Lewis, Megan Mary; White, Davina Cherie; Gotch, Travis Bruce (eds.) 2013, Allocating water and maintaining springs in the Great Artesian Basin. Volume IV. Spatial survey and remote sensing of artesian springs of the western Great Artesian Basin, Canberra, National Water Commission

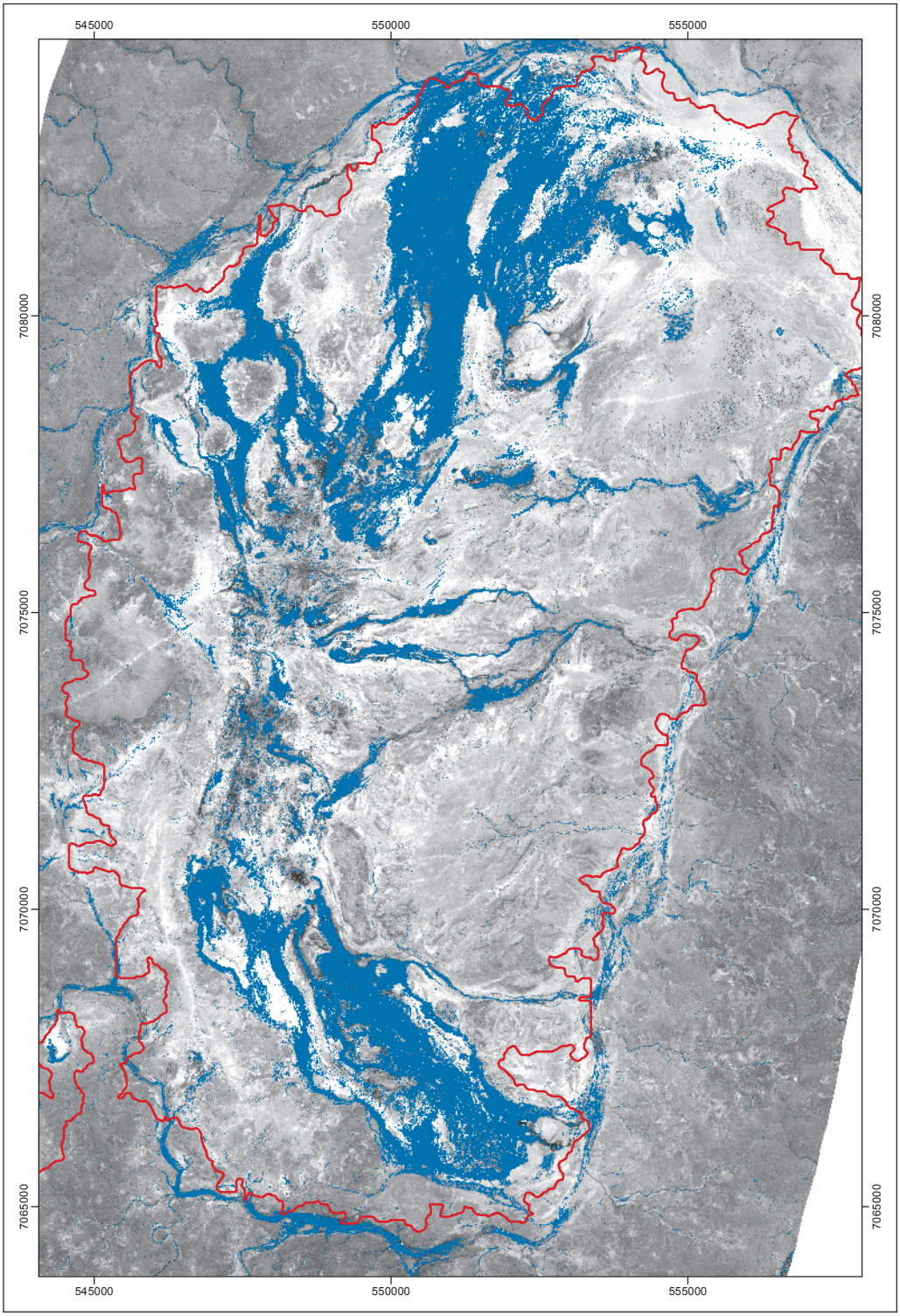


Figure 3.8: Distribution of surface moisture, from NDSMI analysis of HyMap airborne hyperspectral imagery

Surface Moisture

Wetted Area

Spring Discharge Boundary

0 1 2 3

Kilometres

N

Background image: HyMap, 665.7 nm, March 2009.
Produced by The University of Adelaide - School of Earth & Environmental Sciences
Map Projection: UTM Transverse Mercator
Map Datum: Geocentric Datum of Australia 1994
Date: January 2012

3.5. Francis Swamp Spring Complex

The Francis Swamp Spring Complex is situated 65 km south-west of Lake Eyre at latitude 29.16°S and longitude 136.30°E, covering an area of 58 km^2. The complex comprises four spring groups: Francis Swamp, Margaret, Lake William and Emily. This study focuses only on Francis Swamp and Margaret spring groups as the other two groups are some distance outside the study zone. The complex lies on the border of two contrasting bioregions; to the north, east and west the sand dunes of the Simpson-Strzelecki Dunefields dominate the landscape, while to the south the stony erosional plateaus of the Stony Plains region dominate. The intermittently flowing Anna Creek flanks the eastern side of Francis Swamp, while Warriner Creek flows along the southern edge of Francis Swamp Spring Group, separating it from the Margaret Spring Group. These creeks converge on the eastern boundary and continue east as the Warriner Creek. The entire area is geologically stable with no known faults intersecting the Francis Swamp Spring Complex. The surrounding red sands of the dune fields are well vegetated with shrublands, while the stony tablelands to the south support low open chenopod shrublands. The complex lies within Anna Creek pastoral station and is utilised for cattle grazing.

The surface of Francis Swamp contrasts markedly with the surrounding dune fields and plains. It comprises an extensive elongated area dominated by evaporite crust, aligned north–north-west to south–south-east, extending over 10 km. Topographically the swamp is a conspicuous surface depression with an average elevation 66 m above sea level, contrasting with surrounding land surfaces which rise above 100 m (Figure 3.9). The surface of the swamp slopes from the north-west down to the south-east, with the springs in the south-east being 12 m lower than those in the north-west, which reflects a 0.02% decline from the western to eastern edges.

Running down the north–south axis of the spring group is a low linear dune ridge dominated by Umbrella Bush (*Acacia ligulata*). Limestone mounds associated with active and extinct springs provide localised relief of less than 5 m across most of the swamp.

The majority of active spring vents are located on the eastern side of Francis Swamp, although the western portion contains many extinct and unsurveyed vents. These vents became increasingly difficult to identify during the survey, as they were heavily eroded and often only present as a lacework net of limestone

Table 3.2: Spatial characterisation of Francis Swamp Spring Complex

Spring Group Code	Spring Group Names	Aboriginal Spring Group Name	Number of Vents	Elevation (m above MSL)				
				Mean	Maximum	Minimum	Range	Standard Deviation
FES	Emily Springs	Papupunha	3	55.761	55.876	55.615	0.261	0.133
FFS	Francis Swamp	Numerous individual names nothing specific	884	61.602	66.620	54.193	12.427	2.960
FMS	Margaret Springs	Yurilja	9	59.292	60.047	58.082	1.965	0.585
FWS	Lake William Springs	Manja-pulanha	3	62.151	66.702	54.818	11.884	6.412

Photo: Travis Gotch

ridges protruding from the damp saline flats. There are 884 surveyed spring vents (Table 3.2). Of these, over half are damp, supporting groundwater-dependent vegetation but with no surface expression of free water, and one quarter are extinct, clustered heavily towards the northern tip. Active vents with surface water concentrate along the lower eastern-most edges of the swamp. A total of 36 vents have surface water and drainage tails that support wetland vegetation and associated biota. These are predominantly found along the eastern margins, with the majority located in the south-eastern portion of Francis Swamp (Figure 3.10).

Distribution of wetland vegetation is strongly linked to surface flow from spring vents, with the majority of spring-fed vegetation in the eastern side of the swamp (Figure 3.11). Springs with free water and flowing tails generally support limited wetlands of low open sedgelands dominated by *Baumea juncea*, *Cyperus gymnocaulos* and *Gahnia trifida*. Some isolated mounds with no flow are topped by small, dense stands of *Phragmites australis* and/or *Gahnia trifida*. Away from the zone of active springs, halophytic low open shrublands of Samphire (*Halosarcia* sp. and *Sarcocornia* sp.) and Sea Heaths (*Frankenia* sp.) occur along the west and south-west margins of the swamp, and the south-eastern margins bordering Warriner Creek. Thick stands of Bush Grapes (*Nitraria billardierei*) and scattered Coolabah (*Eucalyptus coolabah*) occur along the margin of Anna Creek. The dune bisecting the centre of the swamp supports shrublands of similar species composition to the surrounding dunefields.

Francis Swamp's lack of surface flow is contrasted by its extensive sub-surface moisture. Many active vents do not present surface flow but display moisture on or just below the surface. Analysis of airborne hyperspectral imagery provided evidence of swamp-wide levels of near-surface moisture (Figure 3.12) and measurements of soil samples show highly variable moisture levels ranging up to 46% (Figure 3.13). The east of the swamp was

frequently measured above 10% soil moisture, contrasting with the very low levels (below 1%) recorded in samples from nearby inter-dune swales. Moisture levels were generally higher near active spring vents, decreasing at greater distances from the point of discharge.

Thermal mapping of the surface shows distinctly lower temperatures within the diffuse discharge zones of Francis Swamp compared to the surrounding dunes and stony plains (Figure 3.13). Areas within Francis Swamp measured below 20°C, contrasting the surrounding landscape averages of 24°C. At the extreme this can extend up to a 7°C difference between the swamp and adjacent land. The western side of the swamp exhibits similar thermal characteristics to the east, despite its lack of active vents. This similarity suggests continued seepage is occurring sub-surface.

The evaporation of diffuse discharge leaves a distinctive crust of evaporite minerals, which is more extensive at Francis Swamp than any other spring groups within South Australia. Analysis of their distributions was undertaken using hyperspectral imagery, which provides maps of relative abundance through comparison with distinctive spectral signatures (Figure 3.14). Occurrence of these minerals was confirmed by X-ray diffraction analysis of core samples from the area. The distribution of evaporite minerals appears highly related to spring vents.

Calcite minerals were found in quantities much higher within the swamp, particularly along the eastern side. Calcite is distributed away from immediate transport zones such as vent tails but remains within the vicinity of vents, often deposited as a travertine shelf at or just below the surface. Calcite comprised 10–30% of the weight of most core samples taken, although some reached concentrations of 70–90%.

Gypsum is much more widely distributed within Francis Swamp compared to calcite. It is more broadly dispersed, partly due to its higher solubility, and is found in high quantities in water channels and drainage areas of spring vents. The highest concentrations are observed around spring vents and reduce with distance. Most core samples tested show low concentrations below 5%, although three from dispersed parts of the swamp surface were very highly concentrated.

Halite is highly water soluble and also has a distribution with high concentrations along the eastern side of Francis Swamp. Halite concentrations are focused around vents but show less expression of surface transportation. Halite was shown to be the most common evaporite at Francis Swamp, although in concentrations frequently below 5%, and never more than 10%.

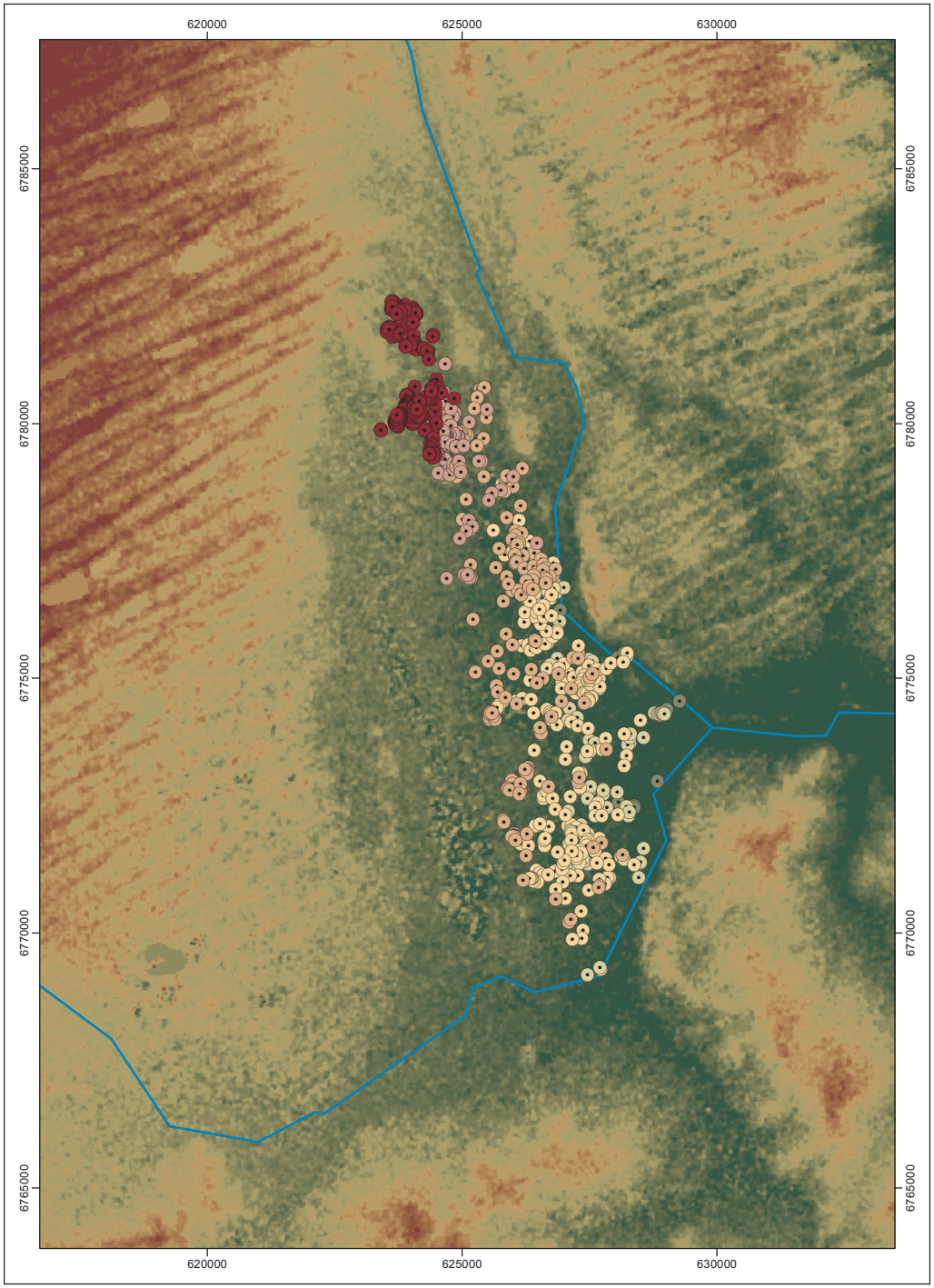
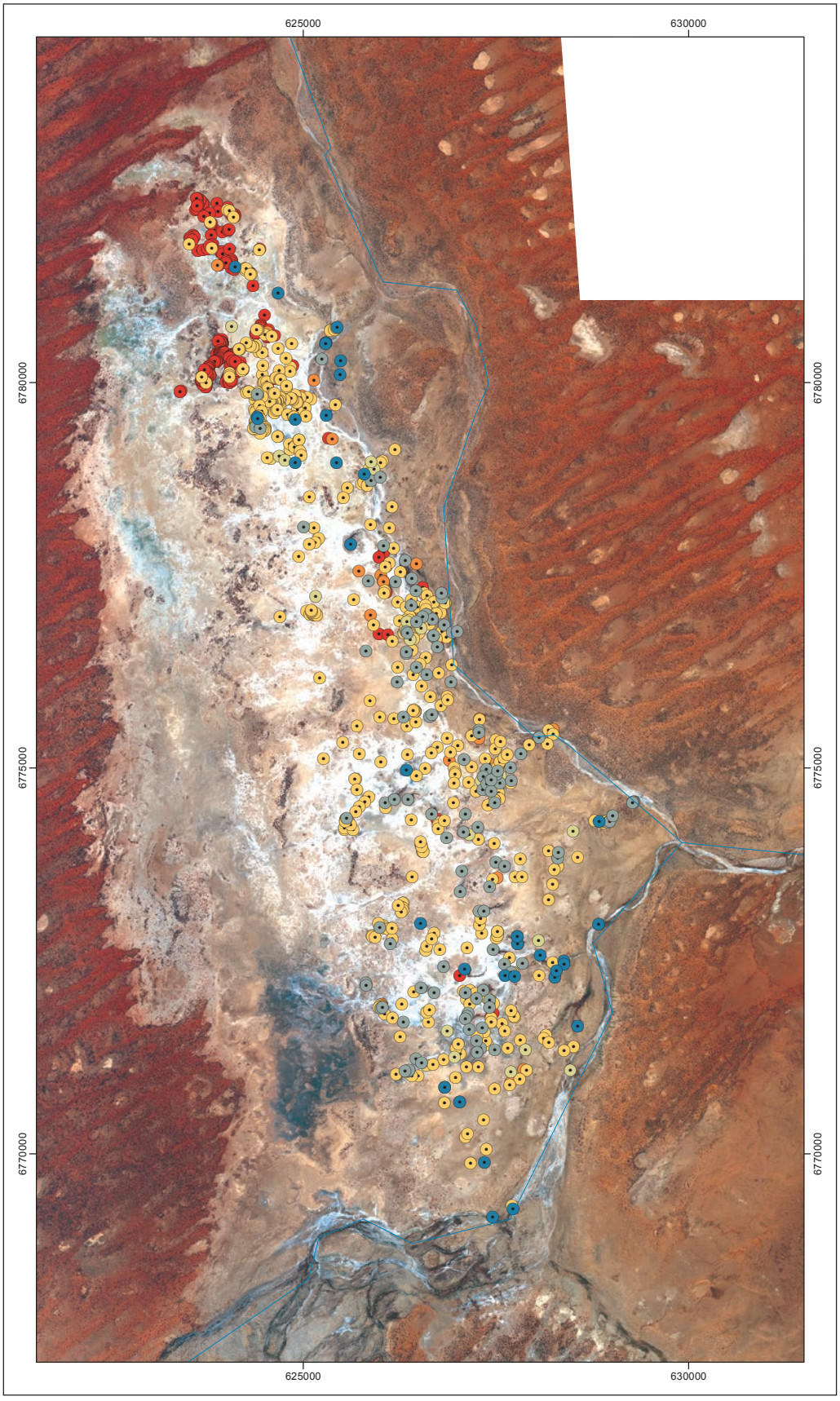


Figure 3.9: Elevation of Francis Swamp Spring Complex and surrounding terrain

Digital Elevation Model, 2010 release.
Produced by The University of Adelaide - School of Earth & Environmental Sciences
Map Projection: UTM Transverse Mercator
Map Datum: Geocentric Datum of Australia 1994
Date: February 2012

Figure 3.10: Distribution and flow status of surveyed spring vents in Francis Swamp Springs Complex



Background image: HyMap, red 889.5 nm, green 559.1 nm and blue 466.9 nm, March 2009.
Produced by The University of Adelaide - School of Earth & Environmental Sciences
Map Projection: UTM Transverse Mercator
Map Datum: Geocentric Datum of Australia 1994
Date: January 2012

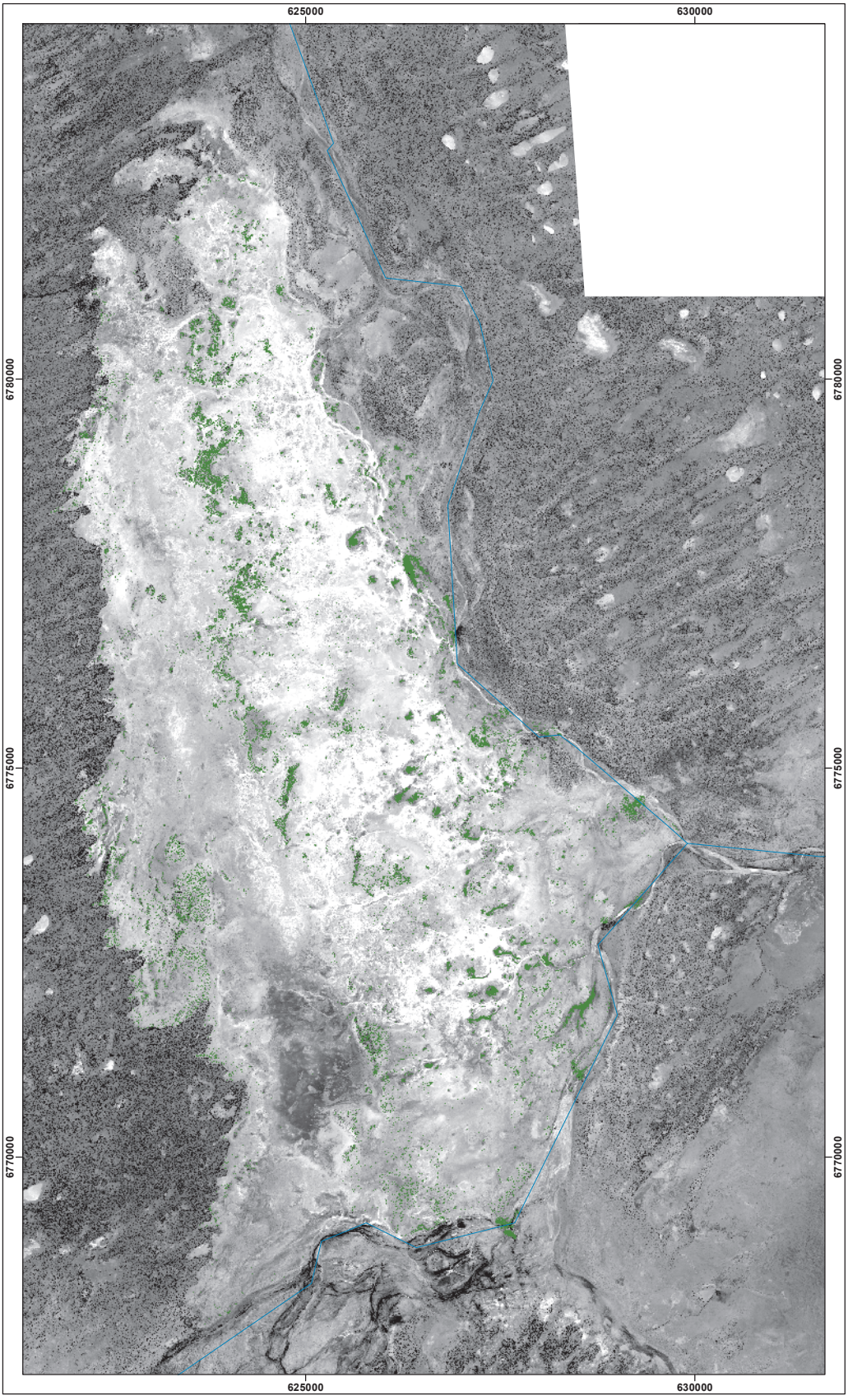


Figure 3.11: Distribution of vegetation in Francis Swamp Springs Complex, from NDVI analysis of HyMap airborne hyperspectral imagery (March 2009)

Legend

Wetland Vegetation

Watercourse

0 1 2 3

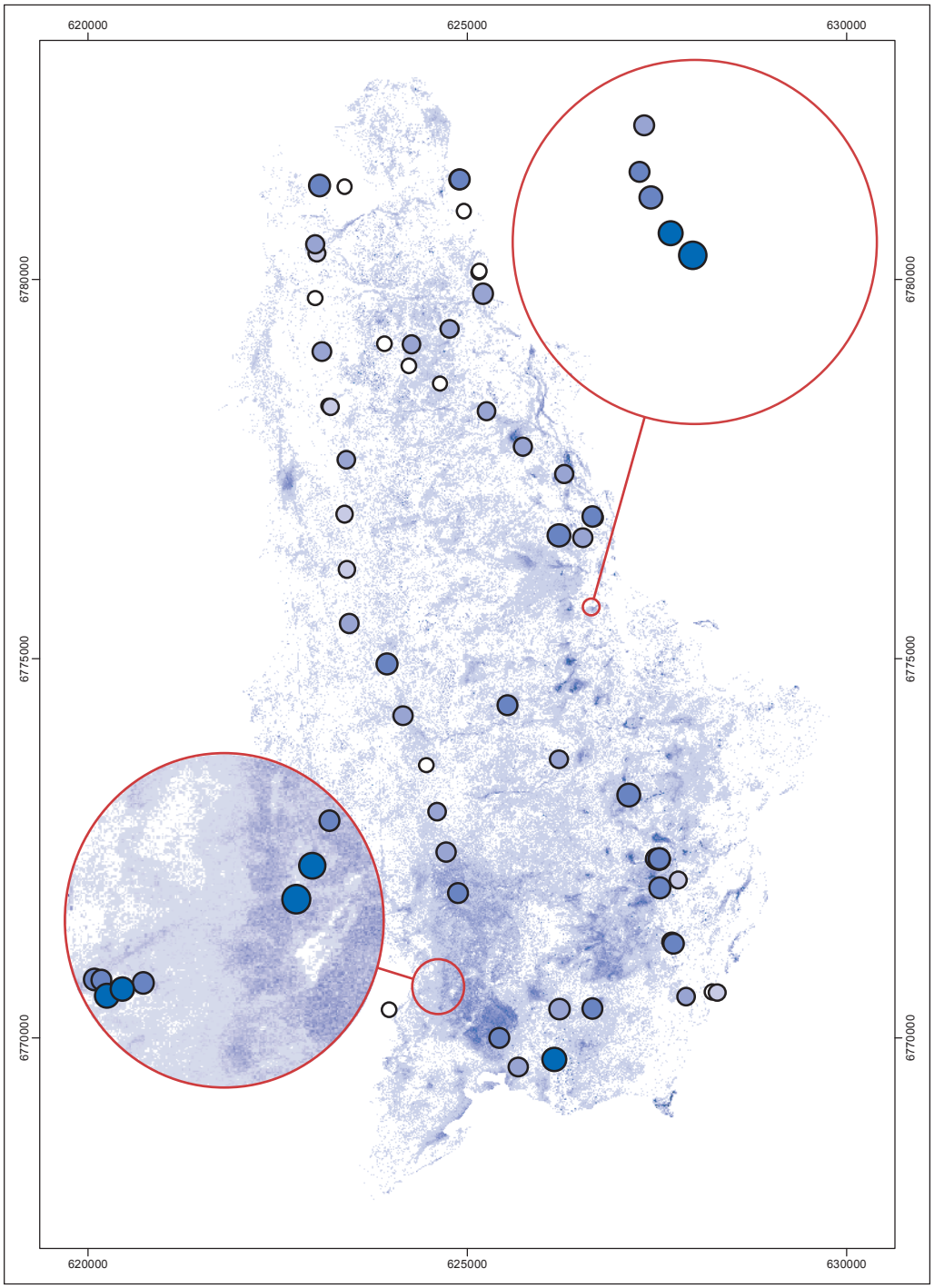
Kilometres

N

Background image: HyMap, 665.7 nm, March 2009.
Produced by The University of Adelaide - School of Earth & Environmental Sciences
Map Projection: UTM Transverse Mercator
Map Datum Geocentric Datum of Australia 1994
Date: January 2012

Figure 3.12: Distribution of surface moisture in Francis Swamp Springs Complex, from on-ground soil samples and NDSMI analysis of HyMap airborne hyperspectral imagery

The large red circles contain detailed insets indicating changes in surface moisture with distance from spring vent (top right) and at the fringe of the swamp (bottom left).



Produced by The University of Adelaide - School of Earth & Environmental Sciences
Map Projection: UTM Transverse Mercator
Map Datum: Geocentric Datum of Australia 1994
Date: February 2012

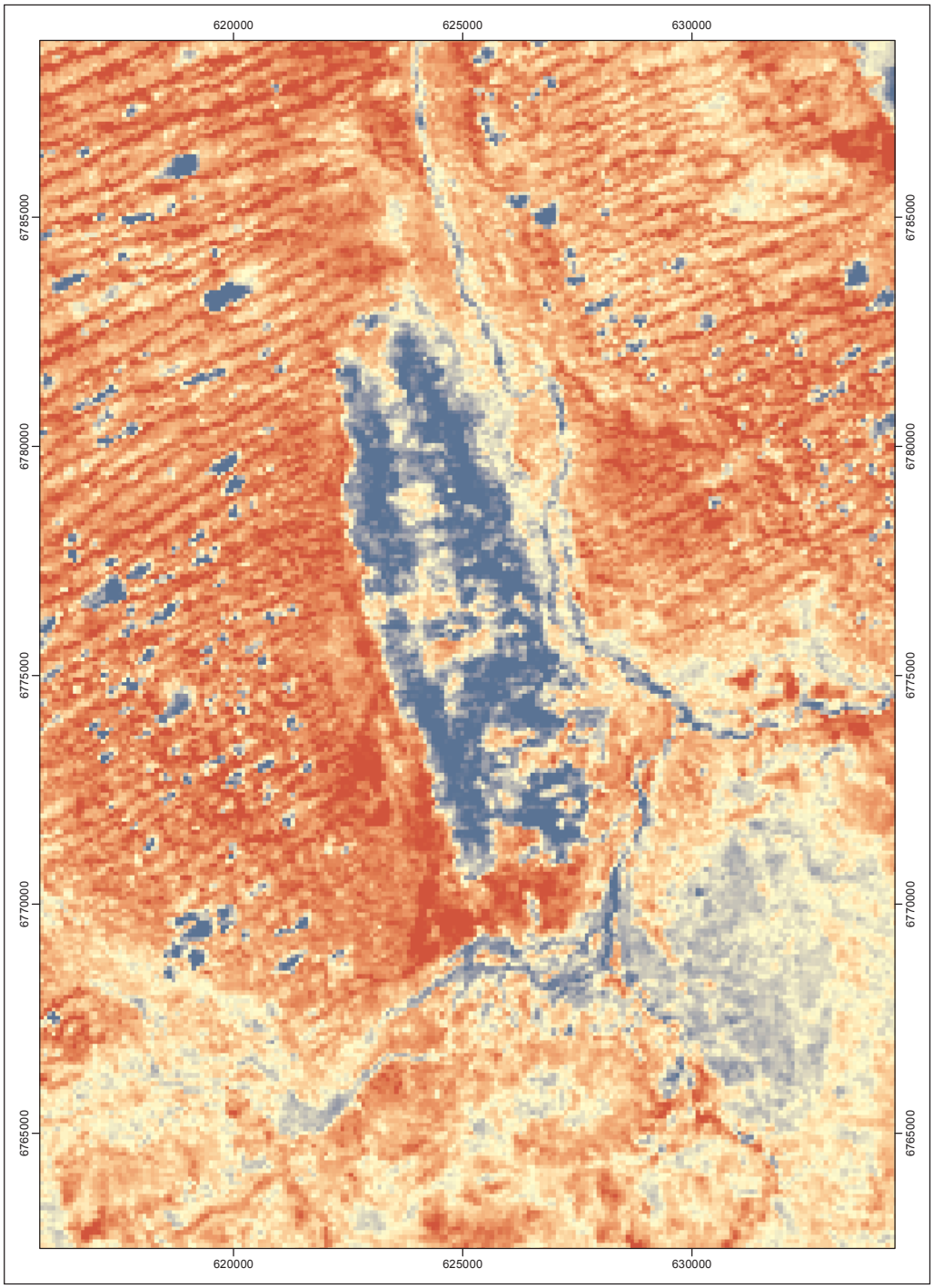
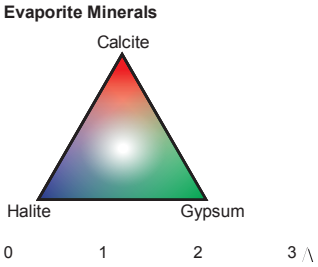
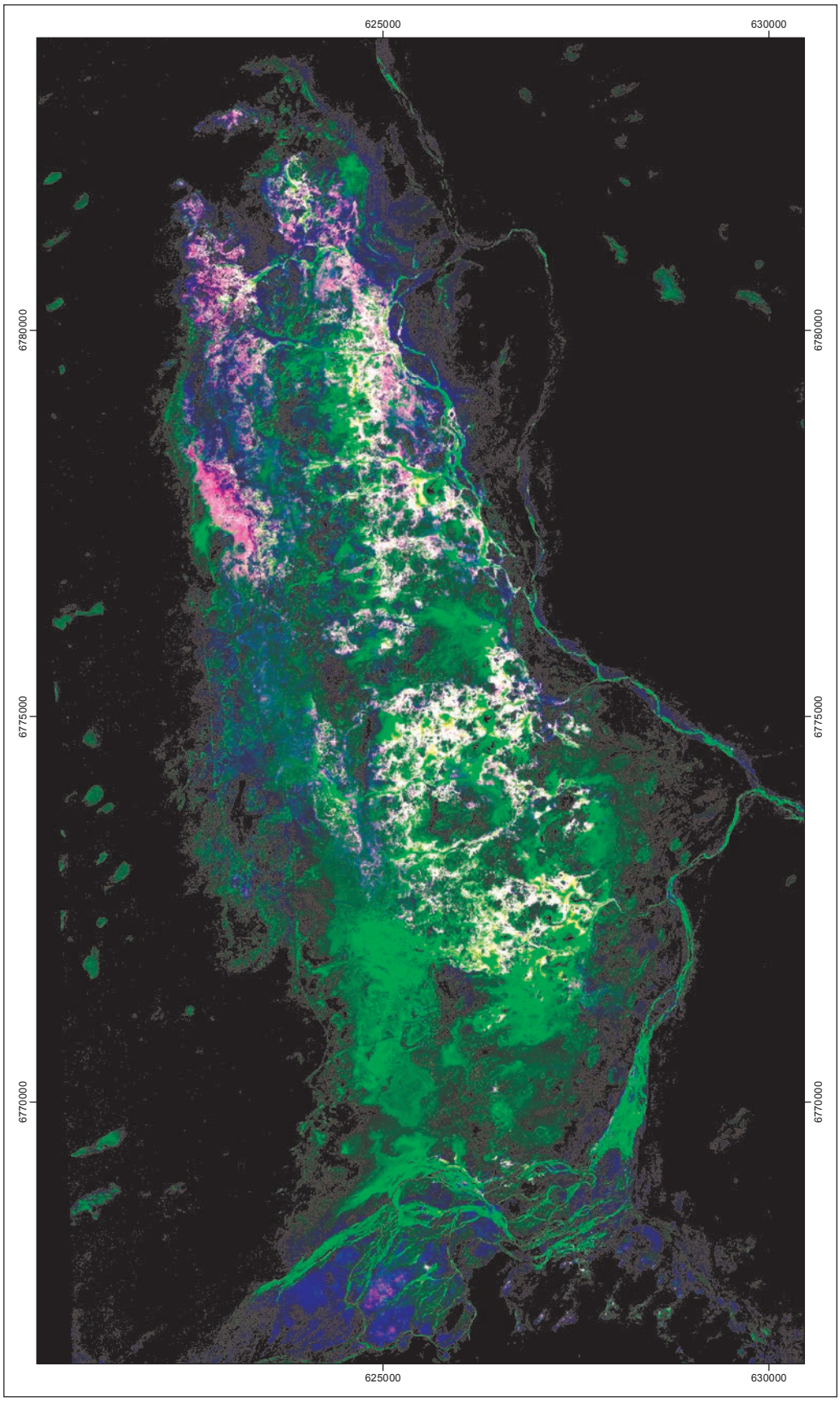


Figure 3.13: Surface temperature of Francis Swamp Springs Complex and surrounding terrain, from ASTER thermal satellite imagery

Figure 3.14: Distribution of calcite, gypsum and halite minerals, from spectral analysis of HyMap airborne hyperspectral imagery (March 2009)



Produced by The University of Adelaide - School of Earth & Environmental Sciences
Map Projection: UTM Transverse Mercator
Map Datum: Geocentric Datum of Australia 1994
Date: March 2012



3.6. Freeling Springs, Mt Denison Spring Complex

The Mt Denison Spring Complex lies immediately to the east of the Denison Ranges at latitude 28.06°S and longitude 135.91°E, within the Stony Plains IBRA region. The complex comprises nine spring groups, of which just three are still active (Figure 3.15). This study focuses on the two major spring groups, Freeling and Freeling North (Figure 3.16). Both of these groups have formed along the Kingston fault where the GAB aquifers abut the Peake and Denison Inlier (Rogers & Freeman 1994). Freeling Spring Group consists of 100 vents that run in an almost north–south alignment. This group contains abutment seeps along the edge of the ranges and carbonate mounds, pools and terraces. Most springs in this group are small to moderate in size, but several vents have extensive braided spring tails associated with them. Freeling North Spring Group, located at the gap where the Peake Creek passes through the Denison Range, is considerably smaller, consisting of 23 surveyed vents and another three vents further north that were inaccessible during the survey due to local flooding.
The group comprises several mounds and abutment seeps, with one notably large spring that maintains the *Inthunintjunha* waterhole. Freeling Springs is the second most biologically significant spring group in South Australia, behind Dalhousie Springs (Social and Ecological Assessment 1985; Gotch unpublished data).

Distribution of vegetation associated with springs and the Peake Creek at Freeling South Springs was identified using WorldView-2 satellite imagery, from a threshold applied to the NDVI (see Appendix 2). This is the first comprehensive mapping of the wetland vegetation associated with the springs at this complex (Figure 3.17).

Table 3.3. Spatial characterisation of Mt Denison Spring Complex

Spring group code	Spring group names	Aboriginal spring group name	Number of vents	Elevation (m above MSL)				
				Mean	Maximum	Minimum	Range	Standard deviation
EBN	Breakneck	Unknown	1	Not Surveyed				
EBS	Blind Springs	Pitja-murrunha	1	Not Surveyed				
ECS	Coppertop	Kadni	1	Not Surveyed				
EFN	Freeling North	Inthunintjunha	23	54.585	56.147	53.371	2.776	0.675
EFS	Freeling Springs	Yardiya	100	63.119	73.331	54.935	18.396	4.147
EMM	Murra Murrana	Wadnamparanha	2	Not Surveyed				
EMS	Mud Springs	Karilimanha	1	Not Surveyed				
ESC	Sandy Creek	Kudna-purrunha	2	Not Surveyed				
EUC	Tidnamurkuna	Thindna-murkanha	1	Not Surveyed				

Within the wetlands, several of the dominant species were differentiated through analysis of hyperspectral imagery (Figure 3.18). Dense homogenous stands of *Phragmites australis* are present at this site and clearly mapped in regions on and surrounding spring vents, covering a total area of 0.53 ha in April 2011 (Table 3.4). Although less extensive than at many other spring groups, *Phragmites australis* has a similar spatial distribution here, occurring in dense monospecific stands surrounding some spring vents. Sparser stands of *Phragmites australis* mixed with *Cyperus gymnocaulos* are dispersed in small patches on spring tails where standing and free-flowing water is present: this association covered 0.22 ha in April 2011 (Figure 3.18, Table 3.4). Interspersed between wetlands supported by spring flows, very sparse low open shrublands of Samphire (*Halosarcia* sp. and *Sarcocornia* sp.) are common on salinised areas fed by diffuse groundwater discharge. These often occur on the flanks and fringes of the springs.

The wetted area within the Freeling Spring Group was delineated using the Normalised Difference Soil Moisture Index (NDSMI) applied to HyMap imagery (Appendix 2). These areas coincide predominantly with the wetland vegetation at this site and extend beyond the springs (Figure 3.19). Zones of elevated soil moisture are particularly extensive to the north of this spring group where the larger springs and their associated tails are present. Areas with saline surface crust associated with evaporation of diffuse groundwater discharge were also mapped successfully for the Freeling Spring Group using hyperspectral analysis (Figure 3.19). These zones are quite extensive surrounding the wetted areas, extending laterally from north to south, and are particularly extensive around the flanks of the main spring in this group.

Table 3.4: Area of wetland vegetation associations, Freeling Spring Group, from spectral analysis of HyMap airborne hyperspectral imagery (April 2011)

Vegetation type	Vegetation area (ha)
Phragmites australis	0.53
Phragmites australis and *Cyperus gymnocaulus*	0.22
Samphire	0.87

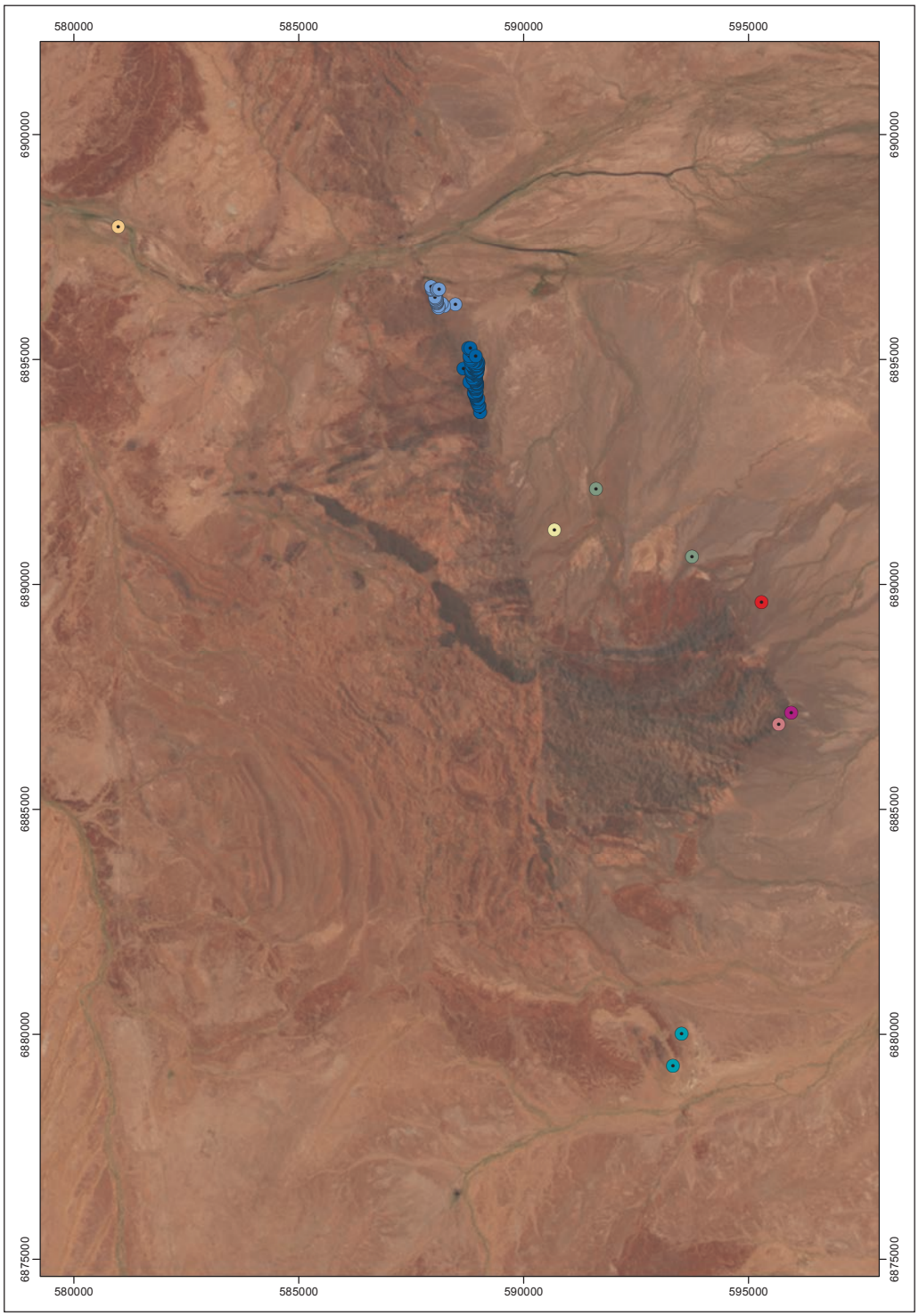
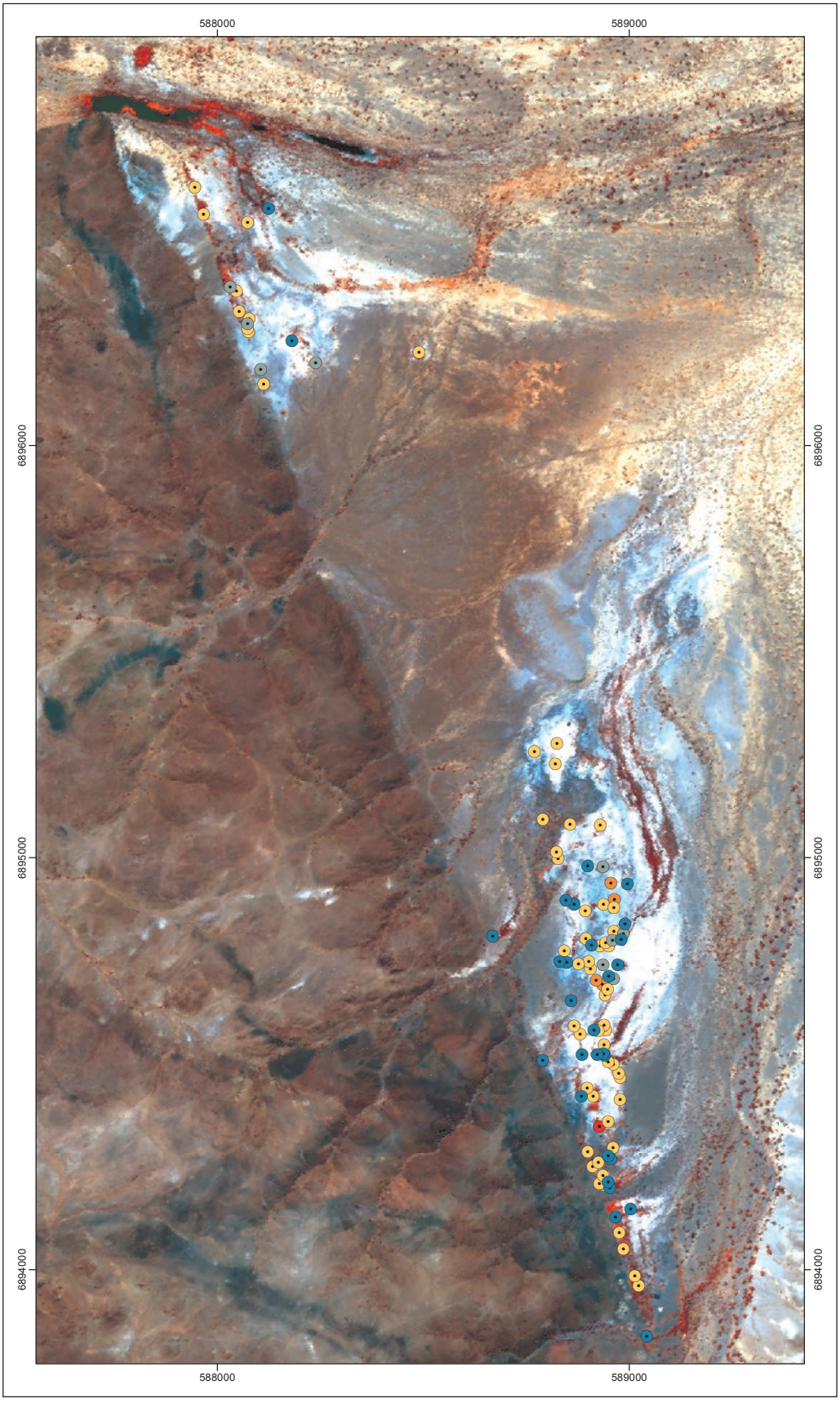


Figure 3.15: Distribution of springs and spring groups in Mt Denison Spring Complex

Background image: Landsat, True Colour, 2006.
Produced by The University of Adelaide - School of Earth & Environmental Sciences
Map Projection: UTM Transverse Mercator
Map Datum: Geocentric Datum of Australia 1994
Date: January 2012

Figure 3.16: Distribution and flow status of surveyed spring vents in Freeling and Freeling North Spring Groups



Background image: HyMap, red 889.5 nm, green 559.1 nm and blue 466.9 nm, April 2011.
Produced by The University of Adelaide - School of Earth & Environmental Sciences
Map Projection: UTM Transverse Mercator
Map Datum: Geocentric Datum of Australia 1994
Date: January 2012

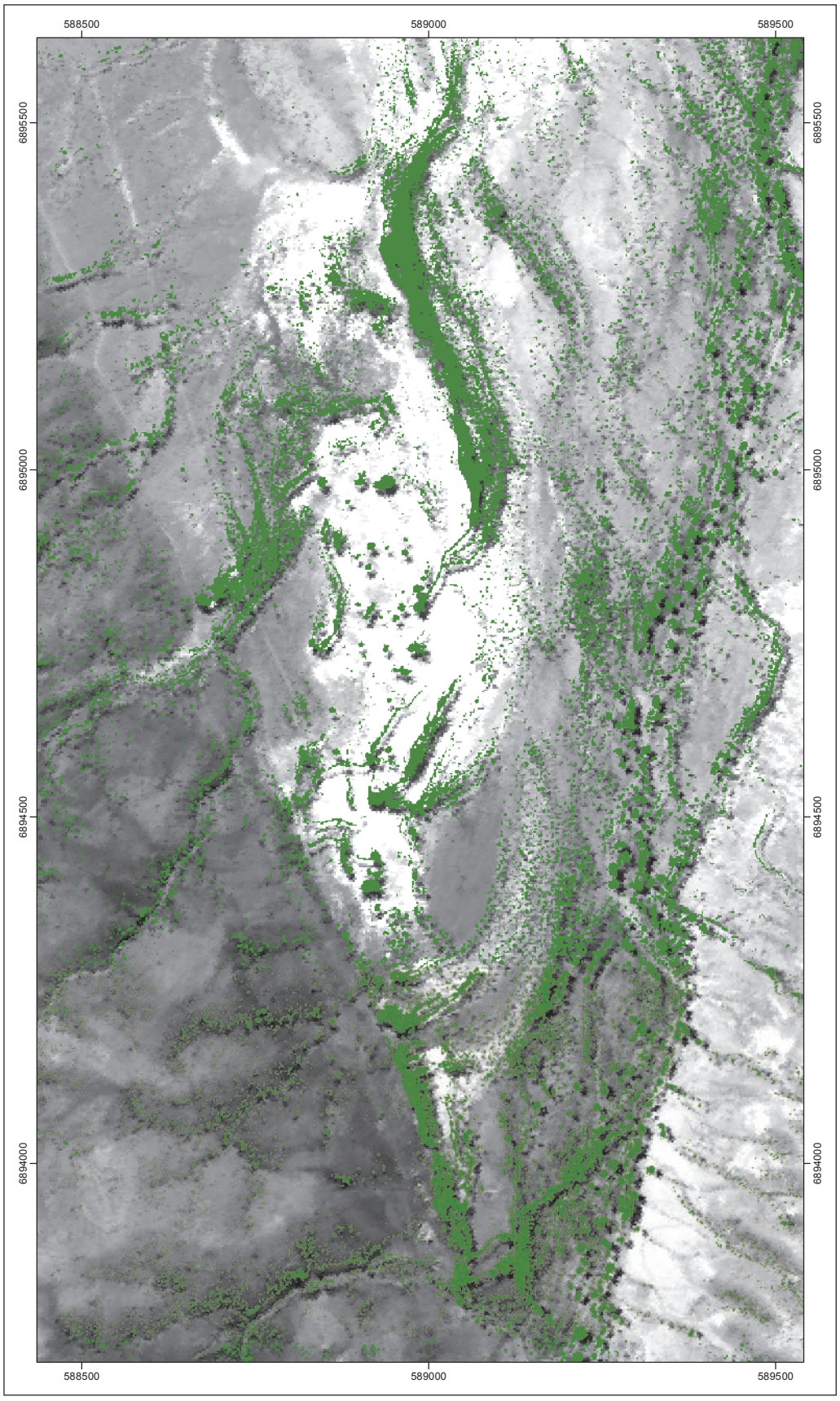
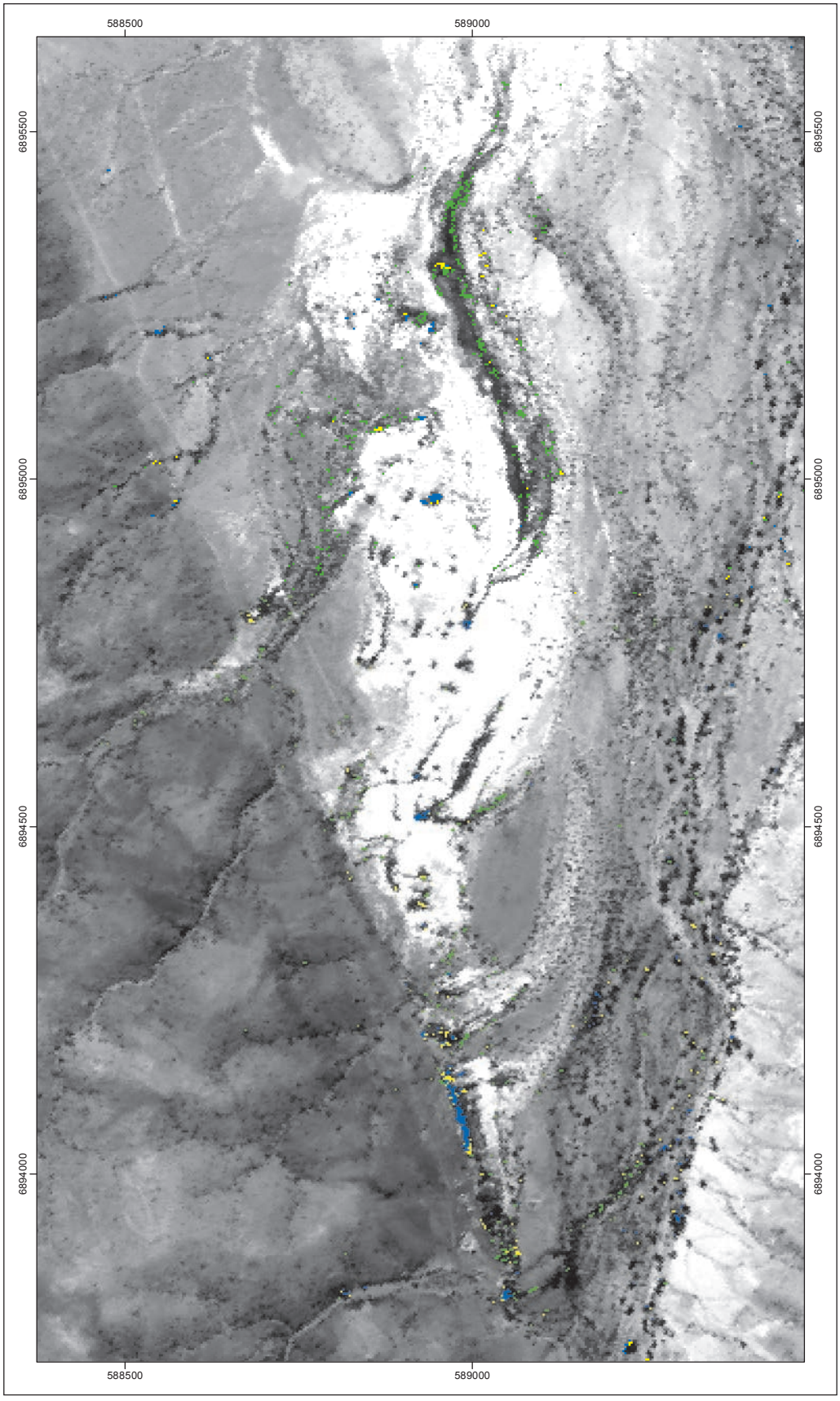


Figure 3.17: Distribution of vegetation at Freeling Springs, Freeling North and nearby intermittent watercourses, from NDVI analysis of WorldView-2 multispectral satellite imagery (May 2011)

Figure 3.18: Distribution of dominant wetland vegetation species at Freeling Spring Group, from mixture tuned matched filtering analysis of HyMap airborne hyperspectral imagery (April 2011)



Background Image: HyMap, 665.7 nm, April 2011.
Produced by The University of Adelaide - School of Earth & Environmental Sciences
Map Projection: UTM Transverse Mercator
Map Datum: Geocentric Datum of Australia 1994
Date January 2012