

## NESP 1.15 Coastal wetland restoration for blue carbon

### Spatial analysis workflow – Fitzroy Basin case study, QLD

Purpose: To identify the coastal wetland restoration opportunity in the Fitzroy Basin study area and manipulation of spatial datasets for input into the following R codes: 1) blue carbon estimates, 2) economic analysis and 3) co-benefits analysis. All spatial analysis conducted in ArcMap 10.8 (ESRI, 2019).

#### RESTORATION OPPORTUNITY

##### 1) Study area

- Download “Land use mapping - 1999 to 2017 - Fitzroy NRM” from QSpatial (<https://qldspatial.information.qld.gov.au/catalogue/custom/detail.page?fid={96228E4D-697D-430C-A3BD-3719F3AF8C30}>). Use the 2017 layer

##### 2) Restorable land uses including Grazing, Defence, wetland production and hydrologically modified (hydromod) wetlands

- Download “Land use mapping - 1999 to 2017 - Fitzroy NRM” from QSpatial (<https://qldspatial.information.qld.gov.au/catalogue/custom/detail.page?fid={96228E4D-697D-430C-A3BD-3719F3AF8C30}>)
- Use the 2017 layer
- Fitzroy basin 2017 land use layer > select by attributes >ALUM\_CODE >
- *Grazing and defence – create two layers as need to keep the land uses separate as Defence land will have different foregone revenue in the cost-benefit analysis.*
- **Grazing layer**
  - 3.2.2 - Grazing modified pasture – woody fodder plants
  - 2.1.0 - Grazing native vegetation
  - 4.2.0 - Grazing irrigated modified pastures
  - 4.2.1 - Grazing irrigated woody fodder plants
  - 6.2.2 - water storage – intensive use/farm dams
  - Save layer “FitzroyBasin\_grazing\_dams”
- **Defence layer**
  - ALUM\_CODE = 1.3.3, Tertiary = Defence
  - Save layer “FitzroyBasin\_defence”
  - Note: tried to access Defence Restricted Areas WMS to include expansion areas north of Styx and around Broad Sound inlet. The data is not accessible.
  - Only include pre-clear Regional Ecosystems (REs) on Defence land if they are in non-remnant areas. Non-remnant areas can be clipped from the remnant regional ecosystem mapping. Saved in the folder under Data.
  - Download “Biodiversity status of 2019 remnant regional ecosystems – Queensland” from QSpatial (<https://qldspatial.information.qld.gov.au/catalogue/custom/detail.page?fid={8FDF54D2-654C-4822-8295-1D8E8E772373}>).
  - Use “Biodiversity\_status\_of\_remnant\_regional\_ecosystems” layer and select attribute: RE = non-remnant “Non-remnantRE”.

- Intersect “FitzroyBasin\_defence” and “Non-remnantRE” to get non-remnant defence land areas “FitzroyBasin\_defence\_nonremnant”.
- **Wetland production layer**
  - Include marsh/wetland production land use 6.5.2 if it’s mapped as freehold or leasehold land on the cadastre.
  - Select marsh/wetland production land use 6.5.2 “FitzroyBasin\_wetlandprod”.
  - Extract “Cadastral data - Queensland - by area of interest” from QSpatial for study area (<https://qldspatial.information.qld.gov.au/catalogue/custom/detail.page?fid={A07975CC-FE78-408F-959F-B0CDEC1C6EDA}>).
  - Import cadastre data “Cadastral\_data\_QLD\_CADASTRE\_DCDB” and select:
    - TENURE = Freehold or
    - TENURE = Lands lease
    - Name layer “FitzroyBasin\_Freehold\_lease”
  - Intersect “FitzroyBasin\_wetlandprod” and “FitzroyBasin\_Freehold\_lease” to get wetland production areas that are freehold/leasehold “FitzroyBasin\_wetlandprod\_freelease”.
- **Hydomod wetlands**
  - Download the Qld Wetlands data V5 from QSpatial (<https://qldspatial.information.qld.gov.au/catalogue/custom/detail.page?fid={986BE78D-FA59-4A9E-92C5-8626E50CF3A8}>).
  - Clip to Fitzroy Basin study area to get “Wetland\_area\_Fitzroy”
  - ‘Select by Attributes’ and then you will be able to scroll down to ‘local hydrology modifier code’.
  - Select H2M2, H2M3, H2M3P (but there isn’t any in Fitzroy) and H2M5 and create layer from selected features “Wetland\_areas\_Fitzroy\_H2M235”.
  - See Appendix 2 Local Hydrology Modifiers: <https://wetlandinfo.des.qld.gov.au/resources/static/pdf/facts-maps/mapping-method/addendum-wetland-map-method.pdf>
  - Note: version 5 - H2M2 in the process of being split into: H2M2a, H2M2b, H2M2c, H2M2d, H2M2e, H2M2f, H2M2g.
- **Merge land use layers**
  - Merge “FitzroyBasin\_grazing\_dams”, “FitzroyBasin\_defence\_nonremnant” and “FitzroyBasin\_wetlandprod\_freelease” and “Wetland\_areas\_Fitzroy\_H2M235” to get chosen restorable land use areas “FitzroyBasin\_grazing\_dams\_defence\_wetland\_hydromod”.

### 3) Historic coastal wetlands

- Download “Biodiversity status of pre-clearing regional ecosystems – Queensland” from QSpatial (<https://qldspatial.information.qld.gov.au/catalogue/custom/detail.page?fid={22E1BC4E-BDFA-470A-AED8-04F38B4FCFC3}>)
- Clip Qld pre-clear regional ecosystem (RE) layer to Fitzroy Basin land use area “Pre\_clearing\_BVG\_FitzroyBasin”.
- Select all Dominant Broad Vegetation Groups (DBVGs) that are wetland Broad Vegetation Groups (BVGs) according to Appendix 2 (Neldner et al. 2016) and create layer from selected features and export as shapefile “Pre\_clearing\_BVG\_FitzroyBasin\_WetlandRE2”

"DBVG1M" = '4a' OR

"DBVG1M" = '4b' OR  
 "DBVG1M" = '15b' OR  
 "DBVG1M" = '16a' OR  
 "DBVG1M" = '16c' OR  
 "DBVG1M" = '16d' OR  
 "DBVG1M" = '19b' OR  
 "DBVG1M" = '22a' OR  
 "DBVG1M" = '22b' OR  
 "DBVG1M" = '22c' OR  
 "DBVG1M" = '26a' OR  
 "DBVG1M" = '29a' OR  
 "DBVG1M" = '34c' OR  
 "DBVG1M" = '34d' OR  
 "DBVG1M" = '34g' OR  
 "DBVG1M" = '35a' OR  
 "DBVG1M" = '35b' OR  
 "DBVG1M" = 'estuary'

Note: Highlighted = none in Fitzroy study area

#### 4) Highest Astronomical Tide (HAT) impact area

- HAT (m above MSL) predictions were obtained from Qld Tide Tables (Semidiurnal Tidal Planes) and Standard Port Tide Times 2021 (Maritime Safety Queensland; <https://www.msq.qld.gov.au/Tides/Tide-Tables>) from Bundaberg north to Mackay and populated in a spreadsheet (HAT\_predictions\_FitzroyBasin\_2021.xls). m above MSL was used instead of m above AHD as there was no AHD available for 2021. Could use 2020 tide data if prefer HAT to be m above AHD.
- Add HAT\_predictions\_FitzroyBasin\_2021 as spatial data layer - add as xy data and export data as shapefile "HAT\_predictions\_FitzroyBasin\_2021".
- Downloaded "Drainage basins - Queensland" from QSpatial (<https://qldspatial.information.qld.gov.au/catalogue/custom/detail.page?fid={F79B22E5-7BD4-44AF-98EB-AC1A46513EDD}>).
- Create layer from selected features and export as shapefile "Drainage\_basins\_Fitzroy".
- Clip Drainage Basins Queensland dataset by BASIN\_NAME attributes (Curtis Island, Coral Sea, Styx, Calliope, Boyne, Waterpark, Shoalwater, Fitzroy) to the Fitzroy Basin 2017 land use area to get drainage basins within Fitzroy Basin study area "Drainage\_basin\_Fitzroy".
- Select those tide prediction locations which are located on the coast or within those basins and convert to shapefile "HAT\_predictions\_FitzroyBasin\_2021\_Selected".
- Spatial join of the "HAT\_predictions\_FitzroyBasin\_2021\_Selected" with the Fitzroy drainage basins (closest) and export table. However there is an extra basin – Coral Sea that we will need to exclude. So manually assign these tide prediction locations to another closest basin – i.e. Boyne needs some locations (South Tree Wharf and Gatcombe Head). There should be 7 drainage basins all up with points.
- Reassigned South Tree Wharf and Gatcombe Head to Boyne River.
- Removed Great Keppel and Marquis Island HAT points.

- Add sea level rise to average tide levels (for HAT (m above LAT), MHWN and MHWS) for each basin with global mean SLR for RCP 8.5 2046–2065 – 0.32m, and 2081-2100 – 0.71 (IPPC, 2019). Excel file “Mean\_HAT\_predictions\_SLR\_FitzroyBasin\_2021.xls”.
- Download Digital Elevation Model (DEM) of Australia derived from LiDAR 5 Metre Grid from Geoscience Australia (5m DEM GDA94 UTM zone 56 NSW QLD Ausgeoid )  
<https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/89644>
- Clip 5mDEM UTM 55 and UTM 56 rasters to “Drainage\_basins\_Fitzroy” (Arc Toolbox > Data Management > Raster > Raster Processing > Clip). Note tick box ‘use input features for clipping’.
- Merge UTM 55 and 55 rasters using the Mosaic To New Raster tool (ArcToolbox > Data Management Tools > Raster > Raster Dataset). Cell size 5 x 5, 4-bit pixel depth and no bands = 1.
- Clip merged raster to “Drainage\_basins\_Fitzroy”.

#### **Extract all areas below HAT m above MSL.**

- Reclassify values for each drainage basin within the Fitzroy Basin 5mDEM according to average HAT value (Arc Toolbox > Spatial Analyst Tools > Reclass > Reclassify). Classify to change values into 4 classes and change break values:
  - 1 (MSL to MHWN)
  - 2 (MHWN to MHWS)
  - 3 (MHWS TO HAT\_m\_aboveMSL)
  - 4 (>HAT)
  - No data

➤ Note tick box ‘change missing values to no data’ for 25m DEM, not for 5m DEM
- Merge reclassified drainage basin rasters into one raster for Fitzroy Basin  
“Reclass\_Dem\_Fitzroy\_allcatchments”
- Then create polygon from raster (Arc Toolbox > Conversion tools > from raster to polygon) selecting ‘create multipart features’. However won’t create polygon from selected features.
- Therefore, select classes 1-3 from attribute table (everything below HAT), and create layer from selected features, then export data to new shapefile for tidal (tid5dem\_fitzroy2).

#### **ADD sea level rise (in DEM\_FitzroyBasin2 folder).**

- Reclassify all rasters 1 = MSL to HAT+SLR, 2 = >HAT+SLR
  - Boyne River=2.99 =Boyne\_SLR
  - Calliope=3.31 =Calliope\_SLR
  - Coral sea=3.92=Coralsea\_SLR
  - Curtis Island=3.62=CurtisIs\_SLR
  - Fitzroy=4.03=Fitzroy\_SLR
  - Shoalwater= 4.83m = Shoalwater\_SLR
  - Styx= 5.68 =Styx\_SLR
  - Waterpark = 3.47 = Waterpark\_SLR
- Note: SLR added (RCP8.5 2046-85 0.32m)
- Mosaic to new raster: reclassified drainage basin rasters into one raster for Fitzroy Basin + SLR = “SLR\_Dem\_Fitzroy\_allcatchments.tif” (number of bands =1)
- Convert to polygon “SLR\_Dem\_Fitzroy\_poly”

- Select class 1 (SLR) from attribute table (everything below HAT), and create layer from selected features, then export data to new shapefile for tidal (tid5dem\_fitzroy\_SLR).

## 5) Identify restoration sites

- Intersect “FitzroyBasin\_grazing\_dams\_defence\_wetland\_hydromod” with new “tid\_5dem\_fitzroy2” to get grazing areas that could receive tidal water up to HAT (“tidal\_grazing\_dams\_defence\_wetland\_hydromod\_fitzroy”).
- Intersect “tidal\_graz\_defence\_dams\_wetland\_fitzroy” with preclear regional ecosystem layer “Pre\_clearing\_BVG\_FitzroyBasin\_WetlandRE2” to get preclear RE types per polygon “tidal\_graz\_defence\_dams\_preclearRE”.
- Dissolve adjacent polygons into one polygon to get restoration sites (Geoprocessing > Dissolve Boundaries > don’t dissolve on a field and disable multipart features) – “tidal\_graz\_defence\_dams\_preclearRE\_Dis”.
- Add field (area\_ha) and choose “double” and save. Then calculate geometry (area in ha) of dissolved polygons.
- Select sites that are larger than 1 ha in size:
  - Select dissolved layer by attributes (Area\_ha >= 1) and create layer from selected attributes – “tidal\_graz\_defence\_dams\_preclearRE\_Dis\_1ha”. Export data as shapefile.

## 6) Identify restoration sites with SLR (In Fitzroy\_restorationsites4 folder).

- Import “tid5dem\_fitzroy\_SLR” shapefile.
- Intersect “FitzroyBasin\_grazing\_dams\_defence\_wetland\_hydromod” with new “tid5dem\_fitzroy\_SLR” to get grazing areas that could receive tidal water up to HAT under SLR (“SLR\_tidal\_grazing\_dams\_defence\_wetland\_hydromod\_fitzroy”).
- Intersect “SLR\_tidal\_grazing\_dams\_defence\_wetland\_hydromod\_fitzroy” with preclear regional ecosystem layer “Pre\_clearing\_BVG\_FitzroyBasin\_WetlandRE2” to get preclear RE types per polygon “SLR\_tidal\_graz\_defence\_dams\_preclearRE”.
- Dissolve adjacent polygons into one polygon to get restoration sites (Geoprocessing > Dissolve Boundaries > don’t dissolve on a field and disable multipart features) – “SLR\_tidal\_graz\_defence\_dams\_preclearRE\_Dis”.
- Add field (area\_ha) and choose “double” and save. Then calculate geometry (area in ha) of dissolved polygons.
- Select sites that are larger than 1 ha in size:
  - Select dissolved layer by attributes (Area\_ha >= 1) and create layer from selected attributes – “SLR\_tidal\_graz\_defence\_dams\_preclearRE\_Dis\_1ha”. Export data as shapefile.
- Export table as csv “SLR\_tidal\_graz\_defence\_dams\_preclearRE\_Dis\_1ha.csv” to calculate total ha and number of sites.

## 7) Land use and pre-clear regional ecosystem areas in HAT (for comparison to areas within restoration sites)

- Intersect Fitzroy basin 2017 land use layer with HAT “tid5dem\_fitzroy2” and add field (Area\_ha) and calculate geometry (area in hectares) to get “tid5dem\_fitzroy2\_LU”. Export to excel “tid5dem\_fitzroy2\_LU.xls”.
- Intersect “Pre\_clearing\_BVG\_FitzroyBasin” with HAT “tid5dem\_fitzroy2” and add field (Area\_ha) and calculate geometry (area in hectares) to get “tid5dem\_fitzroy2\_preclearRE”. Export to excel “tid5dem\_fitzroy2\_preclearRE.xls”.

## **CARBON ABATEMENT**

### **Restoration scenario – Removals and emissions from restored wetlands**

#### **8) Land-uses, pre-clear regional ecosystems, intertidal zone, drainage basins**

- Intersect restoration sites “tidal\_graz\_defence\_dams\_preclearRE\_Dis\_1ha” layer with:
  - “FitzroyBasin\_grazing\_dams\_defence\_wetland\_hydromod” to identify land uses within each polygon “rsites4\_LU”
  - “Pre\_clearing\_BVG\_FitzroyBasin” to identify preclear RE types within each polygon “rsites4\_preclearRE” and then with intertidal zone “tid5dem\_fitzroy2” to get intertidal zone of preclear RE types in polygons “rsites4\_preclearRE”
  - “Drainage\_basins\_Fitzroy” identify drainage basins of polygons “rsites4\_basins”
- Remove duplicate codes per site.:
  - Dissolve layer by site (FID\_Tidal), Area\_ha, and feature
  - Click ‘create multipart features’ to create “rsites4\_XXX\_dis”
  - Add Field (XX\_ha) and calculate geometry (area in hectares) of each polygon. Export table to excel.

### **Baseline scenario – Avoided emissions from ceasing baseline land-use**

#### **9) Agricultural flooded land (hydrologically modified wetlands)**

- Select "HYDROMOD" codes = H2M2, H2M2a, H2M2b, H2M2c and H2M2e, H2M3 and H2M5 from Qld wetlands layer “Wetland\_area\_Fitzroy”.
- Clip hydromod layer to restoration sites and dissolve by FID\_site, Area\_ha, and WETCLASS (rsites4\_hydromod\_wetclass\_dis) and calculate area of each wetclass (wet\_ha). Export to excel “rsites4\_hydromod\_wetclass.xls”.

#### **10) Ponds and other constructed water bodies**

- Download “Water storage points – Queensland” from QSpatial (<https://qldspatial.information.qld.gov.au/catalogue/custom/detail.page?fid={0727147E-819C-4F7F-B410-9C6AD9379E8E}>)
- Download “Reservoirs – Queensland” from QSpatial (<https://qldspatial.information.qld.gov.au/catalogue/custom/detail.page?fid={15C6CEA5-DF96-4D7E-9F3C-266AB09B24A0}>).
- One is a points layer (water storage) and one is a polygon layer (reservoirs).
- Average water storage size in Qld = less than 625 m<sup>2</sup> at full supply level, that’s a radius of 14.1m for a circular dam. Create buffer around points “Water\_storage\_points\_Buffer”.
- Select attribute points that are dams (not swimming pools or water tanks) “Water\_storage\_points\_Dams”.

- Merge layer with reservoir layer “Water\_storage\_points\_reservoir”. Add field (Area\_ha) and calculate geometry (area in hectares).
- Intersect with restoration sites and dissolve by FID, Area\_ha, and FEATURETYPE (“rsites4\_water\_storage\_dis”).
- Add field and calculate area of ponds at each site (pond\_ha). Export table to excel “rsites4\_water\_storage.xls”.
- Fitzroy land use mapping also has constructed water bodies mapped within the rsites – 6.2.1 (reservoir), 6.2.2 (water storage) and 6.2.3 (evaporation pond). Some are overlapping, some are not.

#### **11) Soil carbon loss**

- Download CSIRO baseline map of soil organic carbon (Viscarra-Rossell et al. 2015 from data portal: <https://data.csiro.au/collection/11088>)
- Clip floating raster (average map) to Fitzroy Basin land use area (Arc Toolbox > Data Management > Raster > Raster Processing > Clip. Note tick box ‘use input features for clipping’. Save as “SOCavFitz”.
- Use zonal statistics by table to get mean SOC per restoration site (Spatial Analyst Tools > Zonal > Zonal Statistics as Table). Input restoration sites layer. Input SOCavFitz as raster. Select Ignore NoData in calculations and get ALL statistics.

#### **Baseline scenario – Removals from degraded wetlands**

#### **12) Existing wetlands (mangrove, saltmarsh and supratidal forest)**

- Download “High value regrowth 2019 – Queensland” from QSpatial (<https://qldspatial.information.qld.gov.au/catalogue/custom/detail.page?fid={AA49DD91-1D59-40C1-B9C7-BC472148B90E}>).
- Add data QLD\_EP\_MATUREREGROWTH\_DCDB\_A and clip to Fitzroy Basin study area.
- Select wetland DBVG1M = 35a, 35b, 22a, 22b, 22c and create layer “Fitzroy\_regrowth\_wetland”.
- Download “Biodiversity status of 2019 remnant regional ecosystems - Queensland” from QSpatial (<https://qldspatial.information.qld.gov.au/catalogue/custom/detail.page?fid={8FDF54D2-654C-4822-8295-1D8E8E772373}>).
- Add data Remnant regional ecosystems and clip to Fitzroy Basin study area.
- Select wetland DBVG1M = 35a, 35b, 22a, 22b, 22c and create layer “remnantRE\_fitzroy\_wetland”.
- Union layers and intersect with restoration sites “rsites4\_reg\_rem\_wetland”. Add field (regrem\_ha) and calculate geometry (area in hectares). Export table to excel “rsites4\_reg\_rem\_wetland.xls”.

### **ECONOMIC ANALYSIS**

#### **13) Grazing land management (GLM) types for economic analysis**

- Download Qld Grazing land management land types V6.1 from QSpatial (<https://qldspatial.information.qld.gov.au/catalogue/custom/detail.page?fid={21009A22-BC37-4236-9D11-F66DA7484647}>); see Irvine et al. 2020).

- Clip GLM to the Fitzroy Basin study area.
- Intersect restoration sites with GLM land types to get GLM codes per site (Geoprocessing > Intersect, all fields) to create "rsites4\_GLM".
- Dissolve GLM layer by site (FID\_tidal, area\_ha, GLMCODE1, LTYPE1\_NAM) to remove duplicate GLM codes per site and click 'create multipart features' to create "rsites4\_GLM\_dis". Add Field (GLM\_ha) and calculate geometry (area in hectares) of each polygon. Export table to excel.
- Check that GLMs of ponded pastures (hydrologically modified wetlands) are adequately represented in the GLM data. No they are not. GLM v6.1 uses the RE mapping which maps modified wetlands as marine plains. Therefore need to merge with the wetlands hydromod layer.
- Clip hydromod layer to restoration sites and dissolve by HAB\_ and HYDROMOD\_ "rsites4\_hydromod\_dis". Clip GLM layer to restoration sites and dissolve by GLMCODE1, LTYPE1\_NAM. Erase hydromod from GLM "rsites4\_GLM\_erase\_Hydromod". Then merge erased and clipped hydromod layers "rsites\_GLM\_hydromod\_merged". Intersect with restoration sites "rsites4\_GLM\_hydromod\_intersect". Dissolve by FID\_tidal, area\_ha, LTYPE1\_NAM and HYDROMOD\_ and calculate area of each land type in added field (GLM\_ha) "rsites4\_GLM\_hydromod\_intersect\_dis". Export table to excel.
- Match land types (from Black Speargrass) to each GLM code based on land type names in excel.
- In R: Match land types to GLM codes. Calculate area (ha) of each land type per restoration site.

## CO-BENEFITS

### 14) Biodiversity

#### a) Threatened species diversity

- Obtain verified EVNT (critically endangered, endangered, vulnerable, near threatened, or migratory species) flora and fauna records from the Department of Environment and Science Wildnet (<https://www.data.qld.gov.au/dataset/wildnet-wildlife-records-published-queensland>) for the Fitzroy Basin NRM region and create a shapefile using coordinates of records "EVNT Fitzroy region".
- Count the number of records within 1 km buffer of the restoration sites using Generate Near Table. Save to default folder "rsites4\_EVNT". Export table to excel.

#### b) Connectivity with existing coastal wetlands (not modified)

- Clip Qld Wetlands layer to Fitzroy NRM region - "Wetland\_areas\_Fitzroy".
- Select by attributes pristine estuarine and freshwater wetlands that have not been hydrologically modified (Estuarine, Marine, Riverine OR Palustrine wetclasses AND HYDROMOD=H1) and create layer from selected attributes. Export data as shapefile "Wetland\_areas\_Fitzroy\_nomod".

"WETCLASS\_" = 'Estuarine' OR

"WETCLASS\_" = 'Marine' OR

"WETCLASS\_" = 'Lacustrine' OR

"WETCLASS\_" = 'Palustrine' OR

"WETCLASS\_" = 'Riverine') AND



"HYDROMOD" = 'H1'

- Calculate distance of restoration sites from closest wetland.
  - Use generate near table (Geoprocessing > Arc Toolbox > Analysis Tools > Proximity > Generate Near Table). Input: restoration sites, Near: "Wetland\_areas\_Fitzroy\_nomod", and select: find only closest feature, metres and geodesic method. Save to default because doesn't accept spaces in file names "rsites4\_dist\_wetland". Export table to excel.

**c) Connectivity with Ramsar wetlands**

- Download Ramsar wetlands of Australia data
- Select QLD sites (select by attributes, STATE = QLD), save selected features, and export as shapefile "Ramsar\_QLD".
- Calculate distance of restoration sites from closest wetland.
  - Use generate near table (Geoprocessing > Arc Toolbox > Analysis Tools > Proximity > Generate Near Table). Input: restoration sites, Near: Ramsar\_QLD, Select: metres, geodesic method, find only closest feature. Save to default because doesn't accept spaces in file names "rsites4\_dist\_ramsar". Export table to excel.

**d) Capricorn Yellow Chat – known habitat**

- Add CYC known site coordinates (in GCS\_Australian\_1984) and convert to shapefile "CYC\_known\_sites".
- Add buffer around sites according to the different radius around each site, using Buffer Analysis Tool and Field (<https://support.esri.com/en/technical-article/000013655>). Need to add new field first to shapefile (text) and calculate geometry to add "kilometers" to each field "CYC\_known\_sites\_buffer".
- **No-go restoration areas:**
  - Identify restoration sites that have a known CYC population – spatial join of restoration sites with "CYC\_known sites\_1kmbuf" (points to polygons, all attributes of the point that is closest to its boundary – 0 for within) "rsites4\_CYCsites\_1kmbuf". Export table to excel.
- **Connectivity with known CYC populations:**
  - Identify restoration sites that fall within the CYC buffer zones around the known populations - spatial join of restoration sites with "CYC\_known\_sites\_buffer" (polygons to polygons, each polygon will be given the attributes of the polygon it falls completely inside of – 0 for without) "rsites4\_CYCbuf". Export table to excel.

**f) Capricorn Yellow Chat – potential habitat**

- Select pre-clear REs that contain Yellow Chat habitat:

"RE1" = '8.1.3' OR

"RE1" = '8.1.4' OR

"RE1" = '11.1.1' OR

"RE1" = '11.1.3' OR

"RE1" = '12.1.2' OR

"RE1" = '11.1.2b' OR

"RE1" = '11.3.27x1a' OR

"RE1" = '11.3.27x1b' OR

"RE1" = '11.3.27x1c' OR

"RE2" = '8.1.3' OR

"RE2" = '8.1.4' OR

"RE2" = '11.1.1' OR

"RE2" = '11.1.3' OR

"RE2" = '12.1.2' OR

"RE2" = '11.1.2b' OR

"RE2" = '11.3.27x1a' OR

"RE2" = '11.3.27x1b' OR

"RE2" = '11.3.27x1c'

- Dissolve by RE1 and RE2 to generate one habitat layer for Fitzroy  
"preclearRE\_fitzroy\_CYChab\_dis". This keeps all the different RE polygons that provide habitat.  
Also dissolve on nothing (click create multipart features to creates one layer  
"preclearRE\_fitzroy\_CYChab\_dis2".
- **Potential habitat:** Identify restoration sites that will likely restore to Yellow Chat habitat:
  - Intersect restoration sites with "preclearRE\_CYChab\_dis2" to create "rsites4\_CYChab".  
Add field (CYChab\_ha) and calculate geometry (area in ha).
  - Intersect potential habitat with the two convex zones encompassing the 17 known CYC sites with a 1 km buffer around them representing the northern subpopulation centred on Broadsound and one the southern and southeastern subpopulations  
"rsites4\_CYChab\_convex". Export table to excel.

#### e) Patch size

- Restoration sites already have "Area\_ha" added.

### 15) Fisheries

#### a) Connectivity with fish habitat – permanent watercourses

- Select all 3 order stream and above from watercourse lines:
  - STRM\_ORDER >= 3
  - create layer from selected features and save as shape file "watercourses\_3order".
- Calculate distance of restoration sites from 3 order watercourses.
  - Use generate near table (Geoprocessing > Arc Toolbox > Analysis Tools > Proximity > Generate Near Table) and select geodesic method in metres (rsites4\_3order).

- Export table to excel.

**b) Contains nursery habitat**

- Area of each site within the lower intertidal zone from the HAT polygon.
  - Intersect restoration sites with “tid5dem\_fitzroy2” (rsites4\_tidal).
  - Remove duplicate codes per site dissolve layer by site (FID\_Tidal, area\_ha, gridcode) and click ‘create multipart features’ to create “rsites4\_tidal\_dis”.
  - Add field (Tidal\_ha) and calculate geometry (area in ha). Export table to excel.

**c) Connectivity to declared fish habitat area**

- Download Collaborative Australian Protected Areas Database (CAPAD) 2020 - Marine (<https://www.environment.gov.au/fed/catalog/search/resource/details.page?uuid=%7BAF4EE98E-7F09-4172-B95E-067AB8FA10FC%7D>).
- Clip to Fitzroy Basin NRM region “CAPAD2020\_marine\_Fitzroy”.
- Select TYPE = Fish Habitat Area and create layer from selected features “CAPAD2020\_marine\_Fitzroy\_FHA”.
- Calculate distance of restoration sites from nearest FHA.
  - Use generate near table (Geoprocessing > Arc Toolbox > Analysis Tools > Proximity > Generate Near Table) and select geodesic method in metres (rsites4\_FHA). Export table to excel.

**16) Water quality - Removal of Dissolved Inorganic Nitrogen (DIN)**

- Water residence time
  - Area of each site within the lower intertidal zone from the HAT layer (as for fisheries)
- Hydraulic efficiency: Calculate the area of the restoration site intersected by a 3 order stream or above:
  - Intersect restoration sites with “watercourses\_3order” to create “rsites4\_watercourses\_3order”.
  - Buffer the length of streams by 100m “rsites4\_3order\_buf\_100m”.
  - Add field (Area\_ha) and calculate geometry (area in hectares). Export table to excel “rsites4\_3order\_buf\_100m.xls”
- Basin Dissolved Inorganic Nitrogen (DIN) and Total Suspended Solid (TSS) loads – csv file from catchment loads modelling results.

**17) Coastal protection - Flood mitigation**

- Download “Queensland flood mapping program flood investigation Fitzroy Basin 2015” from QSpatial (<https://qldspatial.information.qld.gov.au/catalogue/custom/detail.page?fid={981554D4-F96A-4081-885D-08535CFF9732}>).
- Identify extent of flood mapping in ArcGIS. This is the Fitzroy River catchment. Doesn’t cover the whole Fitzroy Basin NRM region. The biggest population is around Rockhampton so in terms of mitigating flood risk to people and infrastructure this is ok.
- There is also a QLD flood map - “Queensland floodplain assessment overlay” from Qspatial (<https://www.data.qld.gov.au/dataset/queensland-floodplain-assessment-overlay>).
- Indirect flood mitigation: Calculate the area of restoration sites within the flood zone (100 year flood or 1% AEP) identified from the Fitzroy River Basin Flood Mapping.

- Intersect restoration sites with Fitzroy River Basin Flood Mapping. Add field (Area\_ha) and calculate geometry (area in hectares). Export table to excel "rsites4\_Fitzroy\_flood.xls".
- Direct flood mitigation: Calculate area of preclear mangrove (BVG 35a) within each restoration site – already done.

## **18) Cultural heritage**

### **a) Native title**

- Downloaded "Register of Native Title Claims", "Indigenous land use agreements", and "future act notices" from Native Title Tribunal (<http://www.nntt.gov.au/assistance/Geospatial/Pages/DataDownload.aspx>)
- Open Native\_Title\_Nat layer from "NNTT\_Data\_FGDB" folder.
- Select Determined\_outcome attributes where "Native title exists" both exclusive and non-exclusive (exclude native title does not exist and native title extinguished) and create new layer "Native\_Title\_Nat\_Exists".
- Intersect restoration sites "tidal\_graz\_defence\_dams\_preclearRE\_Dis\_1ha" with "Native\_Title\_Nat\_Exists" to get restoration sites with native title "rsites4\_nativetitle".
- Add field "NativeTitle\_ha" and calculate area in ha of each restoration site that is under native title. Export table to excel.

### **b) Cultural heritage parties**

- Downloaded cultural heritage party boundaries from <https://www.data.qld.gov.au/dataset/cultural-heritage-data-queensland-series/resource/797b408f-316e-43f1-b3a9-60889ec11089>.
- Open layer "Cultural\_Heritage\_Parties" from "QLD\_CulturalHeritage" data folder.
- Intersect with restoration sites "tidal\_graz\_defence\_dams\_preclearRE\_Dis\_1ha" to get cultural heritage parties for each restoration site "rsites4\_culturalheritageparty".
- Dissolve for FID, area\_ha, name and save as "rsites4\_culturalheritageparty\_Dis".
- Export table to excel.

### **c) Protected sites**

- Open layer "Designated\_Landscape\_Areas" from "QLD\_CulturalHeritage" data folder.
- None within the Fitzroy Basin restoration sites. Closest is in Carnarvon NP.
- Also no "cultural heritage study areas" within Fitzroy Basin restoration sites.

### **d) Leasehold and commonwealth land**

- Open layer "Cadastral\_data\_QLD\_CADASTRE\_DCDB" from "QLD\_Cadastraldata" folder.
- Select "Tenure":
  - "State land"
  - "State forest"
  - "Lands lease"
  - "Forest reserve"
  - "National park"
  - "Reserve"
  - "Timber reserve"
  - "Water resource"
- Save layer "Qld\_cadastral\_tenure"

- Intersect with restoration sites “tidal\_graz\_defence\_dams\_preclearRE\_Dis\_1ha” to get leasehold and commonwealth land in restoration sites “rsites4\_cadastraltenure”
- Dissolve by FID, area\_ha, tenure and save as “rsites4\_cadastraltenure\_dis”.
- Add tenure\_ha field and export table to excel.

## RESTORATION FEASIBILITY

### 19) Drains, barriers and tidal zone

- Download from QSpatial “Canal areas – Queensland” (<https://qldspatial.information.qld.gov.au/catalogue/custom/detail.page?fid={77C9BCA1-EB8A-49C0-B374-430CD3AB97AB}>) and “Canal lines – Queensland” (<https://qldspatial.information.qld.gov.au/catalogue/custom/detail.page?fid={5166006C-6A83-4CBE-9AC2-082DEBD784B0}>) and investigate in study area – only canal lines, no canal areas.
- Clip canal lines to Fitzroy NRM region “Canals\_Fitzroy”.
- Fitzroy Basin Association (FBA) have provided Wetlands Bar Priority mapping “FBAW\_ALLCURRENT” which details location of fish passage barriers in the FBA NRM region from a barriers to fish passage project (Marsden 2015).
  - Can’t merge “FBAW\_ALLCURRENT” and “Canals\_Fitzroy” layers as they are point and polyline files.
- Identify restoration sites that have been hydrologically modified by a drain or barrier (If canal present, there would be gate to drain water off land, or bund):
  - Spatial join of restoration sites “tidal\_graz\_defence\_dams\_preclearRE\_Dis\_1ha” with canal lines (lines to polygon, summary of the numeric attributes of lines that intersect the polygon, i.e. count) “rsites4\_canals\_join”. Export table to excel - NO CANALS
  - Spatial join of restoration sites “tidal\_graz\_defence\_dams\_preclearRE\_Dis\_1ha” with FBAW\_ALLCURRENT (points to polygon, summary of the numeric attributes of lines that intersect the polygon, i.e. count) “rsites4\_barriers\_join”. Export table to excel “rsites4\_barriers\_join.xls”.
  - If needed - Intersect restoration sites with canal lines, add field (length\_m) and calculate geometry (length in m) to get length of canal lines within each site (rsites4\_canals\_length). Export table to excel. (this was needed for carbon abatement, but canals not included in new blue carbon tidal restoration method) – NO CANALS.
  - If needed - Intersect restoration sites with FBAW\_ALLCURRENT (rsites4\_barriers). Export table to excel. – ONLY INCLUDE THIS IF POINTS ARE ASSOCIATED WITH AN AREA, HOWEVER CAN’T FIND THAT INFORMATION IN THE REPORT.
- Identify intertidal zone of restoration sites:
  - Intersect restoration sites (tidal\_graz\_defence\_dams\_preclearRE\_Dis\_1ha) with “tid5dem\_fitzroy2” to get intertidal zone (“rsites4\_tidal”). Add field and calculate area of each intertidal zone at each site (Tidal\_ha). Use Type: Double, Precision: 10, Scale: 5. Export table to excel.