Volumetric Surveys of Ash Dams for the Power Industry

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SUMMARY

Aurecon (previously Connell Wagner) Survey department was engaged by Delta Electricity to undertake volumetric surveys of their ash storage dams associated with their Central Coast Vales Point and Munmorah Power Stations with the view to estimating the remanent life of the ash storage dams and assist with the future environmental planning of these dams. Ash is a by-product from the burning of coal during the electricity generation process which is generally quantified at approximately 20-25% of the total coal consumption for each power station.

The ash dam sites required lateral thinking and innovative methods of survey to overcome the significant OHS risks, accuracy requirements and the data capture of the differing surfaces associated with the ash dams. The surfaces requiring survey data capture were located in thick bushland, cleared areas, exposed wet ash and shallow water surfaces and water bodies. The bushland and cleared areas were surveyed utilising conventional TPS and GNSS survey techniques supplemented with aerial photogrammetry contour data for areas outside the area of interest. The exposed wet ash and shallow water areas (having similar properties to that of quick sand) were surveyed using GNSS techniques and a hovercraft. This innovative method of data capture was deemed to be the safest and most cost effective way of surveying the exposed ash surface within the timelines required. Alternative methods such as aerial photography, airborne laser scanning were considered to be too expensive and accuracy standards of these methods for underwater surfaces are yet to be proven. The water bodies were surveyed using GNSS and depth sounding hydrographic survey techniques. Independent checks of our control network were undertaken using the new SYDNET continually operating reference system with very favourable results.

The project delivers outcomes required by the client to assist with the future planning of these major infrastructure installations with the use of innovative survey techniques in a very dynamic environment.

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1. Project overview

Purpose

The purpose of the project was to undertake a capacity survey of Delta Electricity's Central Coast ash dams to estimate the design life expectancy of the ash dams when using the current generation techniques and technology. The survey was commissioned on 11 April 2008 and completed by 30 June 2008.

Background

Delta Electricity is an electricity generation company formed in 1996, as part of the New South Wales Government's restructure of the State's electricity industry. Delta Electricity's generators produce around 12% of the electricity needs of consumers in South Australia, Queensland, New South Wales, Victoria and the ACT. Most of Delta's generation occurs at four power stations located in NSW at Mt Piper and Wallerawang near Lithgow, and Vales Point and Munmorah on the Central Coast. This project is specifically related to the Central Coast power stations.

Coal fired power station generation process brief overview

This brief overview is to assist with the understanding of the complexities of our project and is not intended to be a detailed overview of the generation processes.

Coal is mined in open cut or underground mines which is then transported via conveyor, road or rail to the power station coal storage bunkers. The coal is then crushed to a fine powder and then burnt in a furnace chamber situated below a boiler. The boiler super heats and converts fresh water into high pressure steam which then drives the turbo generator rotor. The rotor which is an electro-magnet revolves at high speed, producing electricity (alternating current). The electricity then passes through a transformer and then a high voltage switch yard for distribution via the electricity transmission line inter-connecting network servicing consumers.

A by-product of the electricity generation process directly related to this project is ash from the furnace chamber following the burning of coal.

Ash from the furnace consists of two components:

a) Furnace ash

Furnace ash is a course grained ash also known as bottom ash which represents approximately 10% of the total ash produced during the generation process. The properties of this material allow this by-product to be re-used for the following purposes:

- Lightweight aggregate in concrete (Lightweight masonry products)

- Sand replacement (Road base, building foundations, pipe bedding)
- Free draining filter material
- Potting mix and top dressing

At present 100% of Vales Point power station furnace ash is re-used. The furnace ash for Munmorah power station flows directly into the Munmorah Ash Dam. Water from Munmorah ash dam flows into Lake Budgewoi via an outlet canal.

b) Fly ash

Fly ash is a very fine grade material which represents 90% of the total ash produced during the electricity generation process. The properties of this material allow this by-product to be re-used for the following purposes:

- Cement replacement (Cement when partially replaced by fly ash creates a more durable concrete)
- Road (Fly ash and can be used for road base)
- Structural fill and embankments
- Coal mine rehabilitation (Landfill)
- Agricultural (Trial purposes for turf farms, park lands and golf courses)
- Fly ash contains cenospheres (usually about 1% of ash) which is harvested from the dam water for fillers in paints

Due to the shear quantity of fly ash produced, only approximately 20% of the total ash produced is re-used and therefore the residue requires storage and disposal. The method of storage and disposal of ash from the power stations related to this project is in ash dams. Fly ash produced at Vales Point and Munmorah power stations is transported as watery slurry via open channels and pipelines to the storage dam where it is then dispersed on to the ground on the upstream side of the ash dams. Ash at Vales Point ash dam is then drained via a series of settlement stages with the majority of the water flowing naturally into the lake section of the ash dam, finally passing through screens and treatments before being returned to Lake Macquarie. Vales Point ash dam consists of areas of exposed ash and water bodies and Munmorah ash dam only consists of a water body.

Ash Dam Management

Energy generators are regulated by a license to operate issued by the Department of Environment and Climate Change (DECC). The license to operate for Vales Point power station states that “All furnace ash must be managed in accordance with an approved ash management plan.” Ash management plans are to be reviewed on a five yearly basis and contain recommendations to be implemented to assist with the compliance of the license to operate. The management plan produced in 2003 for Vales Point ash dam included a recommendation that a comprehensive survey of the ash deposits be undertaken on a five yearly basis to confirm that the maximum filling capacity of the ash dam is being achieved.

Previous surveys of Vales Point ash dam were undertaken in 1958, 1965 and 1991 with a limited survey being undertaken in 1995 with no recorded surveys undertaken on Munmorah ash dam. The ash management plan for Vales Point is now due for review and it was decided by Delta Electricity that a new survey of their Central Coast ash dams be commissioned to assist with the review of the ash management plan.

Sites

Vales Point and Munmorah ash dams are located near Doyalson on the Central Coast of NSW. The dams are separated by the Pacific Highway and are approximately one kilometre apart.

Vales Point

Vales Point ash dam is the larger of the two dams with an area of approximately 450 hectares represented by:

- 70 hectares of capped ash (area 1 in Figure 1)
- 200 hectares of exposed wet ash (areas 2 and 3 in Figure 1)
- 180 hectares of water body with an ash inundation perimeter of approximately 13 kilometres (surveyed perimeter shown in Figure 1).

Fig 1 Vales Point ash dam

Munmorah

Munmorah ash dam is the smaller of the two dams with an area of approximately 105 hectares wholly comprised of a water body with a water/ash inundation perimeter of approximately 6 kilometres (Surveyed perimeter shown in Figure 2).

Fig 2 Munmorah ash dam

2. Project Scope

Client Brief

Our initial client brief was to undertake a capacity survey of the Vales Point and Munmorah ash dams with the limit of survey to be the extremities of ash inundation for each ash dam. Following a site meeting and a greater understanding of the purpose and requirements of the survey our brief was extended to include the calculation of the remanent life of the ash dams.

3. Preliminary investigations

Review of available information

A review of the available information consisting of historical drawings and surveys, aerial photogrammetry data, SCIMS and existing Delta Electricity control, cadastral information was conducted.

Occupational Health and Safety and Environmental Aspects

A thorough safety risk assessment for the work to be completed was undertaken in consultation with Delta Electricity. Ash dam environments are very dangerous work environments. The major risks identified during the risk assessment included:

- Exposed ash when wet is similar to quick sand. There is a significant safety risk of engulfment to anyone working on or near the wet ash surface.
- Working on or near water
- Civil construction vehicle movements
- Wild dogs known to be onsite
- Slips, trips and falls
- Snakes known to be onsite

Based on the risk assessment access onto the exposed ash surface on foot was not permitted, therefore an alternative method of surveying the exposed ash areas or a suitable craft to access these areas was required. The options to survey the exposed ash areas identified were:

- aerial photogrammetry
- airborne laser scanning
- Argo amphibious vehicle
- Hovercraft

Following further consultation with Delta Electricity is decided that the Hovercraft option was the only feasible option for the work to be completed based on accuracy requirements, safety constraints and cost effectiveness.

It was brought to our attention through discussions with other contractor working onsite that there was a risk of an endangered plant (Tetratheca juncea) near Munmorah Power Station. Upon investigation with our environment team it was found that location of the endangered plant was not adjacent to the survey area.

4. Site works

Control survey

A control survey was undertaken for both sites simultaneously using post-processed static GNSS techniques. A combination of local SCIMS marks and existing Delta Electricity control was surveyed to facilitate the establishment of MGA, AHD and Delta Electricity's localised survey datum. Check comparisons to the Newcastle Continually Operating Reference System (CORS) mark TS12051 were undertaken with very good results (approx ±15mm horizontal and ±10mm vertical).

Capacity survey

The capacity surveys ash dam was spilt into the following components:

- Ground survey
- Exposed ash survey (Vales Point ash dam only)
- Hydrographical survey

- Use of aerial photogrammetry data

Ground survey

The ground survey was of the accessible on foot areas including the perimeter of the ash dams. This was undertaken using a combination of conventional TPS and GNSS techniques.

Exposed ash survey

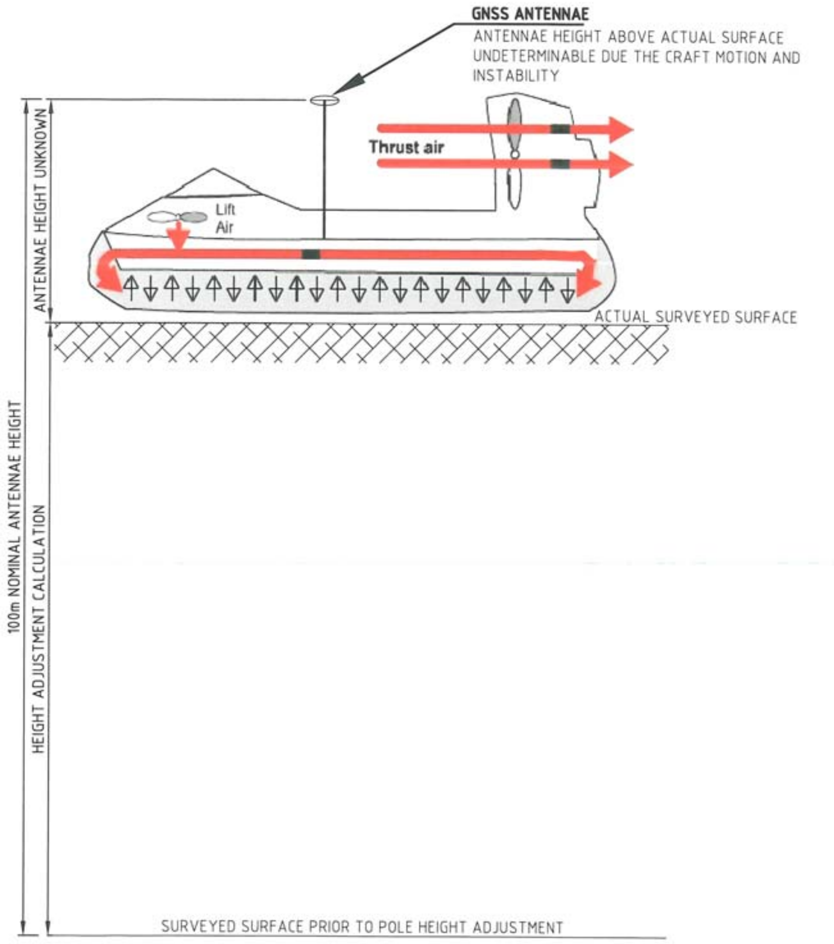
As stated above, it was identified the areas of exposed ash could not be accessed by foot. The services of Hovercraft Services of Australia (QLD), craft and operator, were engaged to assist with the access of the exposed ash areas of the site. With no prior experience in the use of a hovercraft to undertake survey data capture, testing of the hovercraft's performance on fly ash was undertaken. The testing of the hovercraft included:

- Occupant safety whilst the craft was in motion and when stopped
- The ability of the craft to maintain a constant height whilst in motion
- Technical aspects of GNSS equipment being attached to the craft including a target height for the GNSS receiver antenna.
- Identification of areas that were totally inaccessible by the craft and the limitations of our GNSS equipment
- Accuracy of data logged automatically using the GNSS equipment and a process to allow verification of the automatically logged data

A risk assessment was undertaken with specific protocols and control measures established to overcome the hazards identified which included an onshore lookout person to assist the occupants of the craft with any problems encountered during the survey.

Testing for the unknowns associated with the hovercraft was undertaken using a small area test survey which was downloaded, reduced and comparisons computed. Following the test survey, it was established that the height control of the hovercraft was reasonably consistent and a survey method was established. The survey method for the capture of the survey data using the hovercraft included automatically logged GNSS data (10m logging interval, approximately 4,000 points) using a grid pattern initially 50m intervals later extended to 100m due to the flat grades of the exposed ash. The target height for the automatically logged GNSS data was set to 100m to allow for post calculation of a height shift of the automatically logged data. Following the grid pattern survey, navigated individual ground truthing points were located to assist with the height shift calculations and the verification of auto logged data. The navigated position of the ground truthing points were located at grid survey intersection positions. Where possible overlap of data surveyed using other methods was also captured.

Fig 3 Hovercraft GNSS receiver antenna height determination diagram



Hydrographic survey

The Hydrographic survey was undertaken using GNSS and CEEDUCER PRO dual frequency depth sounding equipment, logging data simultaneously. The depth sounding equipment was hired from Bruttour International Pty Ltd located in Hornsby. Previous experience using the CEEDUCER PRO equipment has found that logging of the GNSS data into the CEEDUCER PRO produces a more manageable data set.

Depth data is logged by the CEEDUCER PRO at a rate of 6 depth observations per second while the GNSS data was logged at 1 second intervals; therefore the shear volume of data was extensive with approximately 24,000 points located for Vales Point and 6,500 points located for Munmorah.

The depth sounding data was calibrated on a daily basis using a bar check to verify that the captured depth data was accurate and taking into account the correct velocity of sound in water for the types of water being surveyed. The bar check consists of a purpose built platform apparatus (refer figure below) being lowered in the deepest section of water available the slowly winding it back in at 1m vertical intervals (as graduated on the apparatus support rope) with the associated soundings taken to the platform at 1m intervals.

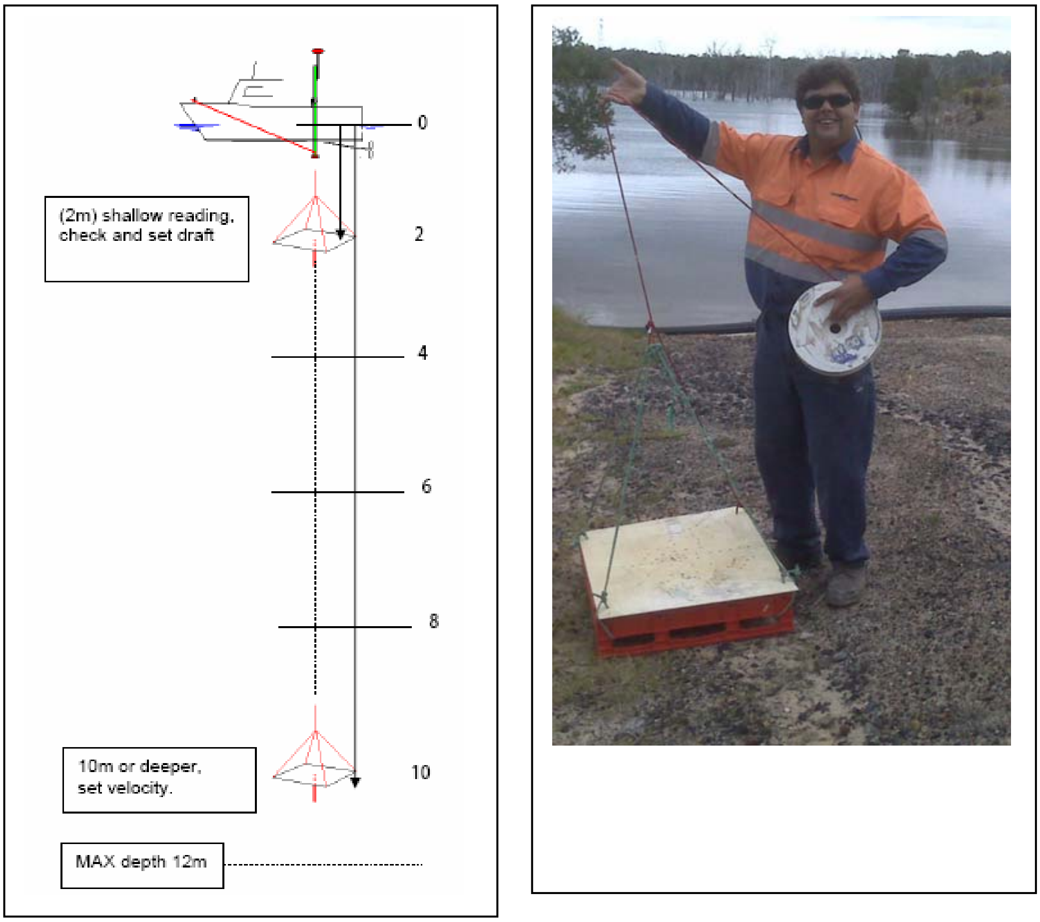


Fig 4 Depth Sounding Bar Check procedure and apparatus

Following the calibration of the equipment, data was captured using a automatic logging grid pattern survey with 10 m interval north/south (parallel to the expected ash flow and perpendicular with the old water course channels) and 50m interval east/west (perpendicular to the expected ash flow). In areas where water depths were below 1.5m single point RTK GNSS observations were captured (using conventional receiver pole placed directly on the underwater surface) as the depth sounding equipment was unable to log water depths below 1m, this process allowed a reasonable overlap of data captured using different techniques and assisted with the verification processes.

Aerial photogrammetry data

Aerial photogrammetry data was used to supplement the captured survey data in areas where it was considered to be outside the limits of our survey and an unnecessary expense for the client. The contour data was trimmed to the extents of our survey and married into the survey using interpolation techniques and general knowledge of the site.

Reductions and calculations

Following the capture of the survey data using the above methods, the data was reduced to a useable format and comparisons undertaken between data sets as follows:

Ground survey

The ground survey data was reduced using a combination of Leica Geo-Office and CivilCAD software. Our usual checks and verification procedures were applied to this data prior to the use of the data.

Exposed ash survey data

Survey data captured using the hovercraft was initially reduced into CivilCAD and comparisons of the crossing grid observations and ground truthing points was undertaken. Following a review of comparison information, it was found that the difference in height between opposing grid lines local to the intersection points generally fell within a difference range of 20-30mm which fell well within our expected accuracy for this work of ±50mm. From this, a single height shift for the automatically logged data was calculated and the data adjusted to agree with the ground truthing points. Following the height adjustment, additional checks were preformed in the areas of overlapping data from other methods of survey, these checks confirmed that height adjustments adopted were correct.

Hydrographic survey data

The hydrographic survey techniques employed resulted in an extremely large amount (24,000 points) of data, some of which was considered redundant/excess. We then undertook a data filtering process to reduce the amount of data to a more manageable size. The depth sounding data was filtered in a 3 stage filtering process.

Stage 1 filtering

The depth sounding equipment was dual frequency and therefore two depth values were captured for any given logged position. Some of the logged data did contain zero values for generally one of the frequencies and sometimes both frequencies. This was due to the return signal not being received by the transducer and/or the depth of water being less than 1m. All depth data with zero values were filtered and removed from the data set.

Stage 2 filtering

Following the stage 1 filtering the data set was then filtered again based on the difference in depth observations between the two frequencies. It was found that generally as data was captured in the shallower waters, the measured difference between frequencies rose and as the water depth deepened, the measured difference between the frequencies became very close. Observations exceeding a difference of 0.2m were then filtered and removed. Following the stage 2 filtering the depth data from both frequencies was averaged and input into CivilCAD.

Stage 3 filtering

Stage 3 filtering was undertaken via visual observation of the data within CivilCAD comparing the RTK GNSS individual point data and the automatically logged data. Where the differences between observations exceeded our accuracy tolerance of ±100mm the data was removed from the CivilCAD Model.

3D model creation

Following the reduction of the captured data and the trimming of the aerial photogrammetry data, the creation of a complete 3 dimensional survey model was required for the existing ground surface. The data from all survey techniques was combined and a digital terrain model (DTM) was formed using 12D software (as the data set exceeded the capacity of CivilCAD). The DTM was then contoured and checked using standard verification techniques.

Design capacity model creation

The purpose of this project was to calculate the capacity of the ash dam and perform expectant life calculations for the ash dam. To facilitate this, a design surface for the upper finish ash surface was required for both ash dams using different criteria for both dams.

Munmorah ash dam finished deign surface criteria

The design criteria for Munmorah ash dam was based on a flat plane using the upper limit reduced level of the spillway. The value of the upper limit of the spillway was established to be RL 4.78m AHD.

Vales Point ash dam finished design criteria

The design criteria for Vales Point ash dam was as follows:

- Ash to flow from nodal points positioned strategically around the perimeter of the ash dam to maximise capacity
- Ash flows from nodal points at a grade of 0.2% with a conical flow pattern
- Surface drainage to be maintained and directed to the existing ash dam outlet
- Earth embankments to used to raise the upper limit of the ash surface and to assist with a staging fill process of the dam to minimise the surface area of exposed dry surface ash
- A 250m radius exclusion area to be maintained from the existing dam outlet

Capacity Volume Calculation

Using the above mentioned design surfaces volumetric calculations were undertaken to establish the design capacities for each dam. The volumetric calculations consisted of existing surface to design surface volumes with various manual techniques used to verify the volume calculations. The volumes calculated were expressed to the nearest 0.5 million cubic metres for the final output.

Lifespan Calculations

Information was supplied from Delta Electricity to assist with the calculation of the remanent lifespan of the Ash Dams. This information included

- Estimated coal consumption in kT
- Estimated ash production following the coal burning process (given as %of coal consumption)
- Density of the Ash
- The potential forward ash sales information scenarios for furnace and fly ash

From this information estimated volumes of ash entering the ash dams on a yearly basis was graphed and compared to the total capacity of the ash dam to predict the lifespan of the ash dam.

Final Output

The final output for the project was a series of plans and calculation spreadsheet which were supplied to the client at the completion of project. Final out plans have not been included in this paper due to the potentially sensitve nature of some of the detail shown.

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