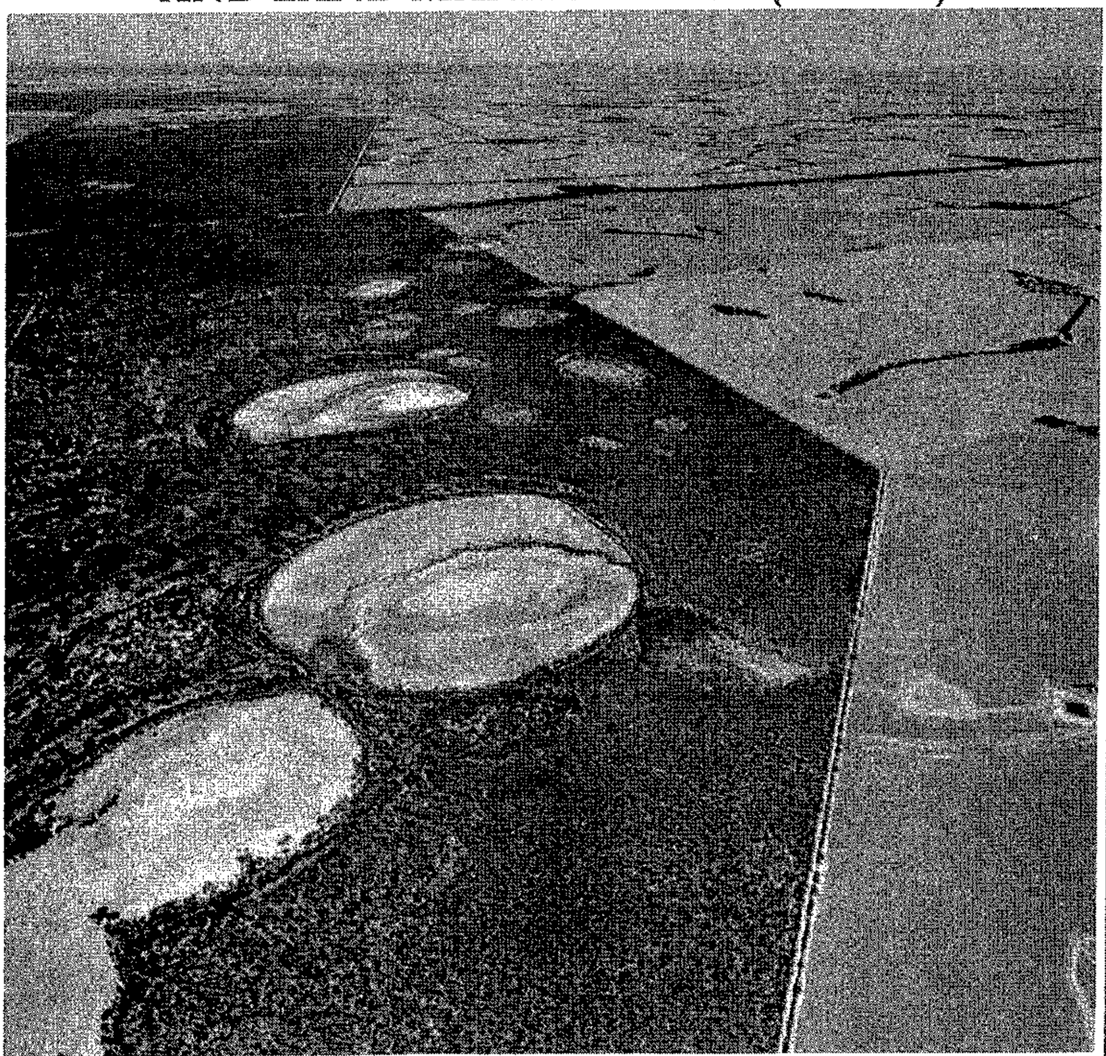
CONSULTANCY - CONTOUR MAPPING IN THE LAKE BRYDE / EAST LAKE BRYDE WETLAND CHAIN

On Behalf of the

DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT (CALM)



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REPORT

LAKE BRYDE WETLAND CHAIN

PHOTOGRAMMETRIC MAPPING AND DIGITAL ELEVATION MODEL

Introduction

This report outlines the procedures adopted by Kevron Aerial Surveys for the aerial survey and mapping of the Lake Bryde Wetland Chain, conducted during June and July 2000.

Scope of Work.

Project requirements, detailed in contract document RFT W2/00, included:

- Provision of aerial photography.
- Installation of ground surveyed mapping control, including the installation of a number of permanent marks.
- Photogrammetric mapping for the supply of a Digital Elevation Model, generation of contours at 0.3 metre intervals and mapping of significant topographic and planimetric features within the

reserve.

- Determination of flowpaths, low-points and the floodplain shape.

Project Location and extents

The project area falls within the Lake Bryde Recovery Catchment located approx. 320 km south-east of Perth and 35 km south-west of Newdegate. Contained within in the shires of Kent and Lake Grace. Color aerial photography was flown over 15800ha and mapping photography (B/W) over 5200ha of valley floors.

Datum.

Mapping was conducted in WGS84. UTM Zone 50.

Deliverables.

- A 1:25,000 scale map, to include contours, roads, lakes, culverts, fences (those visible), survey control stations, surface water flowpaths, low points. 4 hardcopies and 1 digital file in Arcview shapefile format.
- The DEM
- This report

Mapping Phase of Project

Aerial photography

Black and white photography was acquired for the mapping phase of the project, given the time of year for acquisition, the high resolution film delivered the best possible results in determination of detail.

The photography was flown under even overcast conditions to enhance the detail in vegetated areas where long shadows would otherwise obscure such detail

B/W photography was flown on 22 May 2000, using a Wild RC30 camera at a scale of 1:5000 with a nominal 152mm lens cone. 9 runs were acquired with an additional 7 tie runs for aerotriangulation purposes. Total of 252 exposures.

Camera exposure stations were recorded with airborne GPS.

Colour photography as required for the tender requirement was also acquired at a scale of 1:5000 under clear blue skies. 19 runs were acquired for a total of 489 exposures.

Colour photography was flown on the 23 May 2000, using a Wild RC30 camera with a nominal 152mm lens cone.

Flight Line diagrams are detailed in Appendix 1.

Control Survey.

A total of 20 photo control points required pre-marking over the site.

A Kevron field party mobilised on 18th May and completed target laying on 20th May.

Targets were laid in the form of crosses, each arm being 1m long by 0.2 m wide.

Control locations defined as permanent (those within the reserve) were installed with a star iron picket (SIP) driven to refusal.

Dumpy pegs were placed at temporary locations.

McMullen and Nolan were contracted to co-ordinate photo control targets.

Field surveys commenced on 24th May with final co-ordinate listings supplied on 30th May.

Connections were made to a number of existing Benchmarks and SSMs.

A listing of target locations, survey connections diagram and final WGS84 UTM co-ordinates are found in Appendix 2

Aerotriangulation.

A set of B/W film diapositives were produced from the aerial photography.

Point marking of the diapositives was conducted on a Wild Pug4 point marking device.

Prior to aerotriangulation the 'pugged' diapositives were scanned on a Helava DSW300 precision photogrammetric scanner at 15 microns.

Aerotriangulation observations were performed on a Zeiss P1 1st order analytical stereoplotter. A total of 997 tie/pass points were observed.

PATB software was used to perform a bundle adjustment of the aerotriangulation data. Airborne GPS photo-centres were imported into the Pat_B software to assist in the solution.

Mean value of standard deviation of terrain points in units of terrain system

in x *0.045*
in y *0.044*
in z *0.063*

A complete printout of the PATB bundle adjustment is tabled in Appendix 3.

Photogrammetric feature and vector mapping.

PATB aerotriangulation results were imported into SocetSet software. Model orientation parameters were then computed to enable mapping in Helava Softcopy digital workstations.

Vector data (roads, water features, fencelines etc) were mapped into Microstation on the Zeiss P1 stereoplotter. Concurrent with feature mapping, additional breakline data (coded as toes, crest and general breaklines) was also mapped.

Features such as roads, drains etc. were mapped at ground level with the intended purpose that they be used both as graphical map data and also as additional breaklines in later DEM (TIN) creation.

Features that were difficult to consistently map accurately at ground level (e.g. fences, due to grass) were collected as map features only.

A table of feature types collected during the P1 mapping phase is contained in Appendix 4. This table also defines the intended usage of each type. I.e graphical map feature or for inclusion in the DEM process, or both.

DEM production.

Pre-production trials were carried out prior to DEM mapping. Sample stereomodels that included critical terrain types (timbered areas and scrub covered drainage depressions) were selected. Auto-correlation tests were performed over these at various DEM intervals (15m, 10m, 5m). Furthermore, a range of stategies including obstruction (tree) removal were trialled. These proved to be particularly successful and although post DEM editing was required regardless of selected strategy, an optimum set of correlation parameters were defined.

All stereo-models were then correlated at a grid interval of 5metres, in blocks of photo runs (strip DEMs).

Each block was edited utilising the SocetSet range of point and area edit tools to eliminate false correlations and inconsistencies.

Upon completion of strip edits the blocks were progressively merged. Joins between blocks were inspected and corrected where required. During strip join edits, the editor also reviewed and refined the earlier strip edits. The editor brief was to produce satisfactory contours at 0.1 metre intervals when viewed in stereo-superimposition over the 3D model.

The complete 5metre DEM was converted to TIN data, into which the P1 breakline data was merged.

The final TIN comprised approx. 2,850,000 points plus breaklines.

Prior to final processing (extraction of the project DEM at 15metre interval grid and contours at 0.3

metres) the TIN was analysed in SocetSet QA software "Quality Statistics - Check Point File vs DTM File".

A comparison of the Ground Point File (ground control and aerotriangulated pass/tie points) versus the TIN produced the following results:

Number of points = 980
ave Z diff = -0.0742m, rms = 0.1501m, std = 0.1305m

A complete print-out of results is attached as Appendix 5.

Cadastral overlay.

Cadastral boundaries over the project area were acquired from DOLA. This data was supplied as a microstation file in AGD84, converted to WGS84 using GeoCalc software. It was apparent that the fit of the cadastre to the mapped planimetry (fence intersections) was poor.

DOLA was contacted for an accuracy statement.

"Hand digitised off existing 1:50000 maps. Accuracy may be plus or minus 50 metres".

Hydrology

A meeting between CALM, Kevron and Landinfo (Kevron's nominated sub-contractor to assist in hydrological aspects of the project) took place on 6th July. At this meeting the following scope of work was confirmed.:

- Determination of the location of flowpaths and low-lying seasonally inundated areas within the project area as defined by the map provided by Kevron;
- Produce a 1:25,000 map showing flow pathways of surface water (Digital in SHP format and ArcView Project);
- Provide a report description of surface water flows through the wetland system (Digital in Word 97 format).

Subsequently, the following activities were proposed and agreed upon:

- Import Kevron's DEM file of the project area into the GIS based package ArcView.
- Import a broader topographic map to delineate the watershed.
- Using ArcView Spatial Analyst Graphical and Avenue Development, delineate the flowpaths of surface water through linking low areas of the land surface.

- Provide a visual representation of these potential flowpaths.

- Using the contours represent areas of inundation through filling of areas below a certain elevation. This can be undertaken across the catchment project area as a whole as well as behind specific obstacles such as roads and restrictive culverts. SKM believe that photographs of flooding have been taken by CALM and that these may assist to determine inundation elevations.

- Provide a description of surface water flow through the Wetland system based on the results generated by Spatial Analyst.

Whilst the visually displayed flowpaths and areas of ponding are expected to be dry the objective is to demonstrate the potential pathways of surface flow and areas of inundation. Should there be a requirement to represent actual flooding frequencies, storage capacities, rates of drainage and runoff, a more detailed modelling exercise would need to be developed. This is outside of the scope of work described above.

The above is the subject of a separate report tabled below.

Discussion of Flows through the Lake Bryde Wetland System

The study area is 25 km south east from Lake Grace, 38 km east from Pingrup and 37 km south west of Newdegate. Physiographically, the Lake Bryde catchment area is located between Lake Grace and Lake Lochart and comprises a series of northerly draining freshwater and naturally saline lakes. The lake chain is at the headwaters of the Lochart and is a sub-catchment of the Swan Avon. The catchment is an internally drained system and comprises of approximately 6 sub-catchments.

The primary catchment study area covers approximately 200,000 ha from the upper catchment to Mallee Hill Road. Approximately 60% of the catchment has been cleared for agriculture.
The specific area of investigation focuses on the valley floor and covers an area approximately 3.5 km wide by 25 km long (8,750 ha).

Scope of Works

Based on the scope of work as provided by yourself in the letter dated 7 July 2000, the following outputs were required:

- Determination of the location of flowpaths and low-lying seasonally inundated areas within the project area as defined by the map provided by Kevron;

- Production of a 1:25,000 map showing flow pathways of surface water (Digital in SHP format and ArcView Project); and

- Provision of a letter report describing surface water flows through the wetland system (Digital in Word 97 format).

- In order to meet these objectives, the following activities were proposed:
- Import Kevron's DEM file of the project area into the GIS based package Arcview;
- Generate a broader topograghic map to delineate the watershed;
- Using ArcView Spatial Analyst Graphical and Avenue Development, delineate the flowpaths of surface water through linking low areas of the land surface;
- Provide a visual representation of these potential flowpaths;
- Using the contours represent areas of inundation through filling of areas below a certain elevation. This can be undertaken across the catchment project area as a whole as well as behind specific obstacles such as roads and restrictive culverts; and
- Provide a description of surface water flow through the wetland system based on the results generated by Spatial Analyst.

Following subsequent discussions on the resolution detail of the DEM topographic map, it was agreed to generate data on a 2 m grid in order to better represent flow paths and obstructions.
This base map was then imported into in ArcView in order to undertake the stream flow analysis and assessment of inundation. The visual outputs from which subsequent interpretation is made include an:

- A1 sized map showing the Lake Bryde Study Area at a scale of 1:25,000;
- A3 sized map of the lake Bryde Study Area; and
- A3 sized map of the Lake Bryde Catchment Area.

The discussion of the simulated flowpaths and obstruction is provided in the sections below.

Overview of Surface Drainage

Surface water flow through the catchment is poorly defined and ephemeral. Drainage can be divided into the following categories.

- Broad valley sheet flow;
- Mid and up slope valley sheet flow; and
- Up slope hillside creep.

Surface water runoff and flow in drainage lines migrates down the catchment and discharges into wetlands and lakes in the broad valley flats. The broad and mid slope valleys have poorly defined drainage lines and swampy conditions develop where low or at a change in gradients. Much of the low-lying areas within alluvial valleys are seasonally waterlogged and inundated.

The lakes in the valley floor typically behave as closed systems during average rainfall events, with recharge originating from localised surface water runoff. With increased periods of rainfall, the lakes can become full and the water level cascades through natural spillway features, discharging water into the down gradient lakes or wetlands.

Drainage features do not always intersect the broad valley areas. To the south east of the catchment, in the sand plains surrounding Lake Bryde East drainage is limited. Surface water drainage features originating from Magenta Reserve and the surrounding slopes terminate when they intersect the sand plains of the lower catchment. Surface water recharges into the groundwater at this point.

Scattered small Playa lakes and wetlands occupy the valley floors. Many of the lakes are relatively small, shallow, circular depressions and not in direct connectivity with the surface water drainage, eg Lake Bryde and other lakes to the east of the broad drainage flat.

Isolated Sand Plain lakes have also developed to the east of the catchment as scallop shaped features in the deep sand plains on the valley floor, eg Lake Bryde East. These lakes are recharged by sand plain seepage and localised runoff.

Other smaller lakes, which are in direct connectivity with the drainage system occur on the western side of the valley floor or in the drainage depressions. These lakes are very shallow and have low lunette features on the south eastern margins and surface water runoff from western agricultural areas discharge into the lakes during periods of higher than average rainfall. Wetlands and swampy environments surround these features, including species of leptospermum, melaleuca and eucalyptus.

GIS based Interpretation of Surface Drainage

The Lake Bryde Catchment surface drainage as determined using ArcView Spatial Analyst, is depicted on both A1 and A3 sized maps for the total catchment and for the particular area of reporting.

Whilst the visually displayed flowpaths and areas of ponding are expected to be dry, the objective is to demonstrate the potential pathways of surface flow and areas of inundation.
The simulation of the start of the stream network is delineated based on the watershed where greater than 10,000 cells (20,000 m^2) are directed to the same flowline (shown as stream10K on the maps). These streams capture more flow further down their flowpath. Where the stream captures flow from greater than 40,000 cells (80,000m^2), this is depicted as the thicker stream 40k on the maps. It is this latter stream network which simulates the most likely primary flow route for surface drainage across the catchment.

The general flow direction of the main flow path is described below:
Flow north under Ryan's Road culverts 5km towards Lake Bryde. At the intersection with the Lake Bryde Road flow is diverted westwards for 750 m along the side of the road before crossing and flowing towards Newdegate Road some 800 m further on.

A second streamflow from Holland Rock Grain Storage flows through two small lakes, crosses Lake Bryde Road and joins the primary channel 500 m before Newdegate Road.

Newdegate and Holland Soak Roads are elevated against natural ground surface. Road drains and culverts direct flow north west 1750 m towards Bairstow Road.

A further 5 km along the catchment, flow meanders through the Lakeland Nature Reserve from lake to lake over a distance of some 7 km to Mallee Hill Road.

A secondary flowpath runs subparallel 200 m to 500 m west of the primary flowpath from around Newdegate Road to join the primary flowpath approximately halfway between Newdegate Road and Mallee Hill Road.

The primary flowpath through Lakeland Nature Reserve is relatively poorly defined with an increasing number of secondary and tertiary flow paths entering the primary flowpath from both the east and west.

Flow is controlled by subtle changes in topography along the valley floor with broader, less defined flow towards the lower part of the catchment in the Lakeland Nature Reserve compared with the more discrete flow through the Lake Bryde Nature Reserve.

Flowpath Impedance, Channelling and Diversion

Flowpaths are simulated by linking low-lying areas as linear features. The profile of the flowpaths is therefore dictated by the natural topography.

These simulated flowpaths can be obstructed by man made structures and in particular by roads. Often these roads are elevated in relation to the surrounding ground level. To reduce obstruction of natural surface drainage, culverts, spillways and diversionary drains have been constructed.

These culverts, spillways and drains have been designed to facilitate surface water drainage in all but high flow rainfall events. Under periods of high or protracted rainfall, the large catchment and low gradient result in large areas of inundation. This extensive flooding is unavoidable. Culverts and spillways channel restricted flow across roads but do act to reduce flowrates and hence impede drainage to some degree.

It has been calculated that the Eastern Crossing culvert on Ryan's Road reduces drainage rate to cause an additional 56 days of flooding of a 26 ha area (Department of Agriculture, 1995). This investigation focuses on the effects of obstruction on low flow periods, generally the extended tail end of a rainfall event. The analysis is based on the elevation of the surrounding land along the simulated flowpaths and the elevations of breaklines as provided by Kevron.

Based on the scale and resolution possible in this study, areas of ponding are estimated where there are differences in elevation of between 200 mm and 500 mm. Unless culverts are elevated against the surrounding land surface, the analysis assumes no obstruction to flow unless they are blocked. Actual flow rates and volumes would be required to assess potential restriction in more detail. This information is unavailable and beyond the scope of this present study.

Obstruction, inundation and ponding of surface drainage has the effect of extending the retention time of surface water and therefore increases the potential for infiltration and groundwater recharge. Areas of potential inundation have been simulated using the ArcView software package. The attached A1 and A3 Lake Bryde Study Area maps depict in red the areas of low-lying ground that are likely to be flooded to an elevation equivalent to the invert level of the culverts or spillways.

A total of 19 sites have been identified in the analysis where simulated streamflow cross roads or lower lying areas. The area of potential risk of flooding is predicted based on elevation data only. These areas are labelled on the attached A1 and A3 maps of the Lake Bryde Study Area.
The accompanying text on the maps describe the effects on streamflow at each of the 19 identified sites.

The main areas of water obstruction and ponding are predicted to occur where streamflows cross elevated spillways (**sites 2, 3, 5, 6, 7, 9, 11, and 13**).

In addition, streamflow crossing isolated lower lying areas causes localised ponding (**sites 10, 12, 14, 15 and 16**).

Further down the catchment (**sites 18 and 19**), streamflow is through a series of interconnected wetlands and lakes. Roads do not appear to obstruct flow in this area, surface drainage cascading from one lake to another.

The extent of ponding is presented in **Table 1.**

Table 1: The extent of ponding.

Site Identification	Feature	Potential Area of Ponding (ha)
1	Culvert	0
2	Elevated Spillway	121.9
3	Elevated Spillway	1.97
4	Spillway	0
5	Elevated Spillway	4.64
6	Elevated Spillway	6.16
7	Elevated Spillway	1.86
8	Road	0
9	Elevated Spillway	3.41
10	Low-Lying Area	18.86
11	Elevated Spillway	2.73
12	Low-Lying Area	0.67
13	Elevated Spillway	1.41
14	Low-Lying Area	3.11
15	Low -Lying Area	5.37
16	Low-Lying Area	2.67
17	Culvert	0
18	Disseminated wetlands/lakes	0
19	Disseminated wetlands/lakes	0
TOTAL	**Combined Sites**	**174.76**

The largest area of simulated inundation occurs behind Lake Bryde Road where 121.9 ha of land is potentially flooded due to back up as a result of the elevated spillway crossings on the Lake Bryde road. The second largest area of flooding is in the vicinity of site 10 where simulated stream flow crosses a low-lying area.

The total predicted area of inundation covers is approximately 175 ha. Assuming an average depth of flooding of between 200 mm and 500 mm, this equates to a volume of 0.35 Mm^3 to 0.87 Mm^3. Evaporation and infiltration of this water will increase the potential for saline recharge of the underlying groundwater.

Whilst this investigation predicts areas of potential inundation and defines areas of greater risk of flooding based on elevation, it would be necessary to visit these sites to confirm this potential.

Given the relatively shallow nature of the ponding (predicted to be between 200 mm to 500 mm), it would be possible to divert and re route stream flow away from these sites through a series of shallow drains and low embankments and/or up grade the spillway and culvert designs.

From this study, engineered solutions would be most appropriate in the Lake Bryde Nature Reserve and in particular in the vicinity of Lake Bryde Road.

Any diversion of existing stream paths must be assessed and tempered against the need to periodically flush the wetland and lake system.

Although actual surface hydrological modelling and monitoring would be required to more accurately define surface drainage patterns and characteristics, the current study provides a useful representation of the potential flowpaths and areas of potential obstruction.

If you have any queries with regard to this report or require further clarification, please contact the undersigned.

Yours faithfully

Craig Smith | Paul Myers-Allen

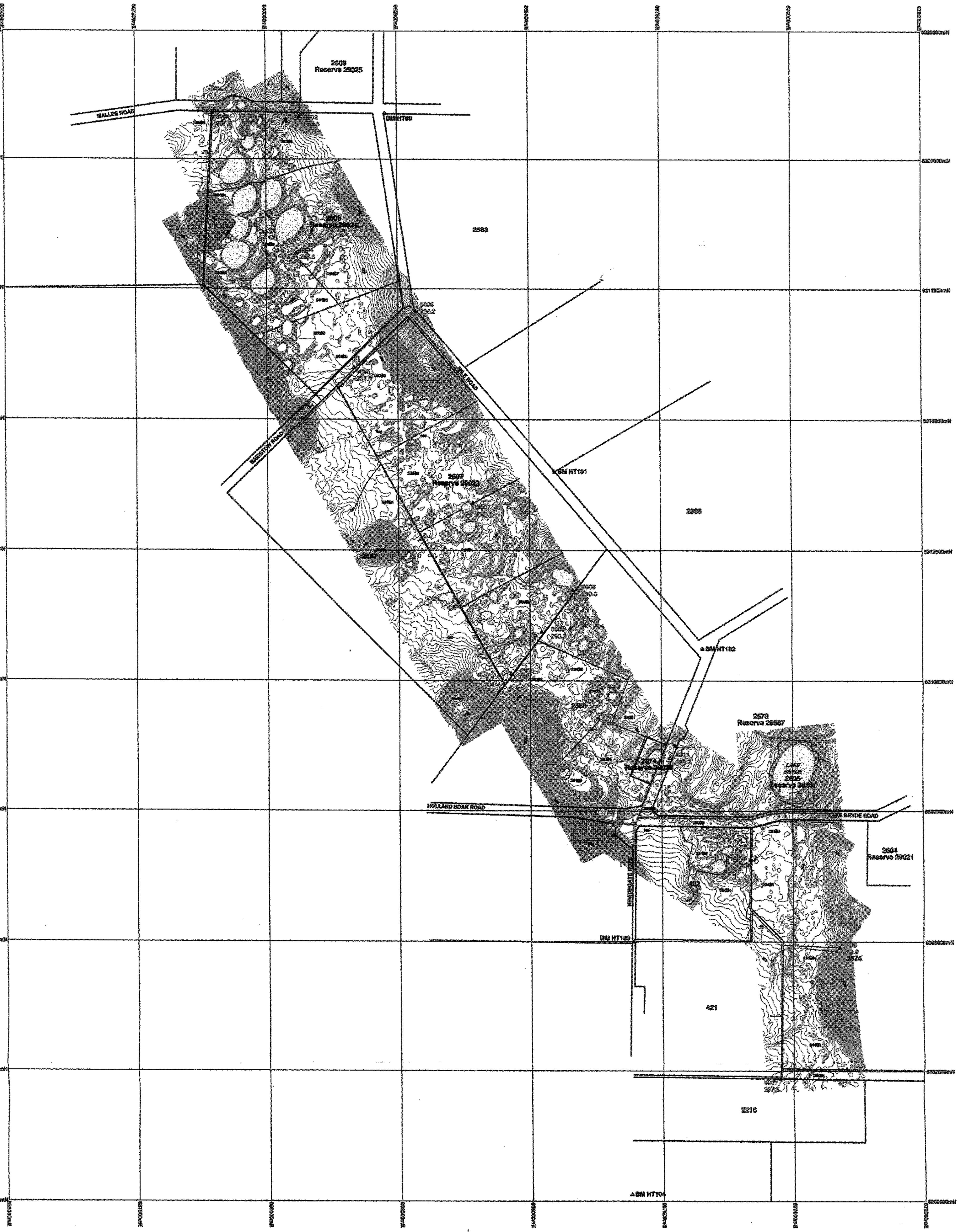
Craig Smith
Manager, Geomatics
Kevron Aerial Surveys Pty Ltd
Photogrammetric Model Queries

Paul Myers-Allen
Project Manager
Sinclair Knight Mertz
Flow Model Queries

Lake Bryde Mapping Project -

List of Attachments

1. **Aerial Photography.**	- Flight line diagram
2. **Control Survey**	- Target locations - Survey connections - WGS84 co-ordinates
3. **Aerotriangulation**	- PATB bundle adjustment results
4. **Mapping vectors**	- Feature usage
5. **DEM**	- QA check
6. **Cartography**	- A3 copy of the Lake Bryde plan
7. **Helava softcopy**	- Model setup - fit to control
8. **Zeiss P1 plotter**	- P1 model orientation records
8. **Flow Model**	- 1:25,000 Plan flow model



CONTOUR PLAN

This contour plan was produced using Terramodel
The contours are accurate to +/- 0.15m

The contour interval is 0.5m

Date of Photography - 22nd May 2000
Scale of Photography - 1 : 8000

INDEX CONTOUR
INTERMEDIATE CONTOUR
INDEX DEPRESSION CONTOUR
INTERMEDIATE DEPRESSION CONTOUR
LAKE
DRAINAGE LINE
DRAIN
CREEK CENTRELINE
CLEARED LAKE

UNSEALED ROAD
TRACK
FENCE
CADASTRAL BOUNDARIES
EARTHWORKS
CAR PARK
POLE
BUILDING
CULVERT

Grid North
World Geodetic System 1984

SCALE 1 : 25000

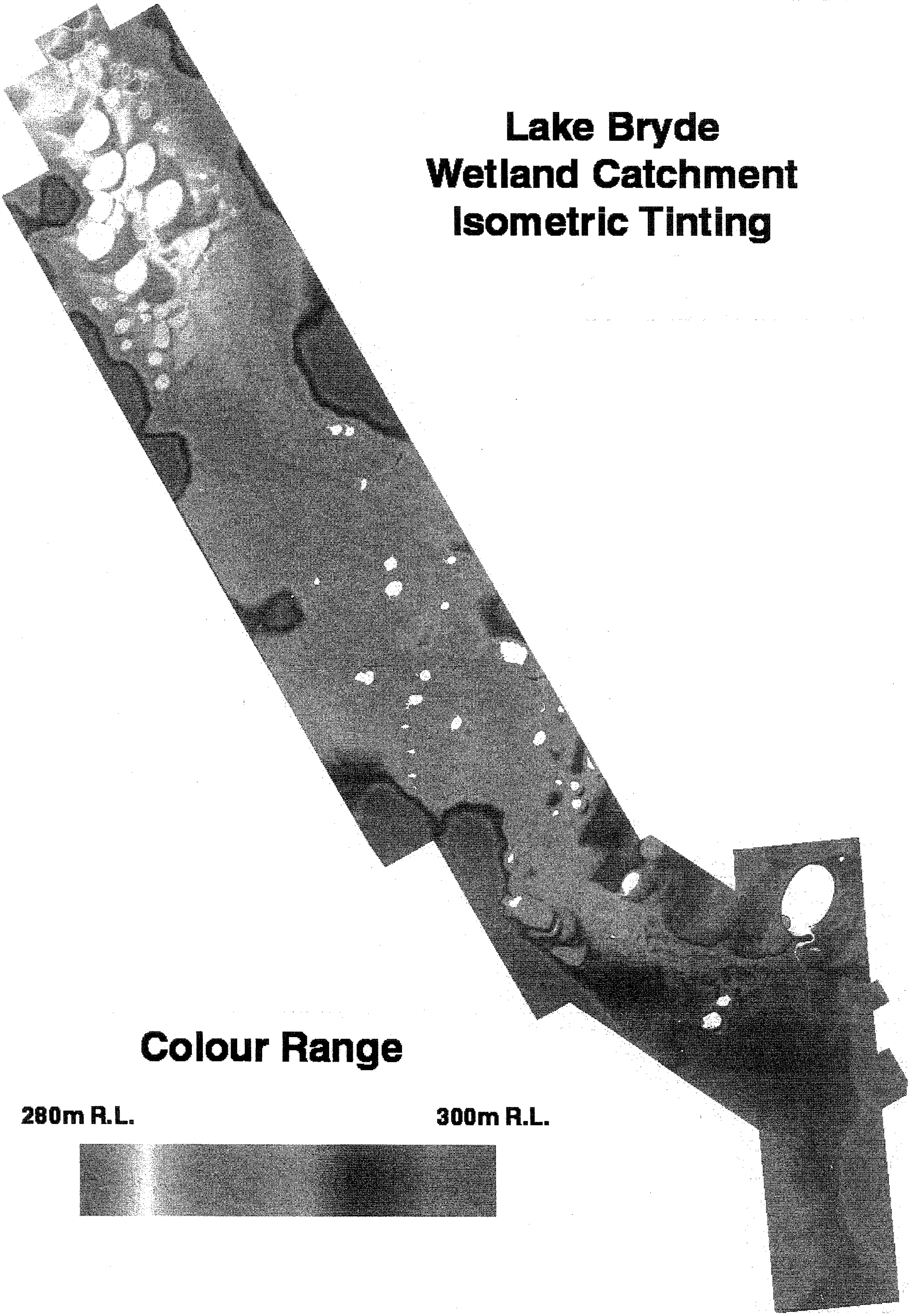
metres

Datum: World Geodetic System 1984 (WGS 84)
Map grid: World Geodetic System 1984 (WGS 84)
Universal Transverse Mercator Zone 50
Vertical Datum: Australian Height Datum (AHD)

DEPARTMENT OF
CONSERVATION AND LAND MANAGEMENT
LAKE BRYDE WETLAND CHAIN
CONTOUR PLAN

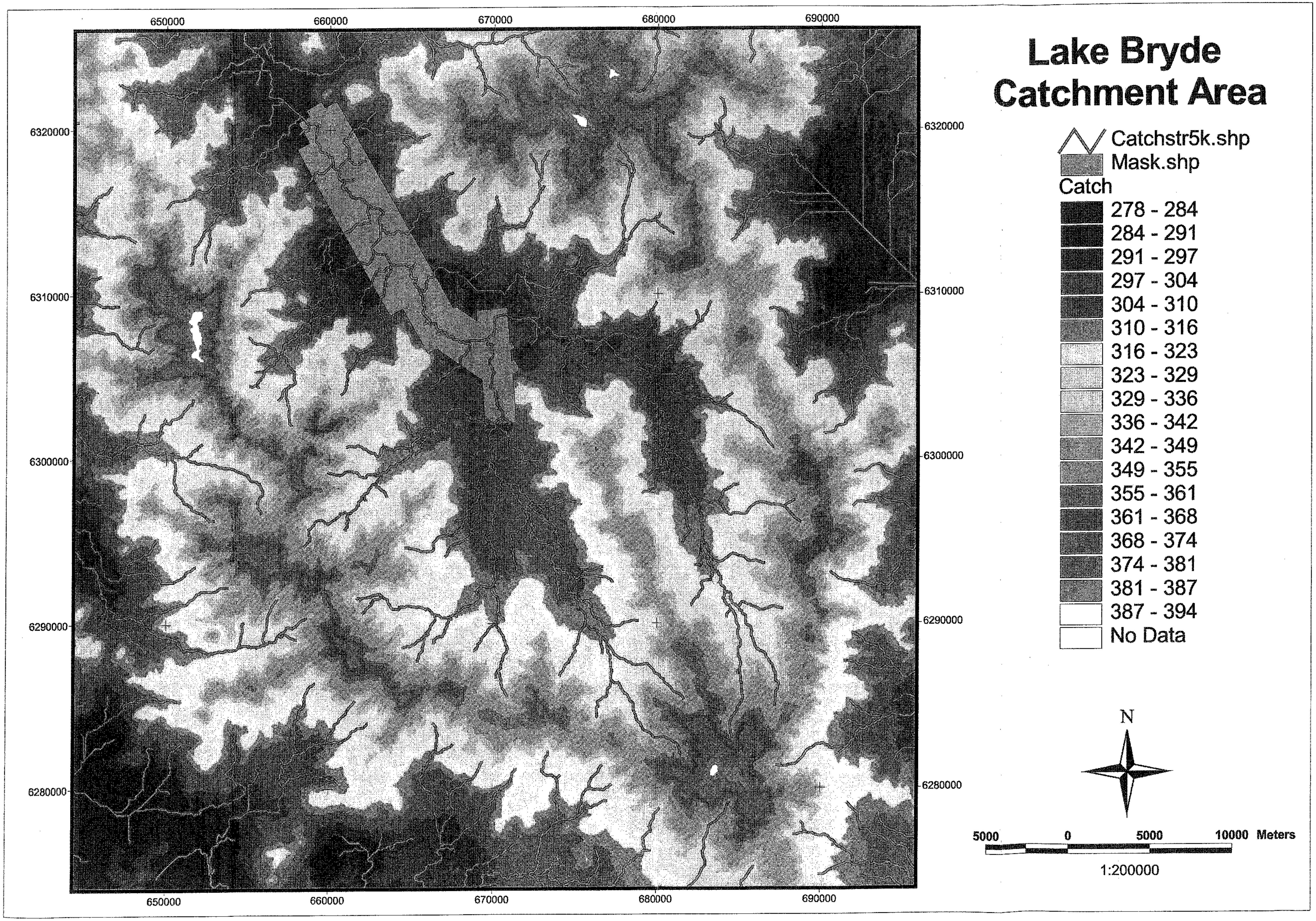
FLOWN AND PRODUCED BY ...
Kevron Geomatic Services

Lake Bryde
Wetland Catchment
Isometric Tinting



Colour Range

280m R.L.
300m R.L.


Lake Bryde
Catchment Area
Catchstr5k.shp
Mask.shp
Catch
278 - 284
284 - 291
291 - 297
297 - 304
304 - 310
310 - 316
316 - 323
323 - 329
329 - 336
336 - 342
342 - 349
349 - 355
355 - 361
361 - 368
368 - 374
374 - 381
381 - 387
387 - 394
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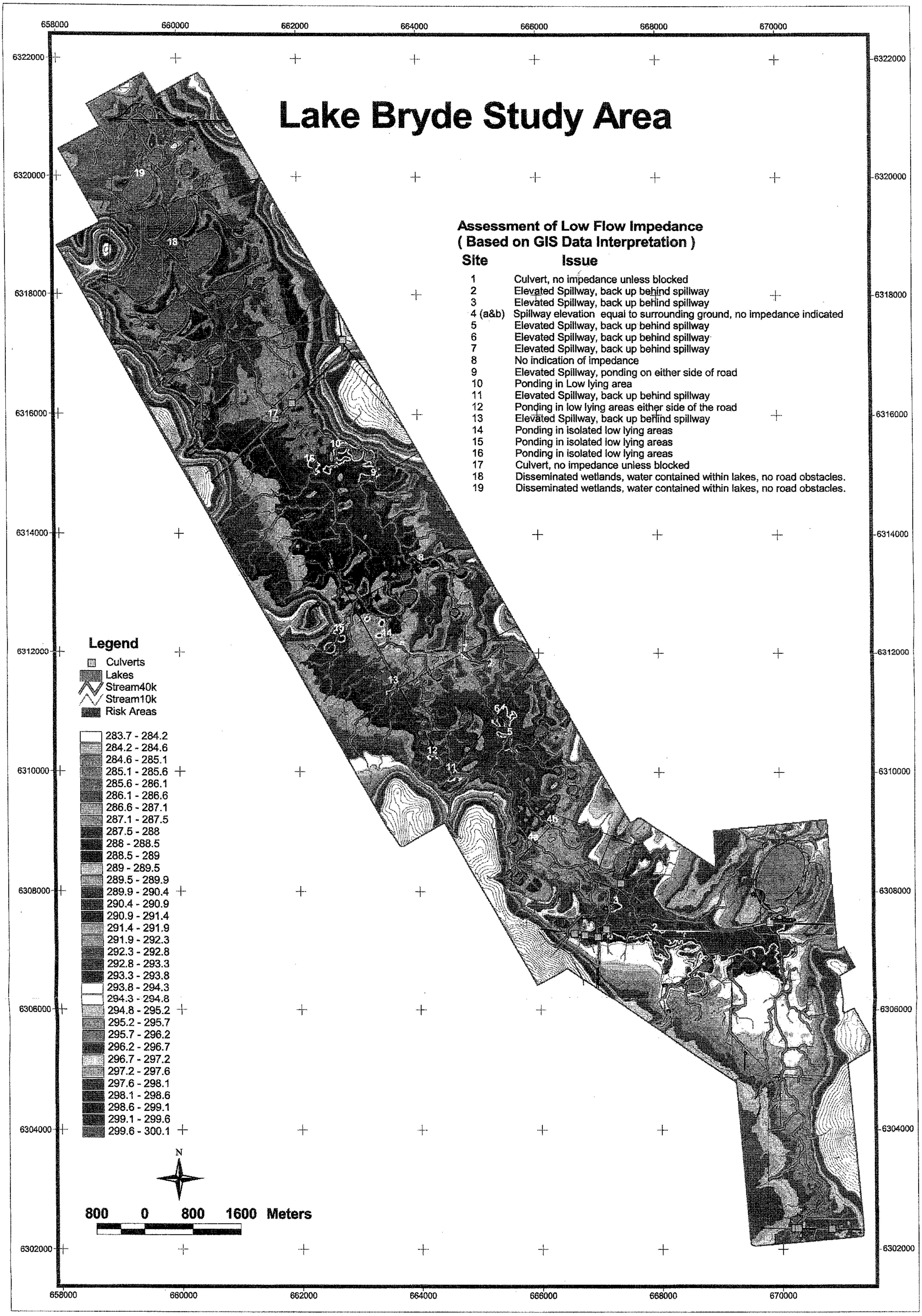
670000
680000
690000
6320000
6310000
6300000
6290000
6280000

Lake Bryde Study Area



Assessment of Low Flow Impedance
(Based on GIS Data Interpretation)

Site	Issue
1	Culvert, no impedance unless blocked
2	Elevated Spillway, back up behind spillway
3	Elevated Spillway, back up behind spillway
4 (a&b)	Spillway elevation equal to surrounding ground, no impedance indicated
5	Elevated Spillway, back up behind spillway
6	Elevated Spillway, back up behind spillway
7	Elevated Spillway, back up behind spillway
8	No indication of impedance
9	Elevated Spillway, ponding on either side of road
10	Ponding in Low lying area
11	Elevated Spillway, back up behind spillway
12	Ponding in low lying areas either side of the road
13	Elevated Spillway, back up behind spillway
14	Ponding in isolated low lying areas
15	Ponding in isolated low lying areas
16	Ponding in isolated low lying areas
17	Culvert, no impedance unless blocked
18	Disseminated wetlands, water contained within lakes, no road obstacles.
19	Disseminated wetlands, water contained within lakes, no road obstacles.