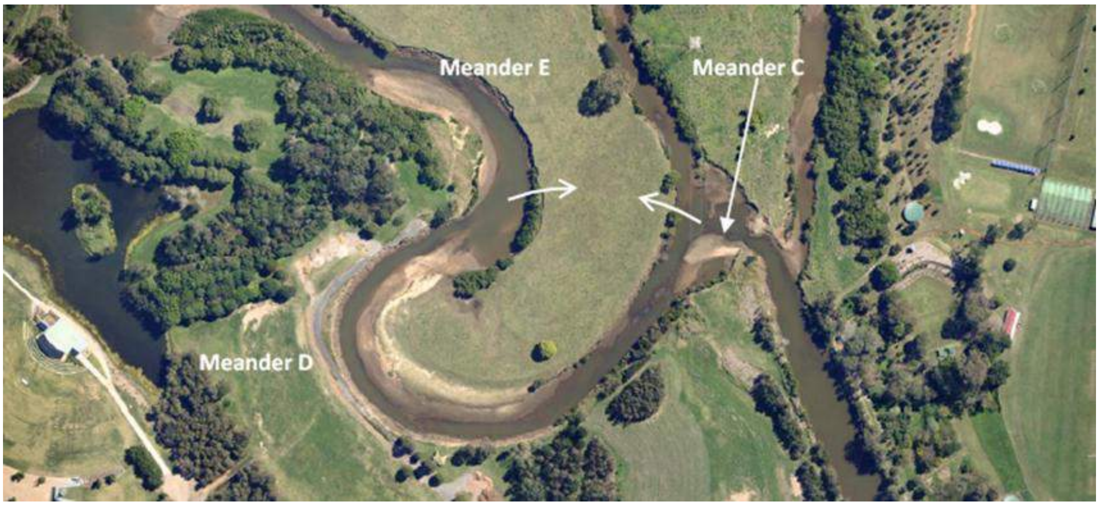



**Figure 5-5 Alluvium Consulting (2011) Study Area**

The study aimed to:

(1) Analyse relevant available information to infer the likely future trajectory of change of the river at the study site.

(2) Identify a range of options for bank stabilisation treatments, reviewing their advantages and disadvantages in relation to the management objectives and likely geomorphic trajectory.

The Alluvium Consulting study found that Meander D eroded at a rate of between 1-1.5m/year between 2009 and 2011. This rate is consistent with the accelerated average migration rate of the river bend documented by Saxton et al (2010) for the post 2002 period.

If erosion continues along the trajectories indicated at Meanders C and E in Figure 5-5, this may lead to Meander D becoming cut-off and any erosion protection work in Meander D becoming redundant.

The Alluvium Consulting study recommended:

- Implementation of an ongoing monitoring program measure the rate of bank retreat.
- Consideration of soft engineering bank stabilisation measures to mitigate current accelerated migration of Section D, shown in Figure 5-6.
  - Armouring of the bank toe using large wood and mangrove planting within the range of tidal water level fluctuations;
  - Battering of the bank to reduce the slope to 1V:3H and erosion matting; and
  - Revegetation of the bank above the large wood toe protection bank and greater riparian zone.
- Hard engineering works aligned with the MBRC's limits of acceptable channel migration (40m setback from the 2011 top of bank location).

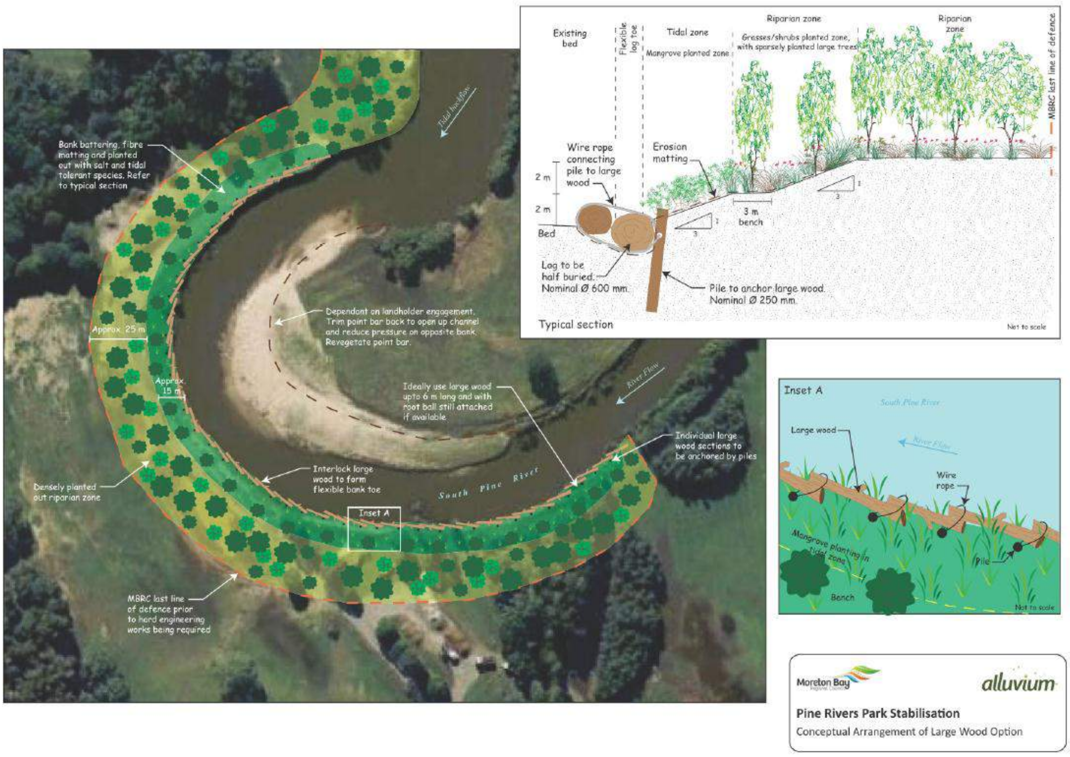



**Figure 5-6 Alluvium Consulting (2011) Recommended Mitigation**

## 5.2 Observations of Existing Condition

Recent inspections of the riverbanks within the study area have been carried out by boat to identify their present state. These inspections indicated varying levels of erosion stress. The current degree of erosion is shown in Figure 5-14, in the following qualitative terms.

- Extreme Erosion Risk (No Erosion Protection, High Rate Eroding Bank) - Exhibiting active bank slumping, often with clean vertical scarps and recent vegetation loss. See Figure 5-7 for example.
- High Erosion Risk (No Erosion Protection, Slow Rate Eroding Bank) - Showing lower rates of bank erosion, albeit with some bank slumping. See Figure 5-7 and Figure 5-8for example.
- Moderate Erosion Risk (Hard Engineering Protection, Eroding Bank) – Areas of past extreme or high erosion risk which have been mitigated using hard engineering protection (e.g. armouring). See Figure 5 9 for example.
- Low Erosion Risk (No/Limited Riparian Vegetation, Stable Bank) – Vegetated areas exhibiting no signs of erosion. This area is typically located low velocity areas, either associated with:
  - Sediment deposition zones adjacent to Extreme or High Erosion risk areas; or
  - Along inside bends of the river.
- See Figure 5-11 for example.
- Low Erosion Risk (Riparian Vegetation, Stable Bank) - Older erosion scarps (possibly flood related) have been revegetated with grass and small trees or where mangrove roots are being slowly exposed with the general lowering of the bank level. See Figure 5-12 for example.

Example pictures demonstrating the above listed erosion risk bank types is provided in Figure 5-7 to Figure 5-12.

Figure 5-7 Extreme Erosion Risk Example

Figure 5-8 High Erosion Risk Example

Figure 5-9 Moderate Erosion Risk Example (Learmonth Street)

Figure 5-10 Moderate Erosion Risk Example (Pitonga Way)

Figure 5-11 Low Erosion Risk (No Riparian Vegetation) Example

Figure 5-12 Low Erosion Risk (Riparian Vegetation) Example

### 5.2.1 Observations

The erosion appears to be greatest in the non-vegetated meandering portion of the South Pine River within the reaches between Gympie Road and Harvey Street. Of particular note was the evidence of high rate of erosion on the outside bend of the meander adjacent to Pine River Park. The erosion in this location is currently undercutting a minor road within the Park.

Erosion of non-vegetated areas downstream of Harvey Street was observed. The erosion rate downstream of Harvey Street to the confluence of the South and North Pine Rivers appeared less than upstream of Harvey Street. This is likely due to the sinuous orientation of the river upstream of Harvey Street resulting in accelerated erosion rates along the numerous river bends. In comparison the South Pine River is more linear in orientation downstream of Harvey Street.

Hard engineering protection was identified in two locations within the study area:

- Fronting the residential properties along Learmonth Street. A boat ramp is located immediately south of these properties at Bob Bell Park. Properties on the left bank of the river are located in the vicinity of an outside river bend, and are, therefore, exposed to a risk of bank erosion. Property owners have used erosion protection (mostly rock armouring) to mitigate this bank erosion risk (refer to Figure 5-9), which appears to be in good condition and effective.

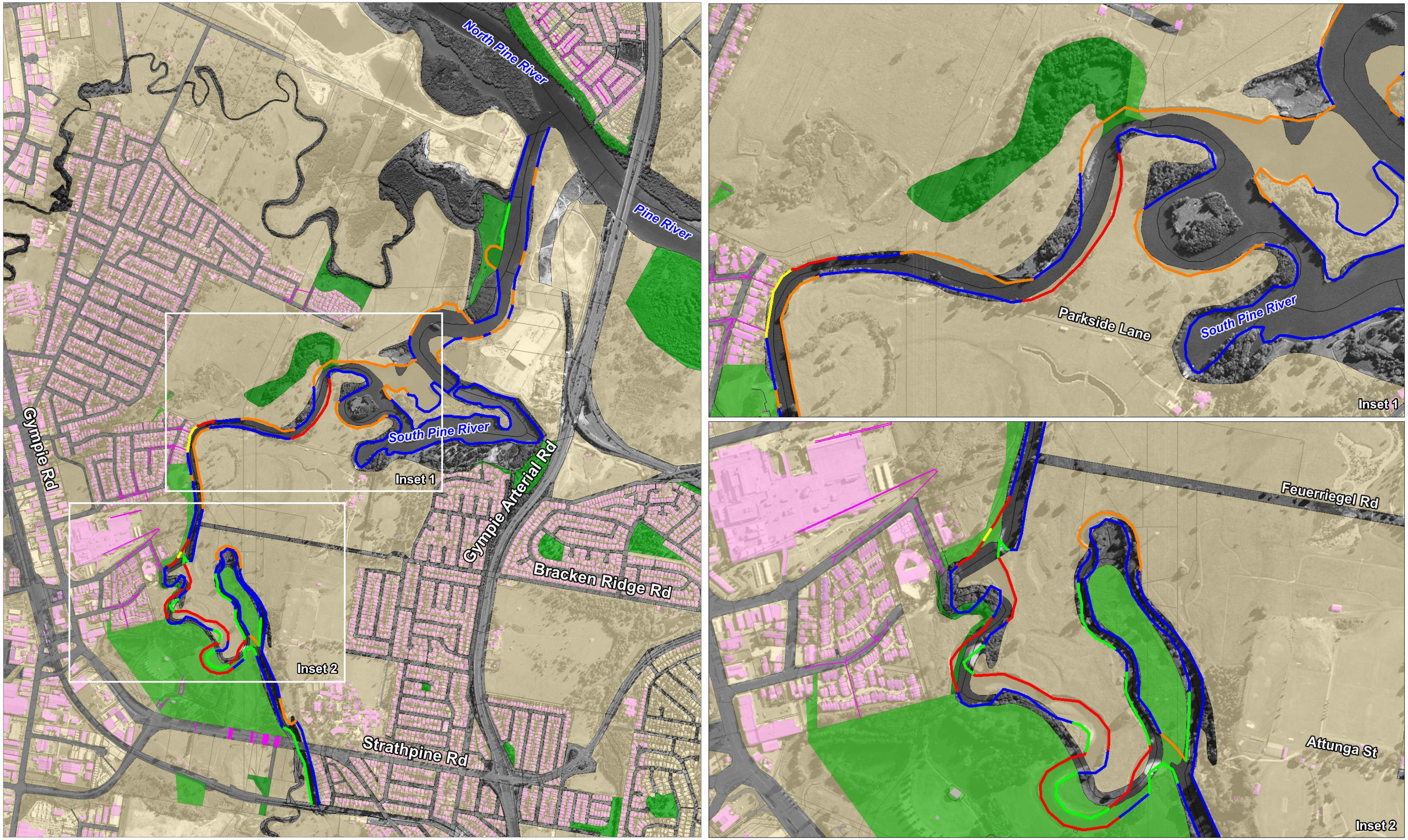
  The structural protection is limited to the location of residential property river frontage, which terminates on the apex of the river bend. Immediately downstream of the structural erosion protection, erosion on the river bank is evident by the steep bank slopes (see Figure 5-13). However, there is little evidence that the structural erosion protection is impacting on the rate of erosion immediately downstream; i.e. the bank alignment remains relatively continuous (see Figure 5-13).

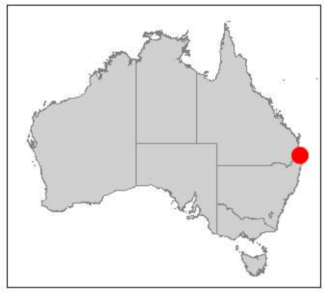
  The structural erosion protection has altered the natural erosion processes at this location. In time, the apex of the river bank may migrate further north, away from the residential property; therefore reducing the erosion risk to the residential area. Whereas, the migration of the river bend may have been through the northern section of the residential area under natural conditions.

**Figure 5-13 Learmonth Street Erosion Protection**

- Adjacent to the Pitonga Way, downstream of the Pine River Hospital – rock filled gabion baskets above the high tide line (refer to Figure 5-10). This erosion protection structure is relatively high up the bank, and was installed in a localised pocket of bank scour. It is aimed at stabilising the steep bank and providing erosion protection during significant flood events to protect a public footpath close to the river bank. The structure is relatively new and there are no signs of bank erosion impacts upstream or downstream of the structure.

Reaches of the river that were either densely vegetated or alternatively located in low velocity areas (e.g. inside river bends, sediment deposition areas) appeared to have stable banks, exhibiting limited erosion or in some cases bank accretion.



**LEGEND**

**EROSION RISK**

- Low Risk (Riparian Vegetation)
- Low (No/Limited Riparian Vegetation)
- Moderate (Hard Engineering Protection)
- High
- Extreme

**MBRC LANDUSE/INFRASTRUCTURE**

- Freehold Land
- Parks
- Road and Rail
- Building Footprints (Adjacent to River Only)
- Stormwater Network
- Cadastre Boundary

Title:

**South Pine River Erosion Risk Mapping**

Figure: **5-14**

Rev: **A**

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Main Map Scale

0m 150 300
Inset Scales

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## 5.3 Historical Catchment Change and Bank Migration

A combination of historic aerial photography and Airborne Laser Survey (ALS) has been used to undertake:

- Qualitative assessment of the land use changes within the catchment; and
- Measurement of bank migration along the river for various dates.

The following datasets have been used for this assessment:

- Historic aerial photography (supplied by MBRC): 1958, 1972, 1978, 1981, 1982, 1983, 1987, 1991, 1994, 1997, 2002 and 2009; and
- Airborne Laser Survey (ALS) data (supplied by MBRC): 2009 and 2013.

### 5.3.1 Catchment Development

The South Pine River catchment is highly modified from its natural state. Significant catchment changes have the potential to impact the catchment runoff and river flow conditions, and subsequently affect the rivers geomorphic processes. Significant catchment changes and implications for river morphology within the South Pine River include:

(1) Historically, land has been extensively cleared in the Pine River catchment area for dairy and cattle farming, which was the primary land use from the 1860's (Pine Rivers Catchment Association).This has resulted in the following:

(a) More persistent freshwater runoff,and increased flood flows. This intensifies normal meandering processes by increasing the power of the river to remove scoured sediment.

(b) Since riparian vegetation naturally helps to stabilise creek and river banks from erosion, removal of riparian vegetation in the South Pine River has increased the rivers susceptibility to bank erosion.

(2) Extensive sand dredging and gravel extraction activities have occurred within the catchment. In addition to offline extraction sites, a number of smaller dredging operations exist for the purpose of improving or maintaining the existing waterways, primarily in the downstream reaches, approaching the confluence of the South Pine and Pine Rivers (Aurecon, 2010).

(a) Dredging of the South Pine and Pine Rivers alters the tidal prism of the respective river systems. Increased tidal prisms at the river entrances results in increased tidal flow velocities in upstream reaches.

(b) Dredging creates a major 'sink' for fluvial sediment and may starve downstream areas of sediment supply, leading to progressive bed and bank erosion until the bed becomes armoured with coarser material after finer material has been carried downstream.

(3) Shortening of the South Pine River stream length.

(a) Gravel extraction pit embankments in the lower South Pine River were breached sometime in the early to mid1980's[9]. The breach resulted in a new dominant flowpath being formed, shortening the stream length of the South Pine River by approximately 1.5km. The breach location is highlighted in Figure 5-15.

(4) Significant portions of the South Pine River catchment are urbanised. Changes in catchment urbanisation from 1958 to 2002 are presented in Figure 5-15.

(a) Urbanisation increases the proportion of the impervious area within a catchment. This results in increased catchment runoff volumes and decreased runoff response times. The combination of these responses generally increase freshwater environmental and flood flow velocities.

[9] Aerial imagery suggests this breach occurred sometime between 1983 and 1987.


**Figure 5-15 South Pine River Catchment Landuse Change**

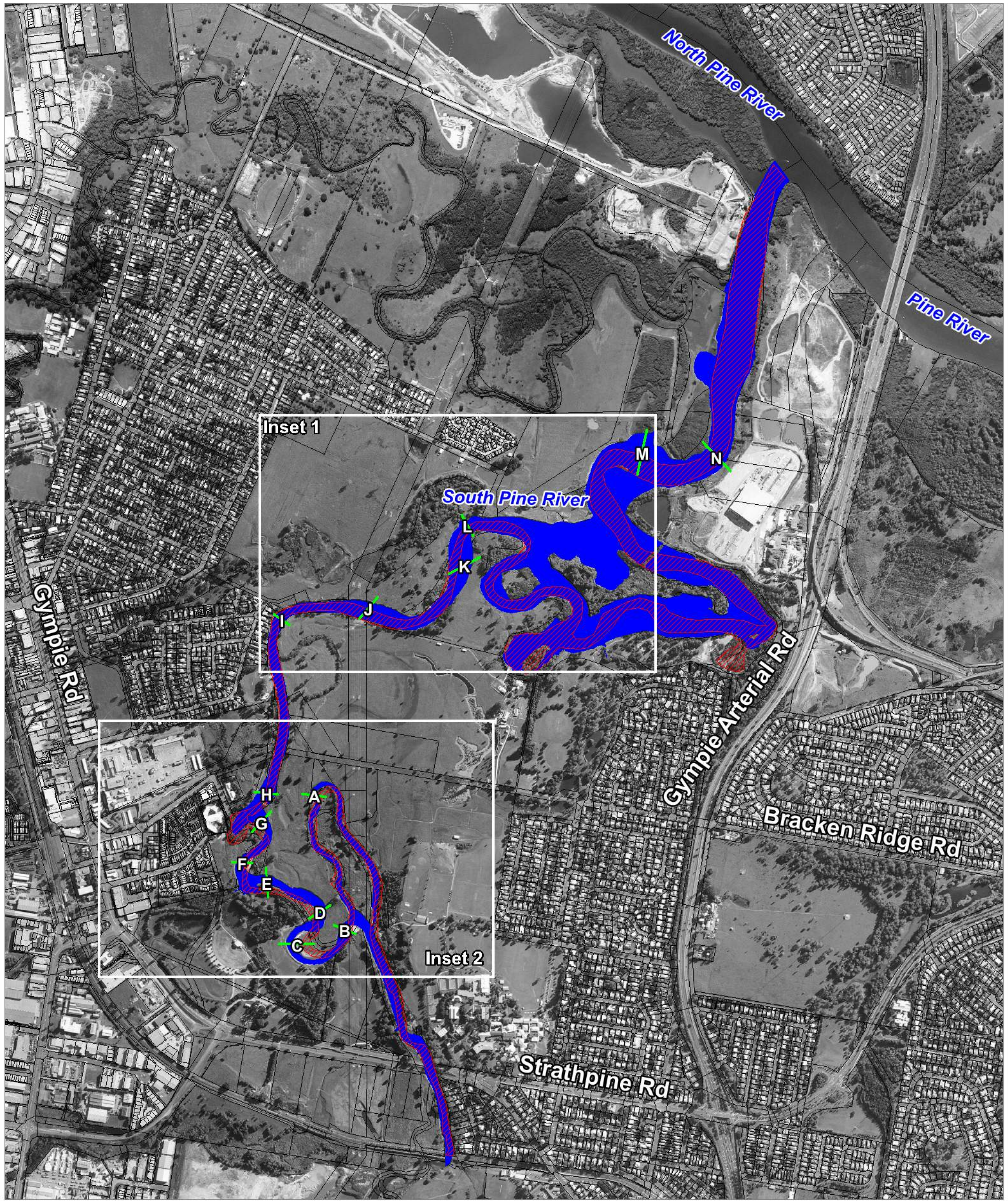
### 5.3.2 Riverbank Migration

Riverbank migration was determined by reference to fixed features (e.g. roads) common to successive dates of photography. An accuracy of about ±2m was possible for each case. Changes in historic riverbank migration rates have been calculated for 14 locations. These locations are highlighted in Figure 5-16. The LiDAR for years 2009 and 2013 are compared in Figure 5-17.

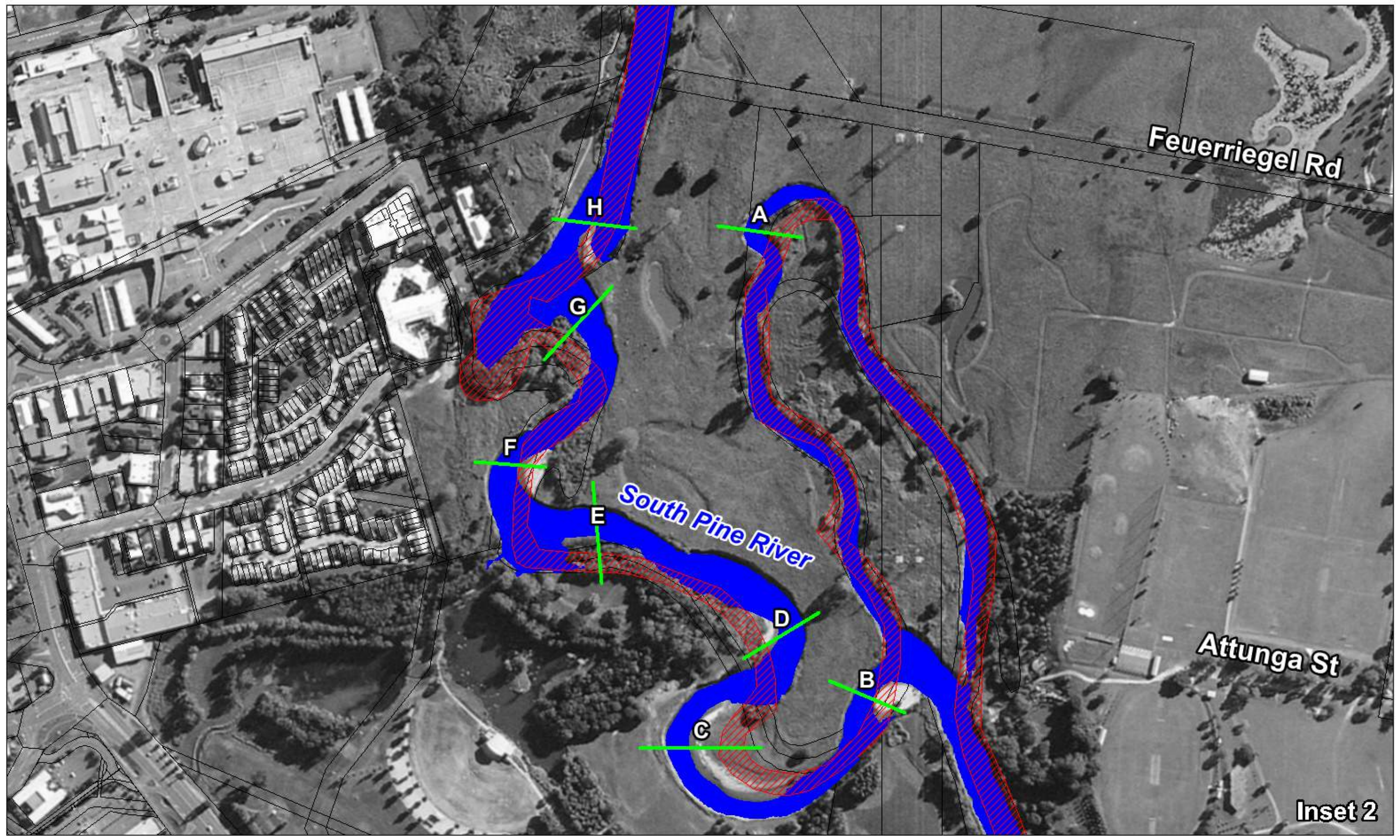
The historic riverbank migration rate assessment results are presented in Figure 5-18 to Figure 5-31. The results highlight that the South Pine River is presently actively eroding / meandering in many of the assessed reaches. General trends observed from the results include:

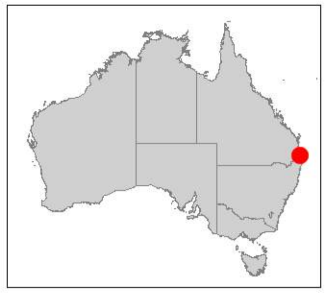
- Most reaches experience increased average channel migration rates during the late 1980s/early 1990s and post 2009. These increased rates occurred as a result of climatic conditions which were wetter than average, resulting in a more regular catchment flood events (refer to Figure 4-1).
- Major river alignment changes have occurred as a result of channel breaches in two locations within the study area. These breaches cause major changes to the river hydrodynamics, and subsequently have a major impact on the surrounding river morphology.
    - Sometime between 1983 and 1987 the main channel of the South Pine River was shifted significantly after the embankment to a sand/gravel extraction pit was breached (refer to Figure 5-15). This breach shortened the stream length of the South Pine River by approximately 1.5km. This change in river condition resulted in increased bank migration rates upstream and downstream of the breach location for a period of up to 10 years. The most pronounced impacts are observed within the results for Reach J, K, L M and N. These reaches are all within 1km of the breach location.
    - Sometime between 2002 and 2009 the meander upstream of Reach B was breached (see Figure 5-32). This has resulted in the meander loop on which Reach A is located being bypassed. This major change in flow path is currently resulting in:
        - Stabilisation of the Reach A. Significant future migration of Reach A is unlikely whilst this meander loop is cut off from the main river channel.
        - Reach B bank migration rates increasing, eroding towards Reach D.
- Presently, all upstream reaches on the main channel of the South Pine River (Reach B, C, D, E, F and G) are actively eroding at a rate greater than the long term average. According to recent aerial photography (2009 to 2013), these reaches are eroding at an approximate rate of 2.5m/year to 3.5m/year (except reach G, which is eroding at approximately 1.5m/year). However, recent erosion rates should be interpreted in the context of recent, relatively infrequent, flood events on the South Pine River.
    - This erosion trend is impacting MBRC infrastructure at Reach C and F.
    - There is potential that that Reach B may breach through to Reach D in as little as 20 years if these erosion rates are sustained. If this occurs, this major river alignment change will result in Reach C no longer being part of the main river channel, significantly reducing the erosion rates in this location.

- Reach I has historically had a stable orientation. This is due to hard engineering erosion protection measures along the western bank of the South Pine River in this location.
- Downstream of Reach I, Reaches J and K are also are actively eroding at a rate greater than the long term average. These reaches are meandering, placing increased stresses on the outside bend of the river.
    - The off axis meandering of Reach K has the potential to alter the flow distributions which impact Reach L. This may increase the future channel migration rate at Reach L.
- Reach M and N, closest to the Pine/South Pine River confluence have been relatively stable since the mid 1990's.







**LEGEND**

- Reach ID
- River Alignment - 1958
- River Alignment - 2013
- Cadastre Boundary

Title:

# River Bank Migration Assessment Locations

Figure: **5-16**

Rev: **A**

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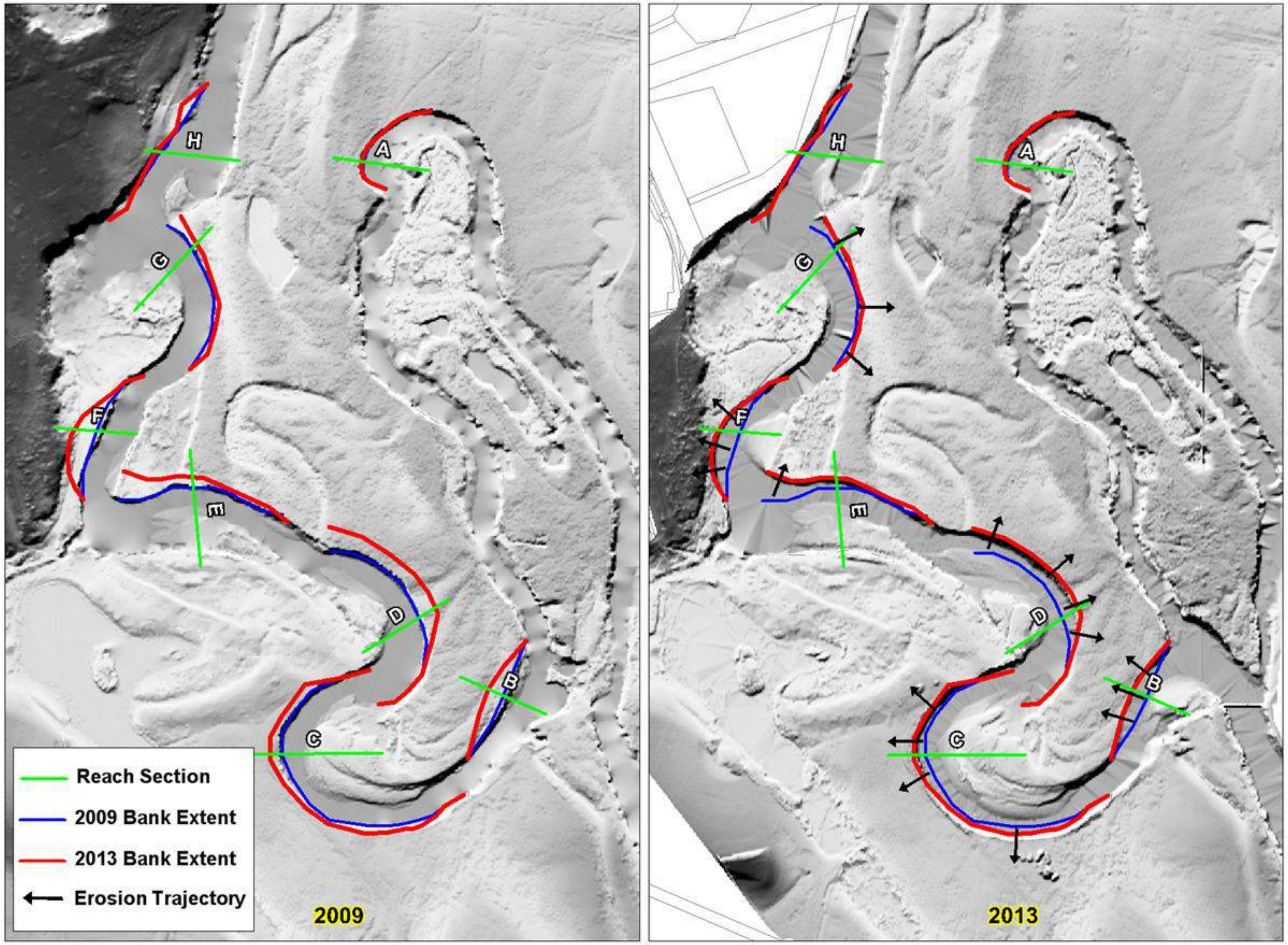



**Figure 5-17 LiDAR Comparison for Years 2009 and 2013**

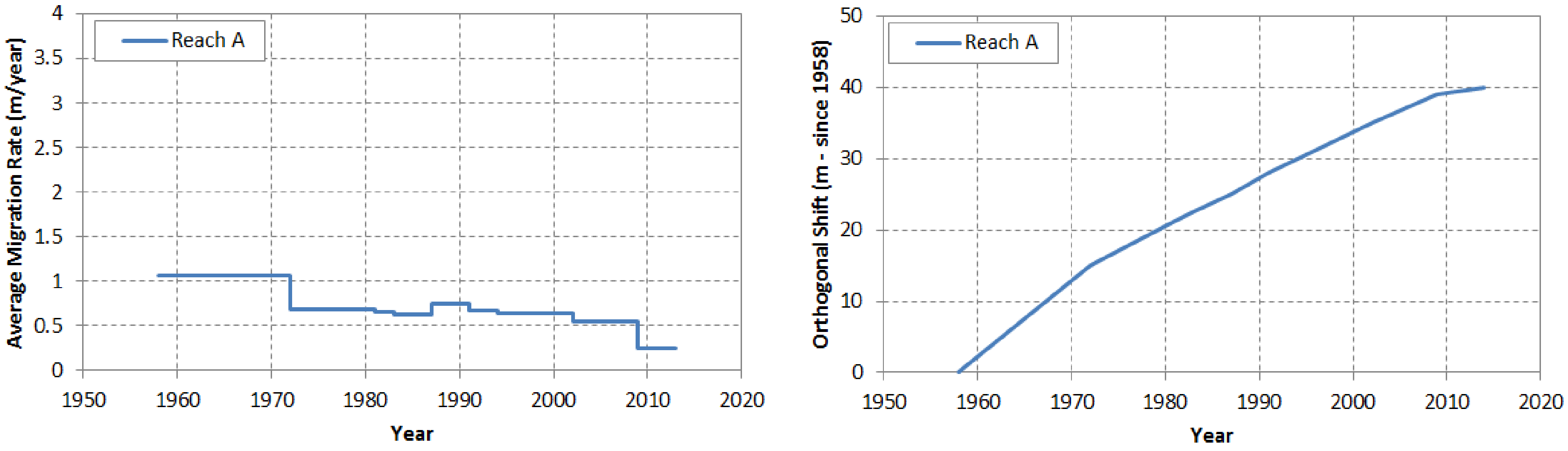



**Figure 5-18 Reach A Migration Rate Assessment Results**

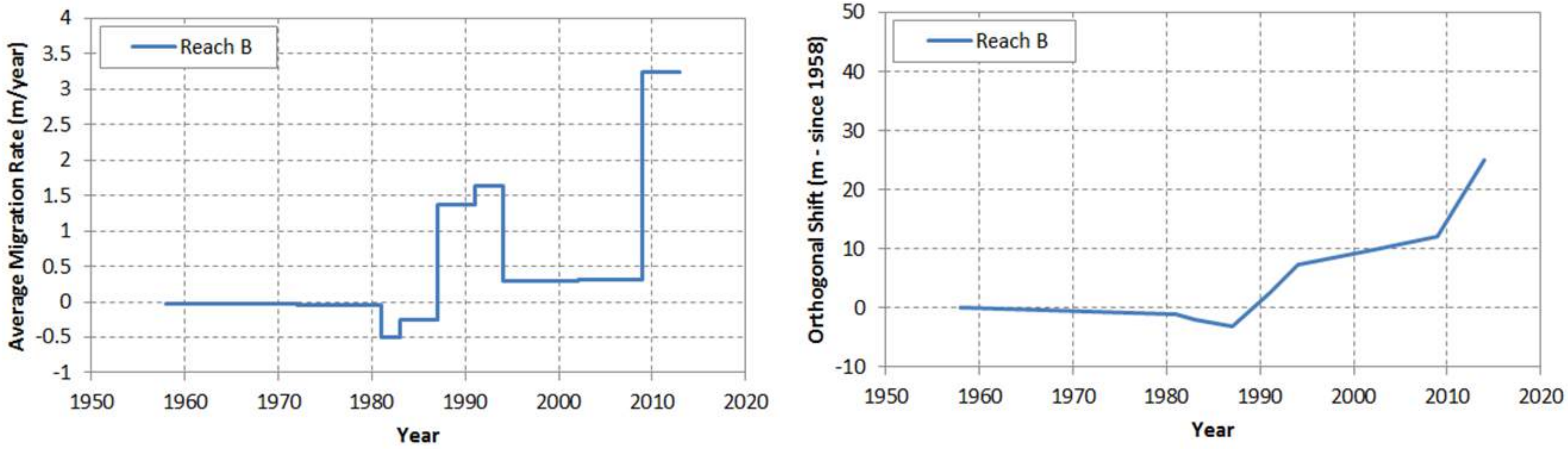



**Figure 5-19 Reach B Migration Rate Assessment Results**

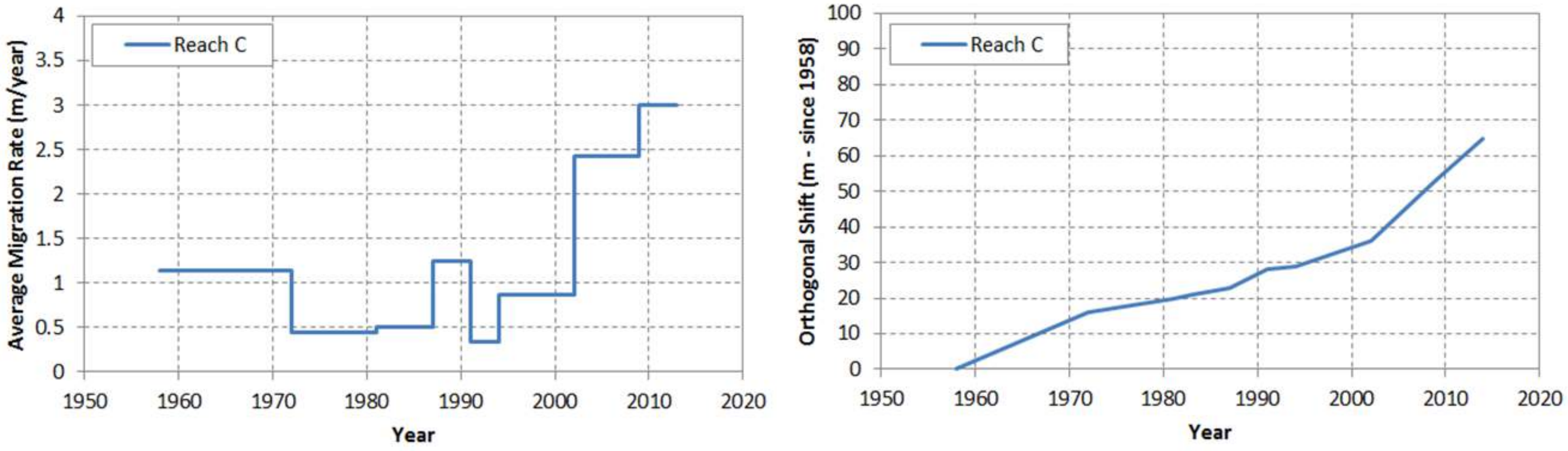



**Figure 5-20 Reach C Migration Rate Assessment Results**

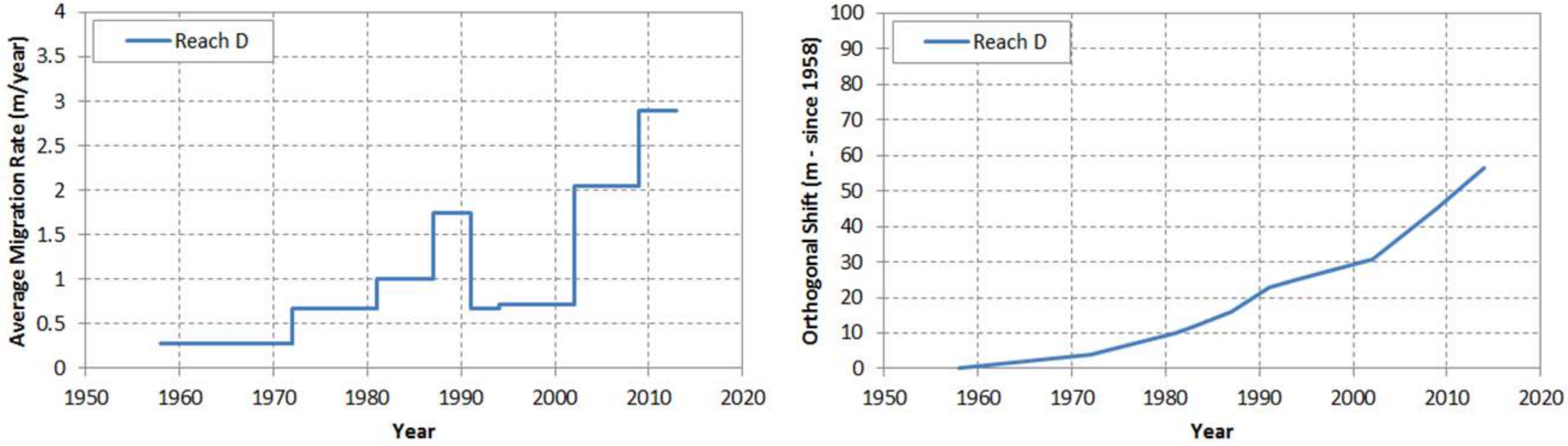



**Figure 5-21 Reach D Migration Rate Assessment Results**

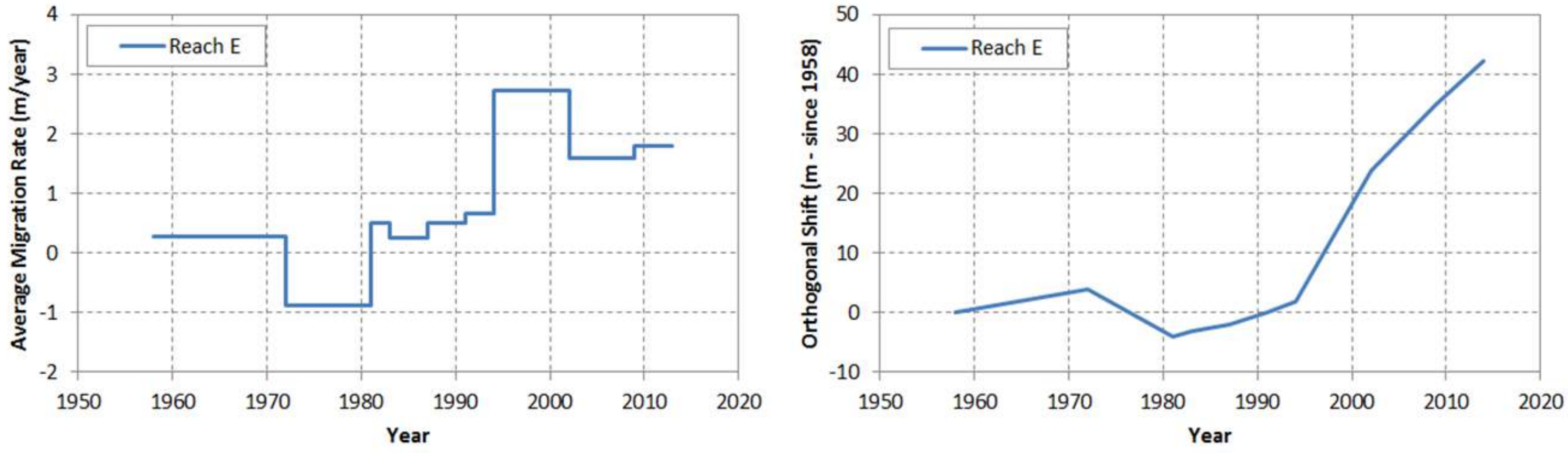



Figure 5-22 Reach E Migration Rate Assessment Results

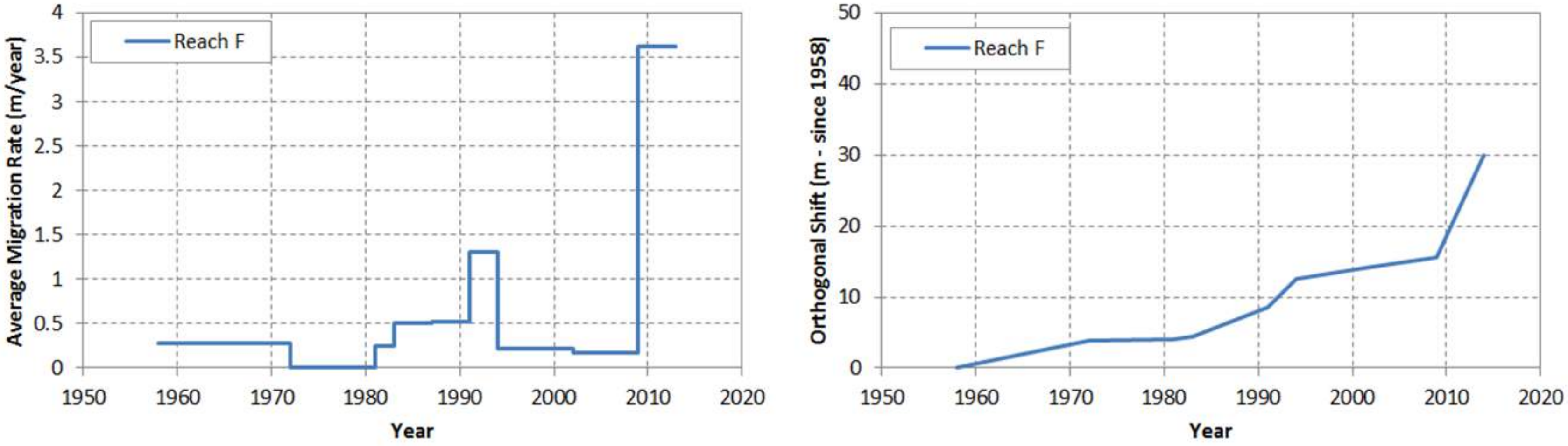



Figure 5-23 Reach F Migration Rate Assessment Results

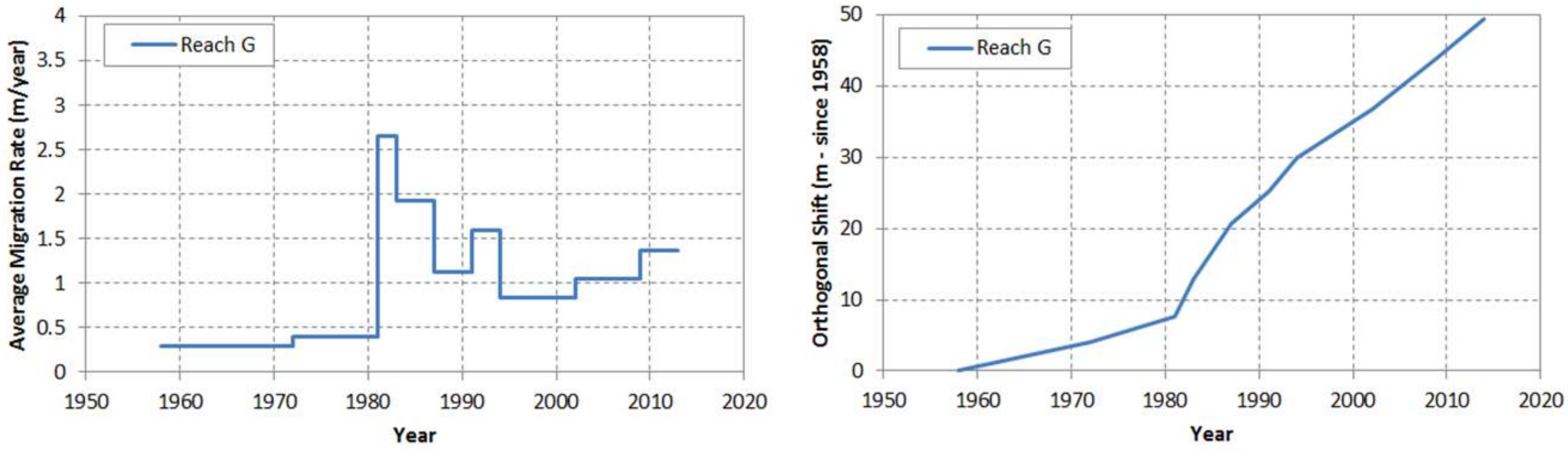



**Figure 5-24 Reach G Migration Rate Assessment Results**

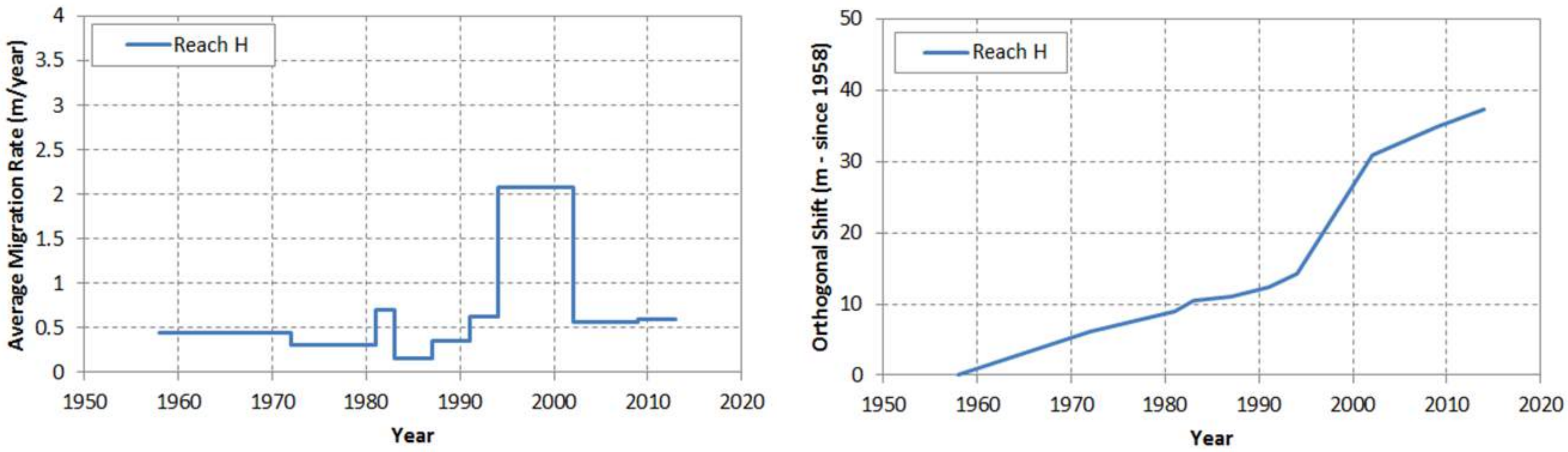



**Figure 5-25 Reach H Migration Rate Assessment Results**

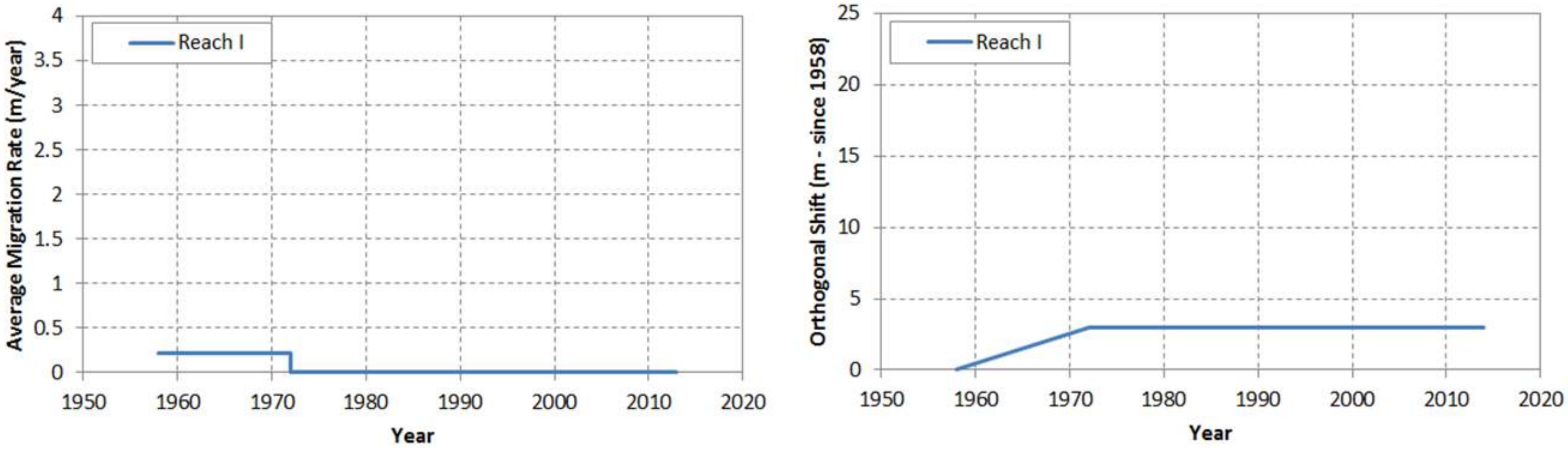



**Figure 5-26 Reach I Migration Rate Assessment Results**

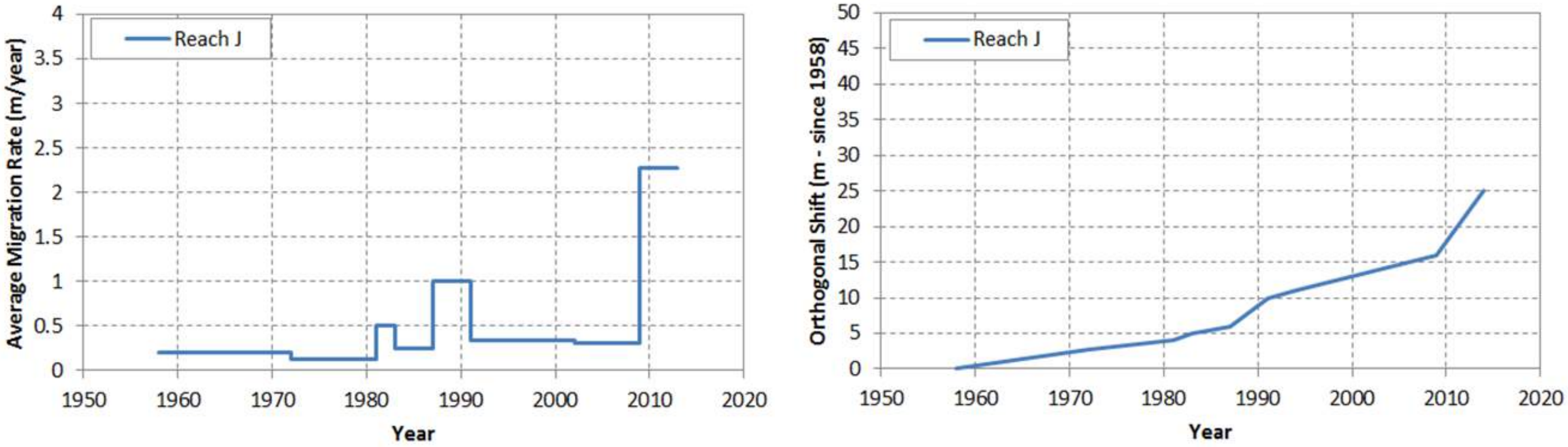
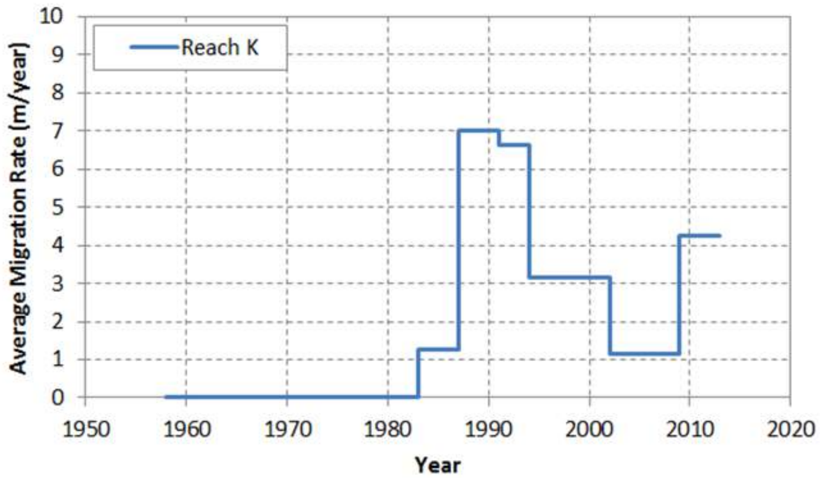



**Figure 5-27 Reach J Migration Rate Assessment Results**



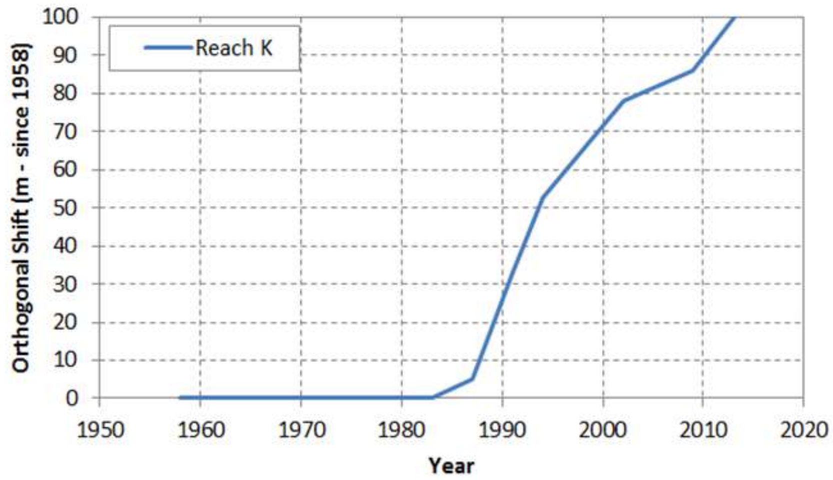
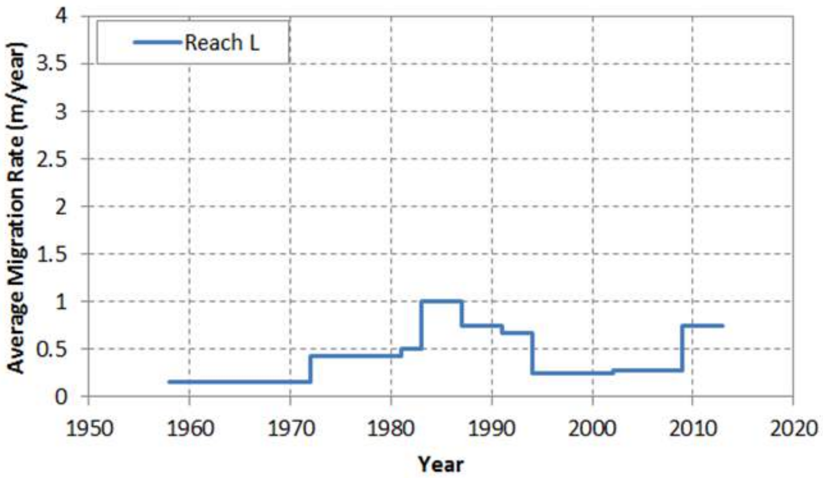




**Figure 5-28 Reach K Migration Rate Assessment Results**



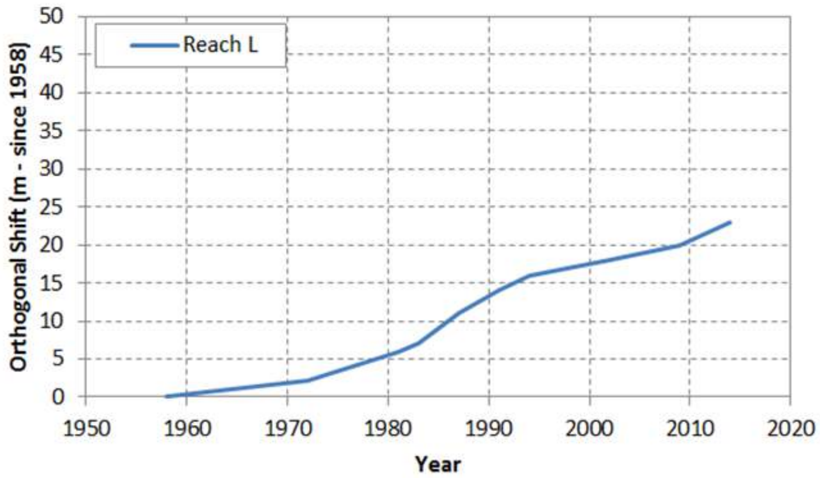




**Figure 5-29 Reach L Migration Rate Assessment Results**

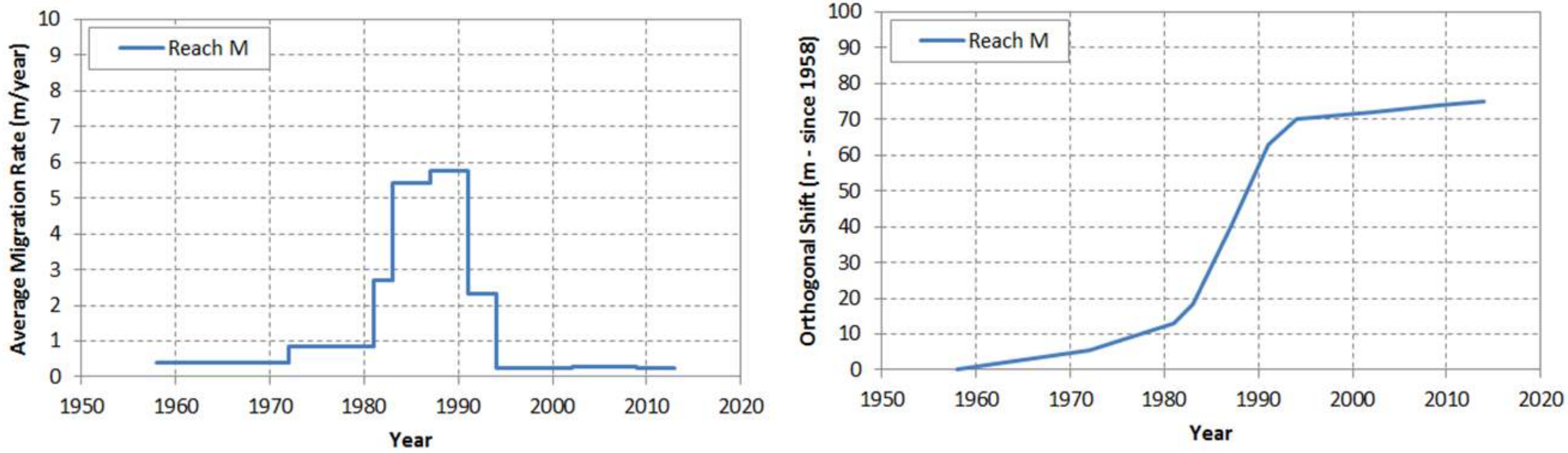



**Figure 5-30 Reach M Migration Rate Assessment Results**

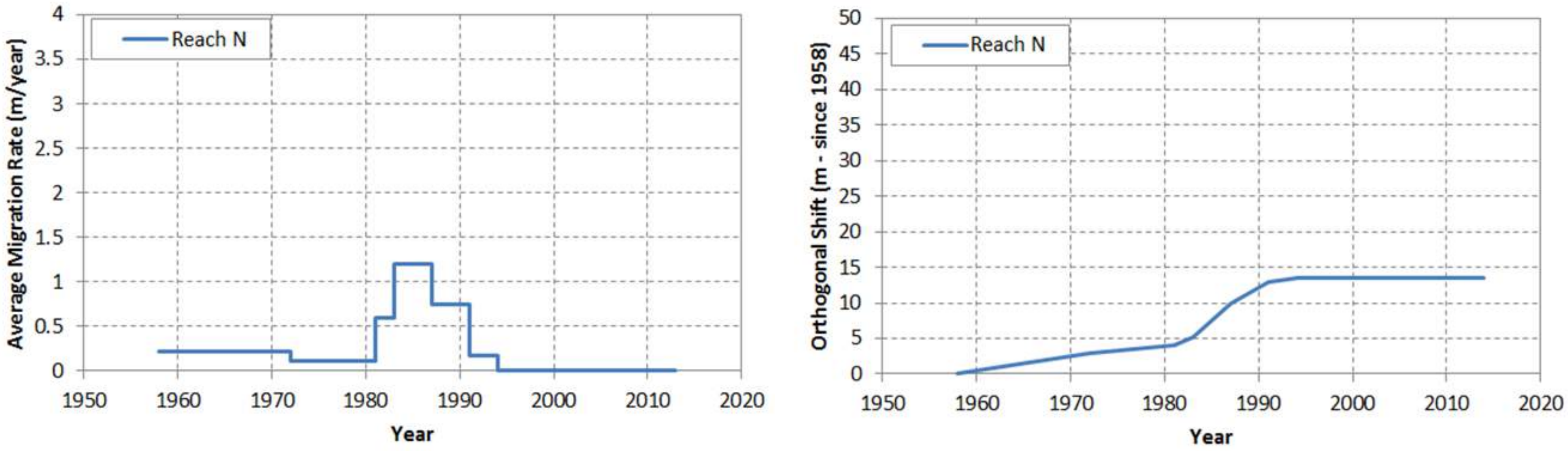



**Figure 5-31 Reach N Migration Rate Assessment Results**


**Figure 5-32 Breach at Pine Rivers Park**

## 5.4 Process Modelling

MBRC commissioned the development of a calibrated hydrologic/hydraulic model of the Pine and South Pine Rivers as part of the Regional Floodplain Database (RFD) project. The model is based on 2009 LiDAR survey for the floodplain topography and a 2005 bathymetry survey for subaqueous topography. A refined version of the RFD hydraulic flood model has been used to inform the erosion potential estimates for the South Pine River.

The hydraulic model has been refined both in terms of model extent and also model resolution.

- The model extent has been refined to the SPR SEMP study area. Model inflows have been extracted from the RFD hydraulic model.
- The model resolution has been increased from 5m to 2m.
- Rogue TIN edges in the bathymetry survey (caused while translating the point survey to a continuous 3D surface) were smoothed out to ensure accurate representation of subaqueous topography.
- The model topography in the vicinity of reach B was modified to capture the breach that has occurred at this location since the 2005 bathymetry survey.
- All other model parameters remain unchanged, reflecting the details included within the RFD hydraulic model. This includes: landuse representation, topography data and hydraulic structure details. The refined hydraulic model is presented in Figure 5-34.

It is recognised that river has undergone some geomorphological change since the surveys that were used in the model were undertaken. However, the model results are only intended to provide a general understanding of the erosion risks and to corroborate the outcomes of historical LiDAR and historical aerial photograph analyses. As such, the modelling is considered adequate for the intended purpose.

Generally, the geomorphic character and behaviour of an estuary is variable and consequently erosion rates and processes also vary. In upper estuary reaches, fluvial processes (i.e. driven by freshwater runoff and floods) tend to predominate and processes such as sediment load, transport and deposition (for example gravel bar formation and meander migration) drive long term channel change. In middle to lower reaches, tidal influences change the energy environment producing different sedimentation patterns, flow dynamics, and erosion effects.

The SPRSEMP study extent is confined to the middle to lower reaches of the South Pine River. In general, there are two main flow conditions which drive erosion processes in the middle to lower estuary reaches:

- Continuous erosion processes, occurring under tidal/low flow condition; and
- Episodic or event based erosion processes, predominantly associated with catchment flood events.

The following event scenarios have been used for this assessment:

- Tidal Event (Figure 5-35) - Spring tide cycle (Continuous erosion processes):

- Current Climate; and
- 2100 Planning Horizon Climate Change (0.8m sea level rise).

- Flood Event (Figure 5-36) - 20% Average Exceedance Probability (AEP) catchment flood event (Episodic or event based erosion processes):
  - Current Climate; and
  - 2100 Planning Horizon Climate Change (0.8m sea level rise and 20% increase in rainfall intensity).

Erosion potential has been measured using modelled bed shear stress estimates. Physically, erosion occurs where fluid bed shear stresses exceed the material shear strength of a material. The shear stress value required to cause the erosion of a material is termed 'erosion shear stress'. Figure 5-33 presents erosion shear stress estimates for a range of material types.

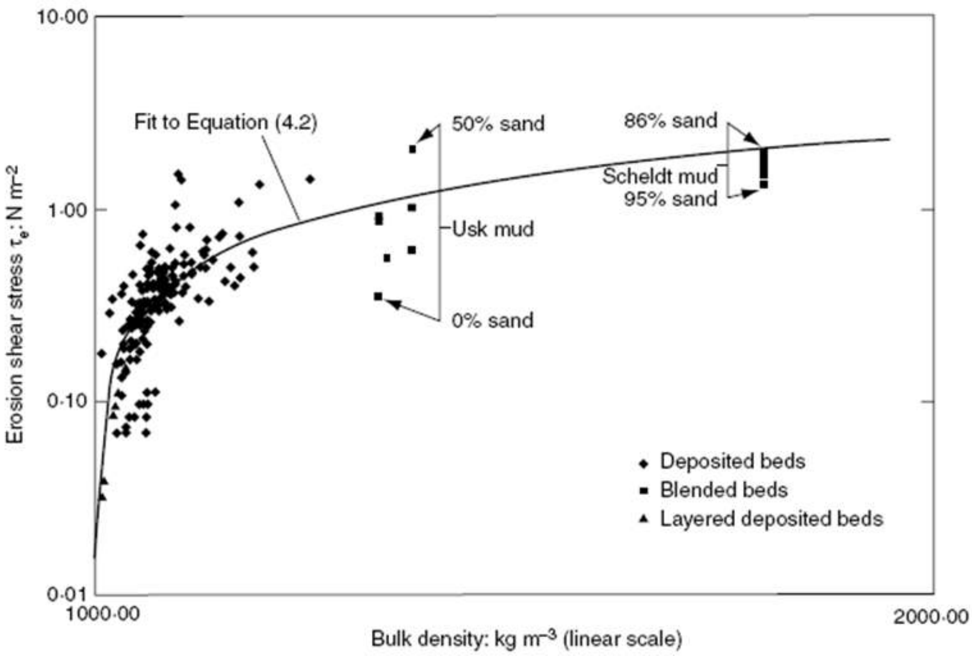



**Figure 5-33 Erosion Shear Stress (Whitehouse et al, 2000)**

## 5.4.1 Modelling Results

*Tidal Event - Spring Tide Cycle* (Figure 5-35):

Current climate tidal modelling indicates:

- Bed shear stresses are greatest (exceeding 1Nm-2) within the1km stretch of river between Reach B and I. It is likely that the tidal fluid bed shear stresses exceed the material shear strength in these locations. These results suggest that erosion/channel migration within this stretch of river due to tidal flows is likely.
- Moderate bed shear stresses are observed between Reach I and L, between 0.1 and 0.3Nm-2. Erosion/channel migration within this stretch of river due to tidal flows may be possible.

- Low bed shear stresses are observed downstream of Reach L, less than 0.1 Nm-2. Erosion/channel migration within this stretch of river due to tidal flows is unlikely.
- Low bed shear stresses are observed at Reach A, less than 0.1 Nm-2. Erosion/channel migration within this stretch of river due to tidal flows is unlikely while the meander loop on which the reach is located is bypassed by main river channel.

The above listed modelling results support the long-term trends present in historic aerial photography and short-term erosion observations onsite.

(1) Riverbank Migration Assessment (Section 5.3.2): The riverbank migration assessment highlighted that the section of river between Reach B and I is currently actively eroding, whereas Reach A, and section of river downstream of Reach I is not eroding.

(2) Site Observations: *"In the location of the Pine Rivers Park (Reach C), the South Pine River is subject to tidal flows. From observations made on site, it appears that regular tidal movements in the river are causing erosion at the toe of the river bank. Erosion at the toe then leads to failure of the lower bank and in turn causes failure of the upper bank. The cycle then begins again. Whilst the impacts during a single tidal event are small, these events are frequent and the cumulative effects are evident. In tidal events of larger magnitudes (eg the spring tides in January/February 2010), erosion effects during a single event are evident." Aurecon (2010)*

2100 planning horizon climate change tidal modelling indicates:

- Projected sea level rise will change the erosion risk due to increased water levels within the South Pine River. Greatest increases in erosion risk are likely to be in areas which are typically dry under current climate conditions, but become inundated due to sea level rise (such as in the river sections downstream of Reach L).

Flood Event - 20% AEP catchment flood event (Figure 5-36):

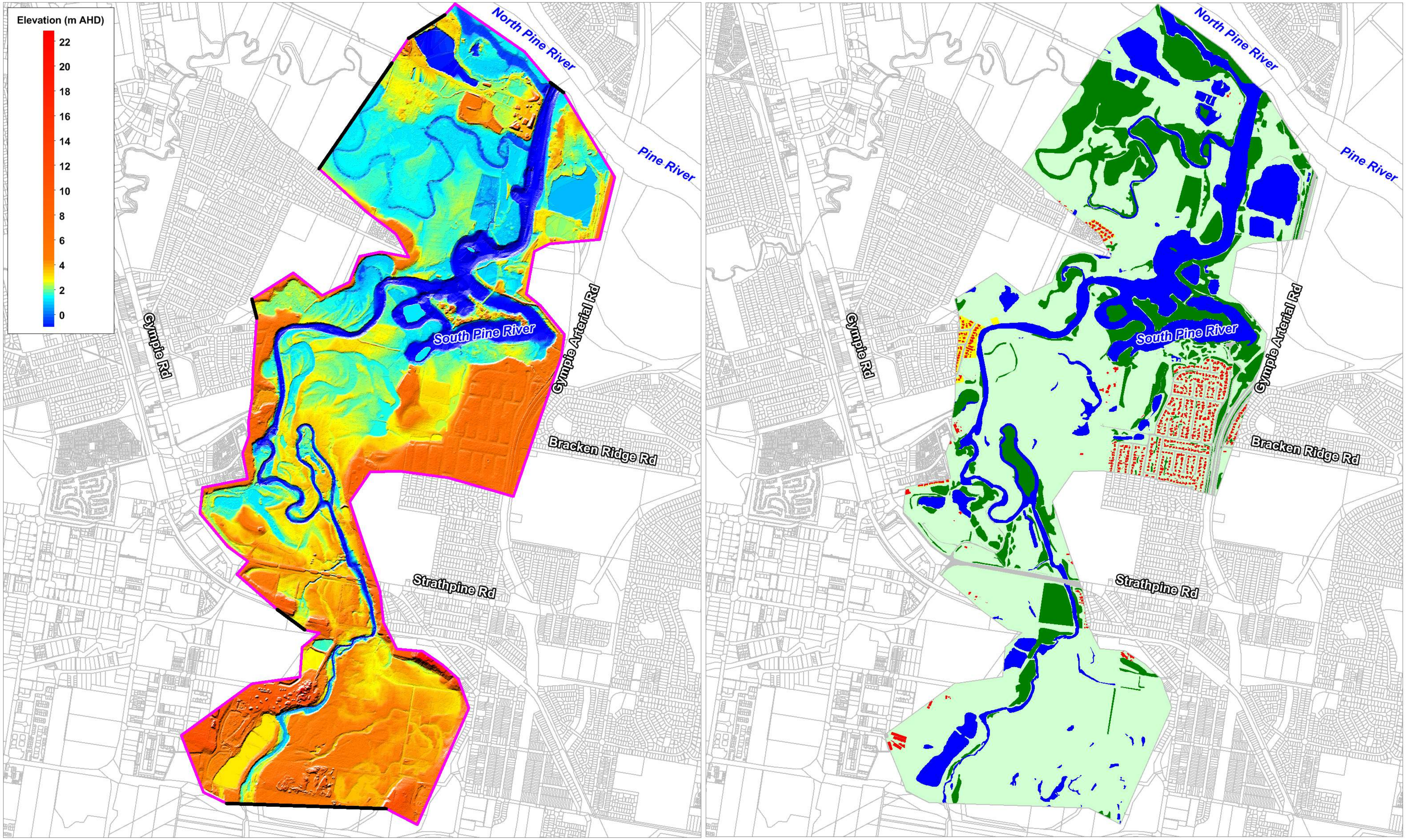
Current climate flood event modelling indicates:

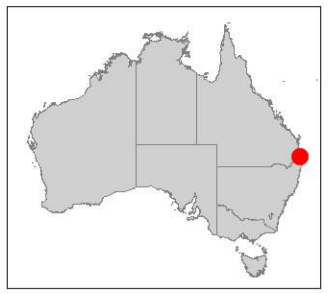
- Bed shear stresses are greatest upstream of Reach L, exceeding 1Nm-2. These results suggest that erosion/channel migration within this stretch of river due to flood flows is likely.
- Low bed shear stresses are observed downstream of Reach L, less than 0.1 Nm-2. Erosion/channel migration within this stretch of river due to flood flows is unlikely.

The above listed trends in modelling result support the long-term trends present in historic aerial photography, which found the river orientation downstream of Reach L has been relatively stable since the mid 1990's.

2100 planning horizon climate change flood modelling indicates:

- Projected increases in rainfall intensity and sea level rise will increase the erosion risk due to increased flood flows and flood levels within the South Pine River.



**LEGEND**

- Model Extent
- Model Boundaries
- Cadastre Boundary
- Grass
- Vegetation
- Roads/Footpaths
- Urban Block
- Buildings
- Waterbodies

Title:

## TUFLOW Model Topography and Land Use

Figure: 5-34

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 400 800m

Approx.Scale

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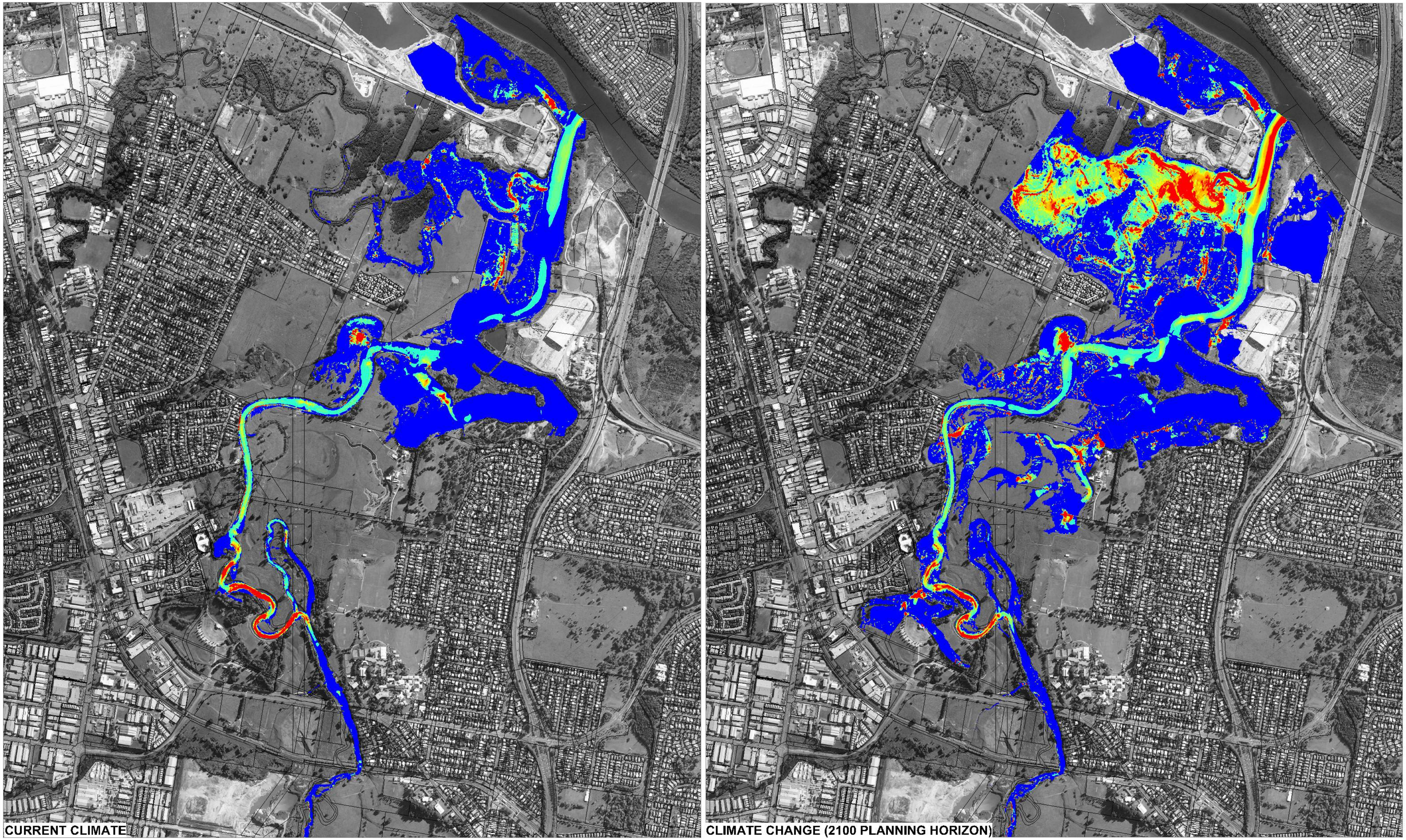


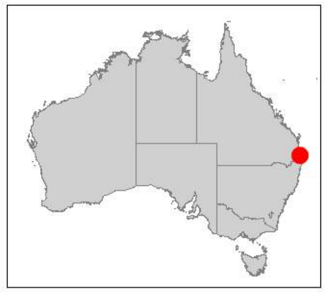

**LEGEND**

**Bed Shear Stress (N/m²)**
- 0.0 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.4
- 0.4 to 0.5
- 0.5 to 0.6
- 0.6 to 0.7
- 0.7 to 0.8
- 0.8 to 0.9
- 0.9 to 1.0
- > 1.0

Cadastre Boundary

Title:
# South Pine River - Spring Tide Erosion Potential

Figure: **5-35**

Rev: **A**



N

0 300 600m
Approx.Scale

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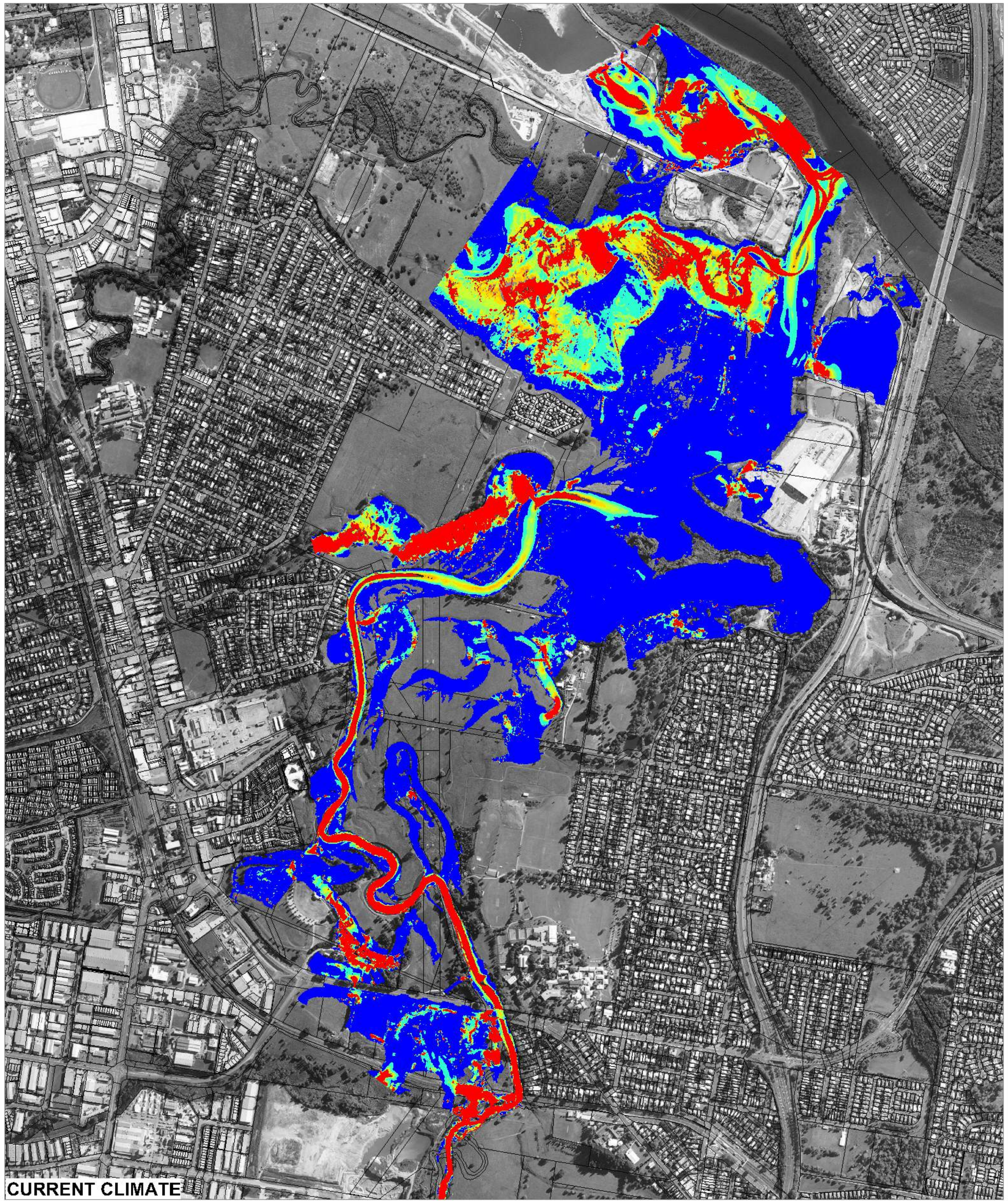


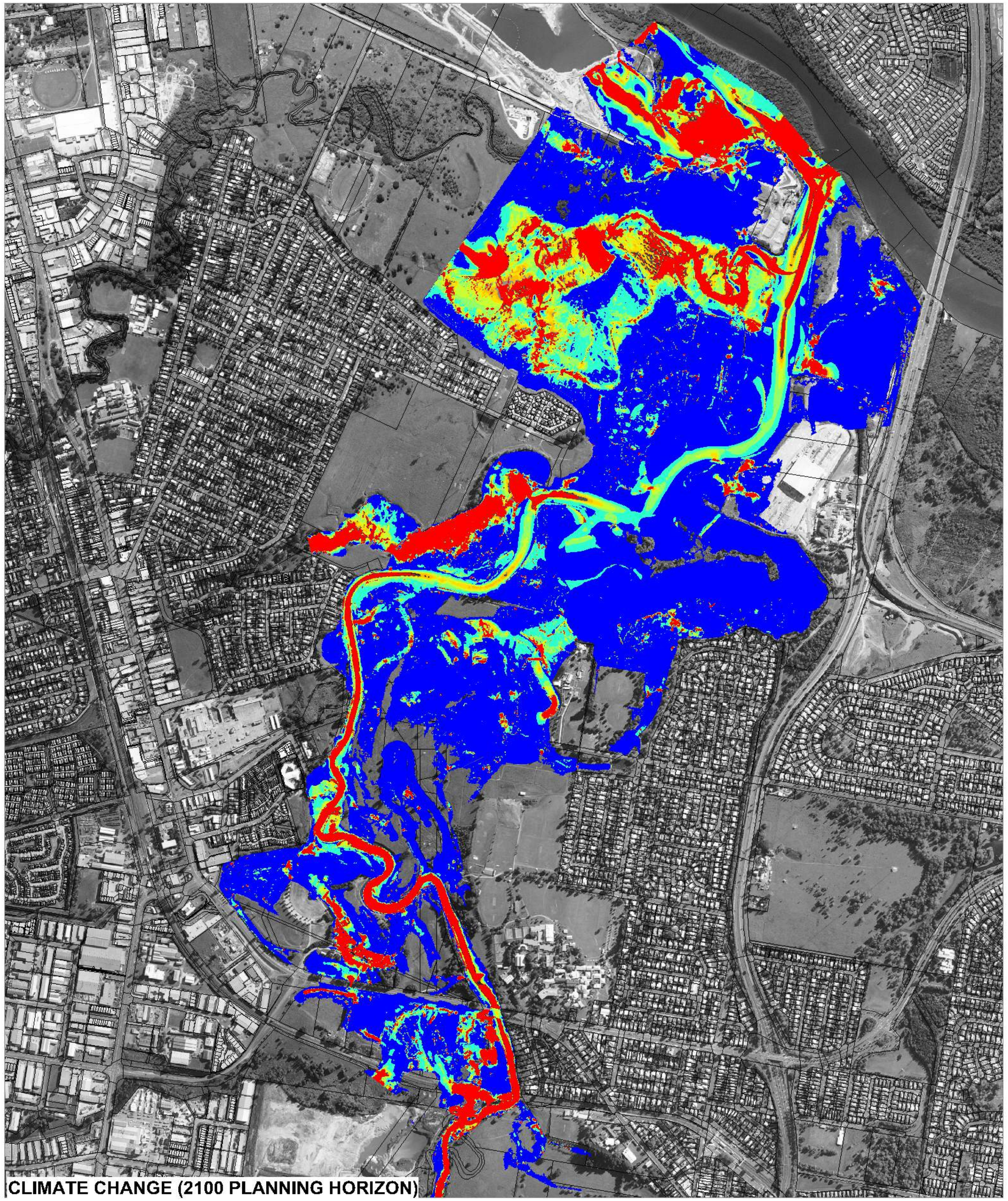


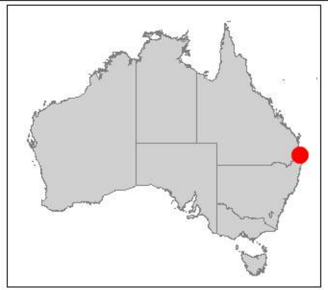

**LEGEND**

**Bed Shear Stress (N/m²)**

- 0.0 to 0.1
- 0.1 to 0.2
- 0.2 to 0.3
- 0.3 to 0.4
- 0.4 to 0.5
- 0.5 to 0.6
- 0.6 to 0.7
- 0.7 to 0.8
- 0.8 to 0.9
- 0.9 to 1.0
- > 1.0

Title:
**South Pine River - 20% AEP Flood Event Erosion Potential**

Figure: **5-36**

Rev: **A**



N

0 300 600m
Approx.Scale

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## 5.5 Discussion

The South Pine River is currently experiencing varying levels of erosion stress along its length. It is likely that more than one mechanism is contributing to the current bank erosion problems in the South Pine River, with the dominant factors possibly related to:

- Changes in the tidal prism as a result of channel dredging;
- Sand and gravel extraction;
- Increased freshwater runoff due to urban development and catchment clearing; and
- Riparian vegetation clearing.

Bank erosion within the study area is the result of:

- Regular tidal movements; and
- High flow velocities associated with catchment flood events.

Site inspections, historic riverbank migration analysis and process modelling indicate the flowing trends in erosion stress/channel migration:

- Presently, all upstream reaches on the main channel of the South Pine River (Reach B, C, D, E, F and G) are actively eroding at a rate greater than the long term average. These reaches are eroding at an approximate rate of 3m/year.
- Reach I has historically had a stable orientation. This is due to hard engineering erosion protection measures along the western bank of the South Pine River in this location.
- Reach M and N, closest to the Pine/South Pine River confluence are relatively stable.
- Future climate change will likely increase erosion stresses in the South Pine River.

Considering the conclusions of the historic riverbank migration analysis and process modelling, it is considered that the area between Reach B and G is likely to show ongoing erosion at a higher rate than other areas. This erosion trend is impacting existing infrastructure at Reach C and F. Prioritised efforts to manage the bank erosion need to be concentrated in this area.