Rowan

Site Specific Flood Risk Assessment

Coffey Construction Ltd, Saggart, Co. Dublin (Hurley Site)

Date: 28th January 2022

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1.0 INTRODUCTION

1.1 Background & Context

It is understood that Coffey Construction Ltd. have applied to South Dublin County Council for planning permission to recontour / infill lands at a site at, Saggart, Co. Dublin (see Plate 1). It is also understood that the Local Authority has requested the following further information pertaining to the potential for flood risk at the site:

'Item 4. Water Services has raised concerns in relation to surface water and flooding. Given the quantity of material proposed to be deposited, the proximity of a water source and presence of flood zones the applicant is requested to submit the following:

Surface Water

(1) Water Services have concerns that the proposed development will result in an increased surface water run off rate from the site which would exacerbate flooding issues downstream. The applicant is requested to submit a report which demonstrates that surface water run off rates will not be increased from the site.

Flooding

(1) The proposed development site is located within Flood Zone A according to OPW's (Office of Public Works) CFRAM maps and South Dublin County Council's Strategic Flood Risk Assessment 2016-2022. The applicant is required to submit a site-specific flood risk assessment report with the inclusion of a justification test in compliance with OPW Flood Risk Management Guidelines for Planning Authorities. The report shall demonstrate how flood risk will not be exacerbated on the site aswell as upstream and downstream of the development. Details of the measures and design features to prevent/mitigate the risk of flooding to the proposed development and to adjoining lands shall be submitted.

(2) Submit a map showing the location of the site and proposed infill works in relation the OPW CFRAM flood risk zones.

(3) The applicant is required to submit a drawing showing the distance between the proposed development and the top of the bank of the watercourse to the east of the site. The minimum setback distance from any works to the top of the bank of the watercourse shall be 10 metres. The existing 10m Riparian strip shall remain in its current state'.

Plate 1. Aerial view of proposed infill site.

Consequently, Hydrec Environmental Consulting was engaged by Elaine Gibson, Senior Environmental Consultant at Rowan Engineering Consultants on behalf of the applicant to complete a Site-Specific Flood Risk Assessment. This document contains the details of said assessment and is structured in the following format:

- Section 2 outlines the planning and flood risk guidelines adhered too;
- Section 3 describes the site setting and existing environment;
- Sections 4 – 6 works through a staged approach to the flood risk assessment;
- Section 7 describes the outcome of the detailed flood risk assessment / hydraulic modelling outputs;
- Section 8 describes the mitigation measures described for the project;
- Section 9 assesses the requirement for a justification test; and
- Section 10 concludes on the findings of the assessment.

2.0 THE PLANNING SYSTEM & FLOOD RISK MANAGEMENT GUIDELINES

The following assessment has been carried out in accordance with *'The Planning System and Flood Risk Management Guidelines for Planning Authorities' (DoEHLG, 2009).* This document is referred to as the 'Guidelines' throughout the remainder of the report.

These guidelines recommend a staged approach to flood risk assessment that covers both the likelihood of flooding and the potential consequences. The stages of appraisal and assessment are:

- **Stage 1 Flood Risk Identification** – to identify whether there may be any flooding or surface water management issues related to either the area of regional planning guidelines, development plans and LAP's or a proposed development site that may warrant further investigation at the appropriate lower level plan or planning application levels;
- **Stage 2 Initial flood risk assessment –** to confirm sources of flooding that may affect a plan area or proposed development site, to appraise the adequacy of existing information and to scope the extent of the risk of flooding which may involve preparing indicative flood zone maps. Where hydraulic models exist the potential impact of a development on flooding elsewhere and of the scope of possible mitigation measures can be assessed. In addition, the requirements of the detailed assessment should be scoped; and
- **Stage 3 Detailed flood risk assessment** – to assess flood risk issues in sufficient detail and to provide a quantitative appraisal of potential flood risk to a proposed or existing development or land to be zoned, of its potential impact on flood risk elsewhere and of the effectiveness of any proposed mitigation measures.

With reference to flood zones, flood zones are geographical areas within which the likelihood of flooding is in a particular range. There are three types or levels of flood zones defined for the purposes of these Guidelines:

- **Flood Zone A** – where the probability of flooding from rivers and the sea is highest (greater than 1% or 1 in 100 for river flooding or 0.5% or 1 in 200 for coastal flooding);
- **Flood Zone B** – where the probability of flooding from rivers and the sea is moderate (between 0.1% or 1 in 1000 and 1% or 1 in 100 for river flooding and between 0.1% or 1 in 1000 year and 0.5% or 1 in 200 for coastal flooding); and

- **Flood Zone C** – where the probability of flooding from rivers and the sea is low (less than 0.1% or 1 in 1000 for both river and coastal flooding). Flood Zone C covers all areas of the plan which are not in zones A or B.

3.0 SITE DESCRIPTION & EXISTING ENVIRONMENT

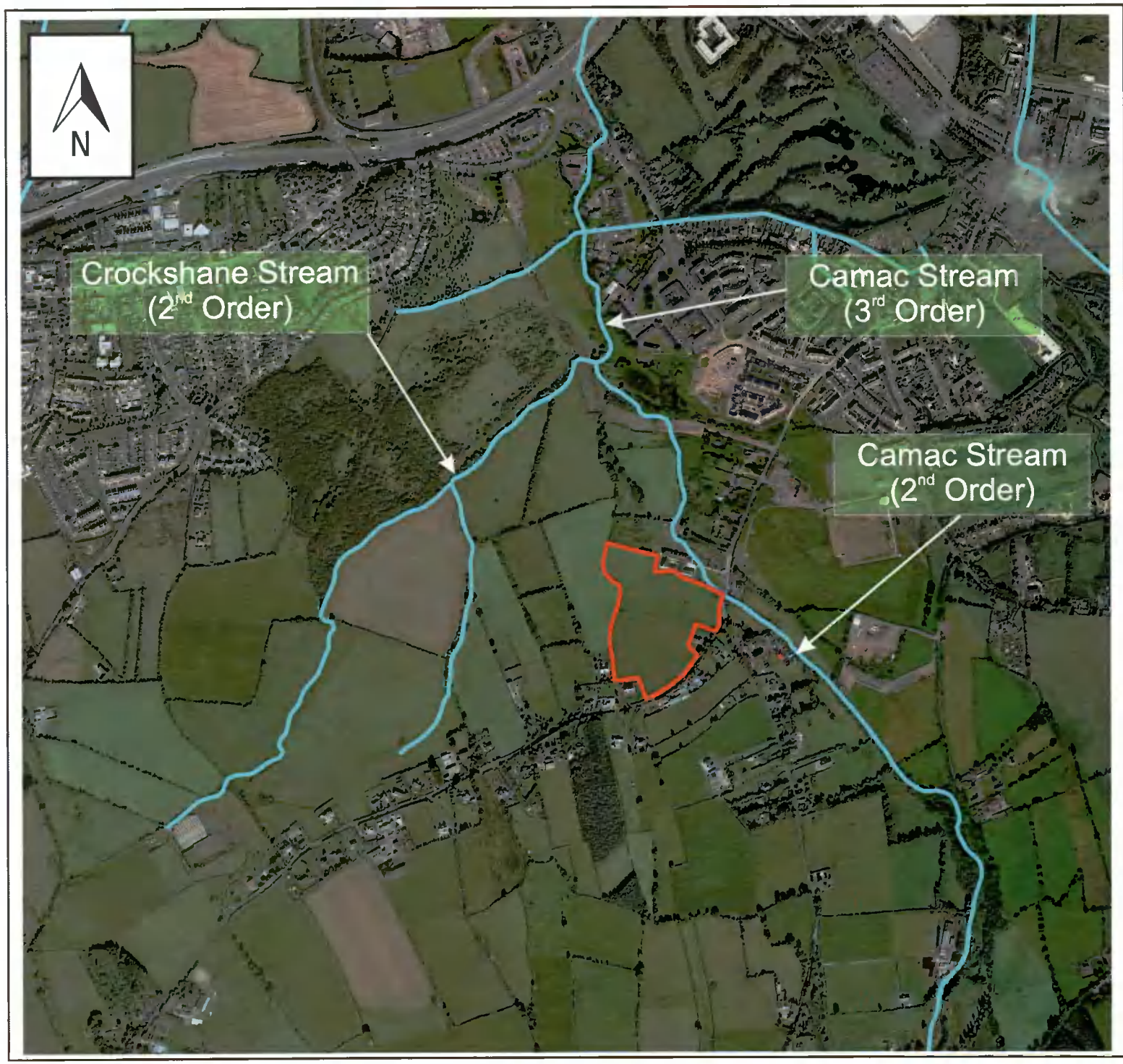
3.1 Site Description & Proposed Development

It is understood that Coffey Construction Ltd. have applied to South Dublin County Council for planning permission to recontour / infill lands at a site at Saggart, Co. Dublin. It is also understood that this infill material will consist of inert soil, subsoil and stone excavated from a nearby site where they are constructing a new 100,000m^3 covered reservoir of approximately 31,520m^2 in area with a height of c.6.7m for Irish Water. In total a volume of 24,009m^3 of material is proposed to be deposited across an area of c. 2.3 ha (i.e. within a land parcel covering c. 5.3 ha). The Camac Stream is approx. 73m to the north-east of the infill area (i.e. at its closest point). It is understood that after all soil / subsoil has been deposited onsite, the site will be reseeded and returned to agricultural use.

3.2 Hydrology

With the publication of Ireland's second River Basin Management Plan (RBMP), the RBMP 2018 – 2021 defines the entirety of the island of Ireland as a single River Basin District (RBD). This single RBD has been broken down into 46 catchment management units. These units are mainly based on the hydrometric areas in use by the local authorities. Each of the 46 catchment management units have been further broken down into 583 sub-catchments. The proposed development site is located within the Liffey & Dublin Bay Hydrometric Area (No.09) and WFD Catchment (No.09). Additionally, the site is located within the Liffey_SC_090 WFD Sub-catchment.

The Camac stream (2nd Order) which runs adjacent to the eastern boundary of the proposed infill site is the closest watercourse (see Figure 1 & Plate 2). This waterbody flows in a general south-eastern to north-western orientation, whereby it is culverted under the L6018 – Local Road. From there it passes / diverted through the Millbrook Manor Nursing Home and afterwards merges with the Crockshane Stream c. 450m downstream. In total, the contributing upstream catchment from the site equates to an area of 5.821km^2.



LEGEND

- Site Boundary
- Stream / River
- Drainage Channel

HYDREC
ENVIRONMENTAL CONSULTING

PROJECT:

Flood Risk Assessment Report
Coffey Construction Ltd -
Slade, Saggart, Co. Dublin (Hurley Site)

TITLE:

Hydrological features in the vicinity of the site

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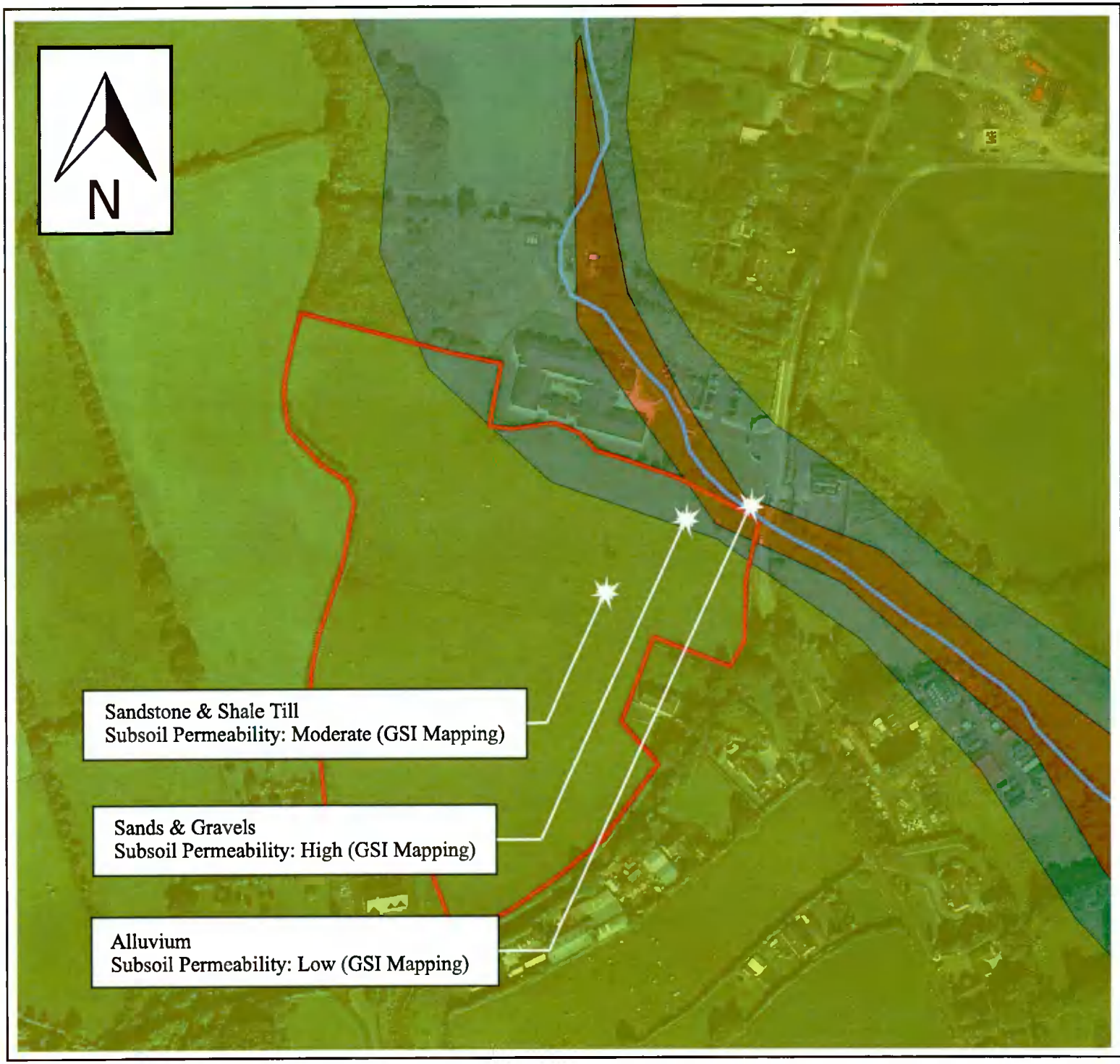
Figure 1.	0

Plate 2. View of the Camac stream after emerges from the nursing home culvert (facing in a south-eastern direction (i.e. against the flow)).

3.3 Geology

According to the Teagasc and EPA soils map, two different soil types are mapped to occur within the site. AminDW – Deep well drained (Mainly acidic) soil belonging to the Acid Brown Earths / Brown Podzolics soil group exists within the majority of the site with BminSW – Shallow well drained (mainly basic) soil present within a small area in the northern corner.

In Ireland, the parent material underlying the majority of the country is comprised of quaternary sediments with the remainder composed of bedrock outcrop. These quaternary sediments have resulted from glacial movement, melting and deposition. Similarly, the Teagasc and EPA subsoil maps identify that there are two different subsoil types present (see Figure 2). Where AminDW is found, TLPSsS – Sandstone and shale till of predominantly clayey texture is present. GLs – Glaciofluvial sands & gravels are found to underly the AminSW soils. Correspondingly, two differing groundwater subsoil permeability classifications are found within the confines of the site. The sandstone and shale till is categorised as being of 'Low' permeability, whilst the glaciofluvial sands and gravels mapped at the northern corner of the site are defined as being of 'High' permeability (see Figure 2).



LEGEND

- Site Boundary
- A - Alluvium
- Gls - Sands & Gravels
- TLPSsS - Sandstone & Shale Till

HYDREC ENVIRONMENTAL CONSULTING

PROJECT:
Flood Risk Assessment -
Coffey Construction Ltd -
Slade, Saggart, Co. Dublin (Hurley Site)

TITLE:
Teagasc Subsoil Maps of Site & Surrounding Lands

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Figure 2	A

Based on the GSI's 1:100k bedrock formation mapping, the entirety of the site is underlain by the Pollaphuca Formation which comprises of medium grey, coarse, graded greywackes and dark grey shales. No bedrock outcrops are present within the boundaries of the site, with the closest outcrop identified approx. 700m to the west. According to The National Karst Database, no karst landforms are identified within or in close proximity the site.

4.0 STAGE 1 ASSESSMENT (SCREENING STAGE) – FLOOD RISK IDENTIFICATION

4.1 Review of Available Data Sets & Potential Sources of Flooding

4.1.1 Fluvial Flooding – Preliminary Flood Risk Assessment (PFRA)

River flooding or fluvial flooding occurs when the capacity of a watercourse is exceeded due to extreme rainfall resulting in excess waters spilling out onto low-lying areas. The Preliminary Flood Risk Assessment (PFRA) was a national screening exercise undertaken in 2011 to identify areas at potential flood risk. The country was divided into 420 map tiles for the purposes of disseminating the output of the assessment. These maps indicate the extent of the predicted 0.5% annual exceedance probability (AEP) for coastal flooding, the 0.1% AEP for fluvial flooding and the 1.0% AEP for pluvial flooding. Based on the PFRA, fluvial flooding from the Camac Stream was mapped to occur directly to the north of the proposed infill area (see Plate 3).

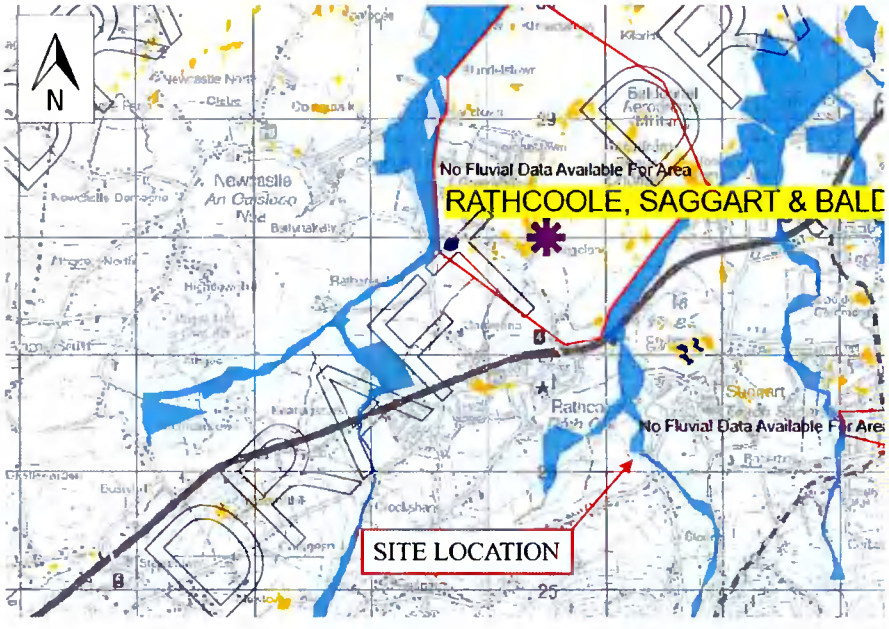


Plate 3. Extract from the Office of Public Works (OPW), Preliminary Flood Risk Assessment (PFRA) 2011.

4.1.2 *Fluvial Flooding – Catchment Flood Risk Assessment and Management (CFRAM)*

Following the PFRA, the catchment flood risk assessment and management (CFRAM) programme identified 300 Areas for Further Assessment where flood risk was deemed to be potentially significant. The Eastern CFRAM Study Area covers approximately 6,250 km² and includes four Units of Management (UoM); Hydrometric Area (HA) 07 (Boyne), HA08 (Nanny – Delvin), UoM09 (LiffeyDublin Bay) and HA10 (Avoca-Vartry). The Eastern CFRAM Flood Risk Review highlighted the Camac catchment as an Area for Further Assessment and a High Priority Watercourse based on a review of historic flooding and the extents of flood risk determined during the PFRA. The stretch of the Camac Stream bordering the applicant's site, is included within the Camac Hydraulic Model – Upper Catchment. As can be seen from the Camac Model flood extent mapping (see Plate 4), flooding under the 1 in 100-year scenario was predicted to occur within a small area within the northern corner of the site.

Plate 4. Extract from the Eastern CFRAM flood mapping showing the 1% fluvial flood extents based on current day scenario (i.e. site boundary outlined by red polyline).

4.1.3 *Fluvial Flooding – National Indicative Flood Mapping (NIFM)*

The National Indicative Fluvial Maps (NIFM) is a project which was finalised in December 2020 which provides an indication of areas that may flood during a flood of an estimated probability of occurring. These indicative fluvial flood maps were developed using hydrodynamic modelling, based on calculated design river flows, Digital Terrain Models, and other relevant

datasets (e.g. land use, data on past floods, etc.) for all subject watercourses with an upstream catchment area of greater than 5 km^2. It should be noted that the NIFM are not as accurate as the Flood Maps produced under the CFRAM Programme but could be regarded as advance from the PFRA where available. Owing to the size of the catchment in which the site is situated, National Indicative Flood Mapping has not been produced for the Camac Stream in the vicinity of the site.

4.1.4 Historic Flood Records

On review of the historic flood event data obtained from the Office of Public Works (OPW) past flood event records (www.floodinfo.ie), it was revealed that no flood events have previously been recorded within the confines of the infill location. Similarly, there is no record within this dataset of any flood events occurring within the catchment upstream from the site. The following historic flood event was recorded a considerable distance from the site (i.e. >600m), however it should be noted that the extent of the flooding associated with this event was not recorded to have impinged onto the study site:

- Flooding at Mill Road, Saggart, Co. Dublin on the 24th October 2011. It was noted that overland flows passing through Mill Race Development lands built up behind a masonry wall causing the wall to collapse and flows to be routed through properties across Mill Road.

It is understood that in January 2021, planning permission was granted by the Local Authority for an extension of the Millbrook Manor Nursing Home which is situated directly to the north east of the proposed infill site. It also understood that a Site-Specific Flood Risk Assessment (FRA) was prepared as part of that application. A review of that FRA has also been undertaken to further inform on the potential for flooding in the vicinity of the applicant's site.

The FRA concluded that the CFRAM mapping did not align with the nursing home site topography. There was a level variance of 3.0m across the site to the north-west from the existing building and 0.5 – 2.0m variance to the east towards the site entrance. Whereas the predicated flooding levels for the 1% AEP was 0-250mm. It was also noted in the FRA that the site had been filled by several metres as part of the initial development of the nursing home.

Details of the Section 50 application completed in 2014 for the diversion of the Camac Stream through the site was also included within this document. The assessment concluded that the 1 in 100-year flood level (i.e. including climate change allowance) was calculated at 129.34m AOD. Subsequently it was determined that a freeboard of 1.34m for the 1% AEP could be achieved for the proposed culvert design.

4.1.5 *Pluvial Flooding*

Pluvial flooding occurs when extreme rainfall exceeds the soil infiltration capacity or drainage capacity causing excess rainwater to pond above ground at low points in the topography. The OPW's PFRA maps does not identify any part of the site as being susceptible to pluvial flooding.

4.1.6 *Coastal Flooding*

Coastal flooding is caused by higher sea levels than normal, largely as a result of storm surges, resulting in the sea overflowing onto land. The development site is located approx. 19km from the coast and therefore coastal flooding is not deemed to be an issue at the site.

4.2 Stage 1 Conclusion

Pluvial and coastal flooding are not anticipated to occur onsite and therefore no further assessment in terms of risk from either is required. According to the PFRA and CFRAM mapping, there is the potential for fluvial flooding to occur within the confines of the proposed infill site. It is therefore concluded that the assessment should proceed to Stage 2 (Scoping Stage) and concentrate on the potential fluvial flood risk.

5.0 STAGE 2 ASSESSMENT (SCOPING STAGE) – INITIAL FLOOD RISK ASSESSMENT

As mentioned previously, more detailed hydraulic modelling of the Camac Stream / River was completed as part of the Eastern CFRAM Study. In order to assess the sufficiency of the model in respect to the client's site the following reports have been reviewed:

Eastern CFRAM Study, HA09 Hydraulics Report (Final 09/08/2017); and

Eastern CFRAM Study, HA09 Hydrology Report (Final 29/04/2016).

At each node point published from the model an estimated water level (mAOD) for the 10% AEP Event (1 in 10-year), 1% AEP Event (1 in 100-year) and 0.1% (1 in 1000-year) is predicted. One node (i.e. Node 09CAMM01704) is located on the Camac Stream approx. 170m upstream of the north-eastern corner of the site (see CFRAM Mapping in Appendix 1). A further node (i.e. Node 09CAMM01660) is located approx. 100m downstream from the infill site. Under the 1 in 100-year flood event a water level of 135.81m AOD was predicted at the upstream node and a water level of 127.15m AOD was modelled at the downstream point (see Appendix 1). These flood levels represent the current day scenario (i.e. without climate change

allowance). On review of the Flood Extents and Flood Depth maps produced for the applicant's site, it was determined that a small portion of ground within the northern corner was classified as 'Flood Zone A'.

It is understood that post infilling, the site will be reseeded and returned to agricultural use. Consequently, the development can be classified as a *'Less Vulnerable Development'* according to Table 3.1 of the 'Guidelines'. As can be seen from Plate 5, *'Less Vulnerable Development'* is appropriate in lands demarcated as Flood Zone B (i.e. 1 in 1000-year event), whilst a Justification Test is required for development with a Flood Zone A (i.e. 1 in 100-year event). Thus, it was deemed necessary that a hydraulic model of the Camac Stream in the vicinity of the site should be completed. In addition, design / flood flows incorporating a climate change allowance should be modelled.

	Flood Zone A	Flood Zone B	Flood Zone C
Highly vulnerable development (including essential infrastructure)	Justification Test	Justification Test	Appropriate
Less vulnerable development	Justification Test	Appropriate	Appropriate
Water-compatible development	Appropriate	Appropriate	Appropriate

Plate 5. Matrix of vulnerability versus flood zone to illustrate appropriate development and that required to meet the Justification Test (Extract from The Planning System and Flood Risk Management Guidelines)

As the flood maps produced during the Eastern CFRAM study are dated 2017 (with hydraulic model finalised in 2016), it was deemed prudent that these flood levels should be checked based on current stream channel conditions (i.e. to account for any potential deviation of the elevation of the stream bed, surrounding lands or channel orientation over the past 5 years etc.).

6.0 STAGE 3 ASSESSMENT – SITE SPECIFIC DETAILED FLOOD RISK ASSESSMENT

6.1 Site Survey

Previous to this study, Hydrec Environmental Consulting carried out a survey in 2021 of the stretch of the Camac Stream in the vicinity of the applicant's site. The purpose of this survey was to select the locations of topographical cross sections to be used in the construction of a hydraulic model of the watercourse. This modelling pertained to a Flood Risk Assessment completed to support planning application Ref No: SD21A/0159.

During that assessment, the stream channel survey extent ranged from approx. 480m upstream of the current proposed project to approx. 60m downstream from the current proposed infill area. As part of that assessment, it was noted that the stream bed comprised largely of a gravel / cobble substrate with a degree of substrate siltation evident on the base of the channel. Minimal instream vegetation was observed. Additionally, two pieces of instream infrastructure were noted, including:

- An arched bridge culvert (i.e. 2.135m rise and 3.429m span), located within the channel directly to the north-west of the site (i.e. L6018 – Local Road Culvert); and
- A rectangular box concrete culvert (1.359m rise and 3.843m span), located within channel and within the grounds of the Millbrook Manor Nursing Home.

In total twelve topographical cross sections and topographical data relating to the instream infrastructure was collected to construct an accurate model of the watercourse. It was determined that this data was appropriate for use in the hydraulic modelling component of this project. However, additional downstream cross sections of the Camac Stream were required in order to ensure that the flood levels relating to the site under focus were not underestimated. On the 18th January 2022, Patrick McCabe of Hydrec Environmental Consulting completed a river walk of the downstream stretch of the Camac Stream in an effort select appropriate topographical cross section locations. An additional five cross sections were selected. When the previous survey extent is combined with the additional data, the new model extent covers a c.900m stretch of the Camac stream (i.e. including a sufficient distance upstream and downstream from the site). A summary of the cross-section locations and their justification for selection is described in Table 1. below.

As was the case with the previous surveying (October 2021), all additional cross-section surveying was completed by Horizon Surveys Ltd (19th January 2022). This topographical data offers concise and highly accurate details of the top and bottom levels of the stream banks and the watercourse bed elevations. The cross-section profiles are included in Appendix 2 and illustrated on Figure 3. Detailed site topographical data was supplied by Coffey Construction Ltd and further supplemented by additional topographical data taken on the 19th of January 2022 by Horizon Surveys Ltd.

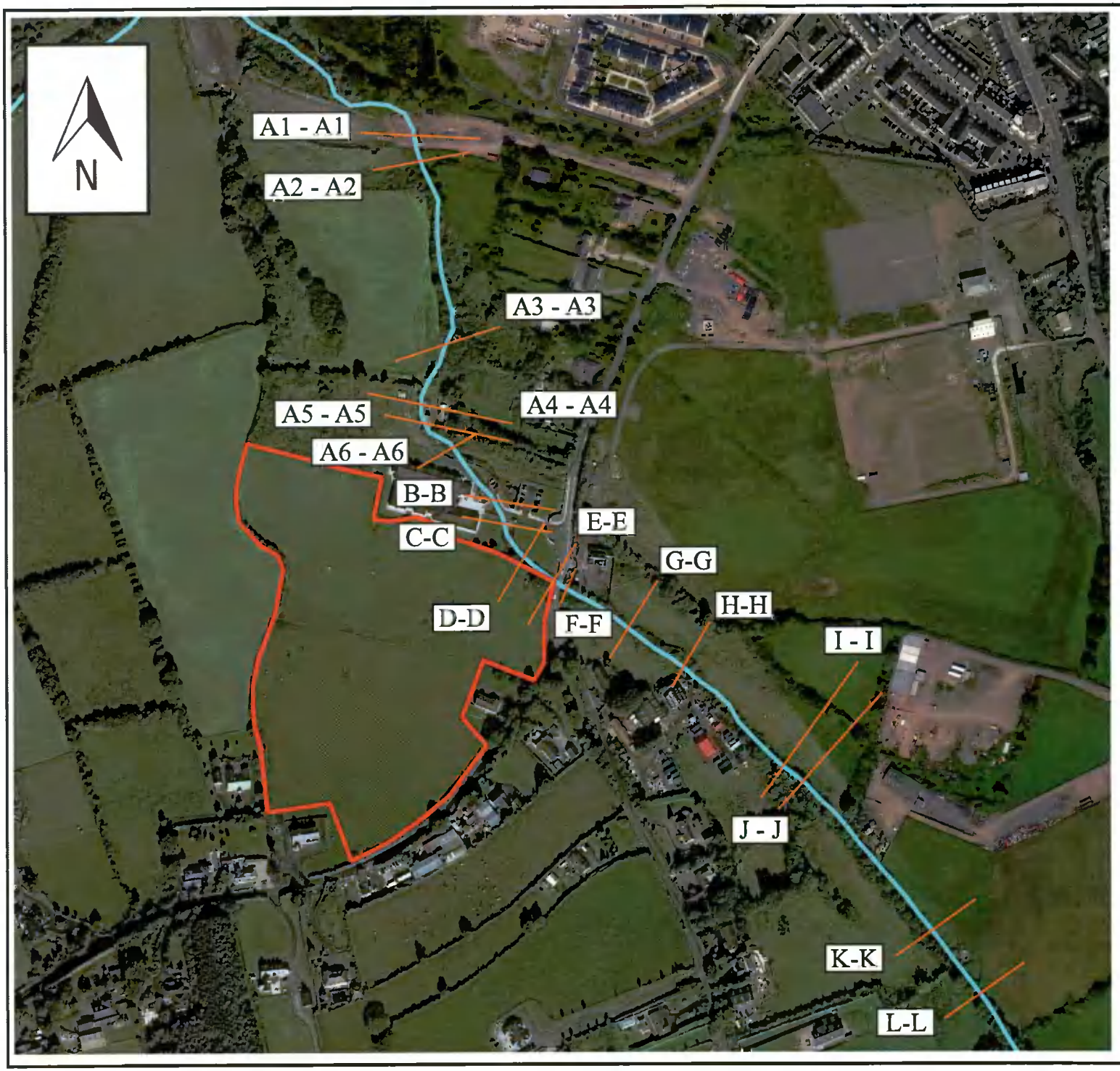
Table 1. Description of the cross-section locations utilised in the HEC – RAS hydraulic model.

Cross Section No.	Description of Cross Section Location
Cross Section 1 (L-L)	Upstream Section (Surveyed in October 2021)
Cross Section 2 (K-K)	Upstream Section (Surveyed in October 2021)
Cross Section 3 (J-J)	Upstream Section (Surveyed in October 2021)
Cross Section 4 (I-I)	Upstream Section (Surveyed in October 2021)
Cross Section 5 (H-H)	Upstream Section (Surveyed in October 2021)
Cross Section 6 (G-G)	Upstream Section (Surveyed in October 2021)
Cross Section 7 (F-F)	Upstream of local roadway culvert (Surveyed October 2021)
Cross Section 8 (E-E)	Downstream of local roadway culvert (Surveyed October 2021)
Cross Section 9 (D-D)	Through Millbrook Manor Nursing Home (Surveyed October 2021)
Cross Section 10 (C-C)	Upstream of Nursing Home lane culvert (Surveyed October 2021)
Cross Section 11 (B-B)	Downstream of Nursing Home lane culvert (Surveyed October 2021)
Cross Section 12 (A6-A6)	Downstream of study site (Surveyed October 2021)
Cross Section 12 (A5-A5)	Downstream of study site (Surveyed January 2022)
Cross Section 12 (A4-A4)	Downstream of study site (Surveyed January 2022)
Cross Section 12 (A3-A3)	Downstream of study site (Surveyed January 2022)
Cross Section 12 (A2-A2)	Downstream of study site (Surveyed January 2022)
Cross Section 12 (A1-A1)	280m downstream of study site (Surveyed January 2022)

6.2 Peak Flow Estimation

6.2.1 Flood Studies Update (FSU) Flow Estimate

The Flood Studies Update (FSU) programme was undertaken by the Office of Public Works (OPW), to provide improved methods of extreme rainfall and flood estimation at both gauged and ungauged locations across the Republic of Ireland. The FSU web-based application portal facilitates the estimation of flood flows, extreme rainfall depths and other hydrological variables at river node points at 500m centres along the entire Irish river network.



LEGEND

- Site Boundary
- Stream / River
- Cross Section Location
- Drainage Channel

HYDREC ENVIRONMENTAL CONSULTING

PROJECT:

Flood Risk Assessment
- Coffey Construction Ltd. -
Slade, Saggart, Co. Dublin (Hurley Site)

TITLE:

Topographical cross sections locations used within the hydraulic model assessment

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At each node point, the Qmed value can be obtained from catchment descriptor data through the application of the following regression model:

$$Qmed_{rural} = 1.237x10^{-5} \times AREA^{0.937} \times BFIsoils^{0.922} \times SAAR^{1.306} \times FARL^{2.21} \times DRAIND^{0.341} \times S1085^{0.185} \times (1 + ARTDRAIN2)^{0.408}$$

Where:

AREA = Catchment area (km^2);

BFIsoils = Base flow index derived from soils data;

SAAR = Long term mean annual rainfall amount (mm);

FARL = Flood attenuation by reservoirs / lakes;

DRAIND = Drainage density;

S1085 = Slope of the main channel between 10% and 85% of its length (m/km);

ARTDRAIN2 = Percentage of the catchment river network included in Drainage schemes.

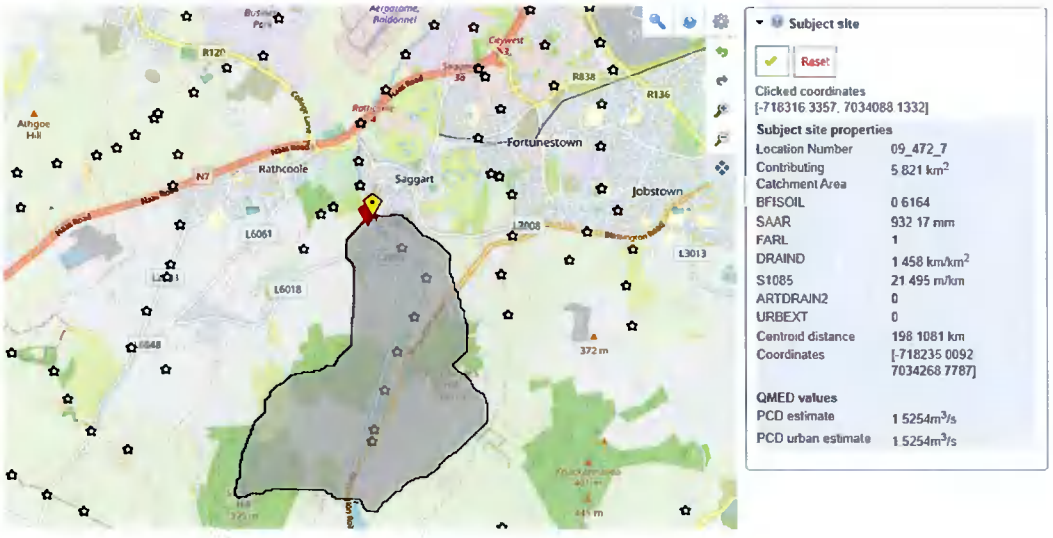


Plate 6. Output from the flood frequencies tool for gauged sites on the OPW FSU web portal.

The programme output for the subject site can be summarised as follows:

- Catchment Area: 5.821km^2
- SAAR: 932.17mm
- S1085: 21.495m/km
- Qmed: 1.525m^3/s

It is important to note that the use of the FSU Qmed is typically designed for catchments that are greater than 25km^2 in area. Caution should be exercised when using this methodology for smaller catchments. Given that the upgradient catchment area equates to 5.821km^2, it is imperative that other methodologies designed for use on smaller catchments are assessed and compared.

6.2.2 Flood Studies Supplementary Report 6

In the absence of sufficient flow records, one of the most appropriate methods for estimating ungauged design flood flows in Ireland is based on the Flood Studies Report (FSR) and subsequent modifications. The original 1975 Flood Studies Report (FSR) equation when tested showed that floods on small catchments were less well predicated than on large ones. The Flood Studies Supplementary Report (FSSR) No. 6 was introduced to overcome the shortcomings in the estimation of mean annual floods from small catchments through the use of the FSR. A total of 53 catchments with <20km^2 catchment area were used in the regression analysis during this study. The FSSR 6 Q_{BAR} equation for use on catchments of less than 20km^2 is:

$$Q_{BAR} = 0.00066 \times AREA^{0.92} \times SAAR^{1.22} \times SOIL^{2.0}$$

Using the FSSR 6 formula, the 1 in 1-year flow is as follows:

$$Q_{BAR} = 0.00066 \times 5.821^{0.92} \times 932.17^{1.22} \times 0.3^{2.0}$$

$$Q_{BAR} = 0.00066 \times 5.06 \times 4195.5 \times 0.09$$

$$Q_{BAR} = 1.26 \text{ m}^3/\text{s}$$

6.2.3 *Institute of Hydrology (IH) 124*

In 1994 the Institute of Hydrology carried out further regression studies on small catchments (areas <25km^2). A total of 87 catchments ranging from 0.9km^2 to 24.7km^2 were available. Seventy-one of these catchments were chosen as completely rural catchments having urban fractions of less than 0.025km^2. The following 3-variable equation was derived:

$$QBAR = 0.00108 \times AREA^{0.89} \times SAAR^{1.17} \times SOIL^{2.17}$$

This equation is widely used in Ireland to estimate flood flows and Greenfield runoff from small catchments (i.e. between 0.5km^2 and 25km^2).

Using the IH124 formula, the 1 in 1-year flow is as follows:

$$Q_{BAR} = 0.00108 \times 5.821^{0.89} \times 932.17^{1.17} \times 0.3^{2.17}$$

$$Q_{BAR} = 0.00108 \times 4.80 \times 2980.64 \times 0.073$$

$$Q_{BAR} = 1.13\ m^3/s$$

6.2.4 *Flood Frequency Growth Curve for Ireland*

Single-Site Flood Frequency Analysis is a statistical analysis of flood data for a particular gauged location and is only possible at locations where recorded time-series data exists. It is a method used to derive flood growth curves and frequency curves so that peak flows can be calculated from the Qmed. The appropriate growth curve for an ungauged catchment is estimated using a Pooled Analysis. This method uses catchment characteristics (PCDs) to identify a number of gauged catchments that are hydrologically similar to the catchment of the subject site. The observed flood data for the "similar" gauged catchments are then pooled to effectively create a longer time-series and used to estimate the peak flow at the ungauged subject site. In this way Pooled Analysis may also be used to supplement Single Site Analysis to improve the robustness of the design estimation particularly for long return period events. A Pooled Flood Frequency Analysis has been performed to derive the AEP growth factors outlined in Table 2 and Plate 7 using the FSU method. These growth factors have been applied to the design flows estimated using the FSU methodology. Conversely, it is possible using the standard growth factors set out in the FSR to calculate the 1 in 100-year design flows for the FSSR 6 and IH 124.

Table 2. Determination of flood flows for selected return periods

Peak Flow Estimation Method	QMED / Q_{BAR} Value (m^3/s)	Growth Factor (1 in 100 Years)	Growth Factor (1 in 1000 Years)	1 in 100 Year Predicted Flow (m^3/s)	1 in 1000 Year Predicted Flow (m^3/s)
FSU	1.53	2.59	3.46	3.96	5.29
FSSR 6	1.26	1.96	2.6	2.47	3.28
IH 124	1.13	1.96	2.6	2.21	2.94

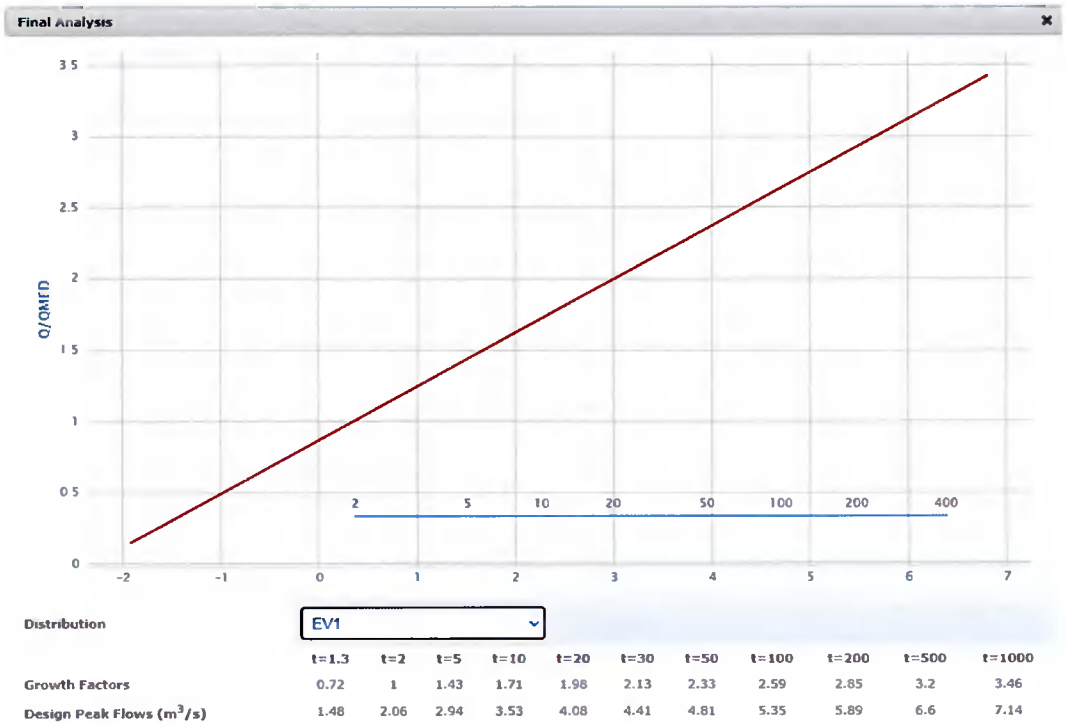


Plate 7. Pooled Flood Frequency Analysis derived from the OPW FSU web portal for the site.

6.2.5 Climate Change Allowance

It is proposed to apply a further growth factor of 1.2 to these estimated design year flows, in order to allow provision for predicted increased rainfall and associated run-off volumes over the coming century. The design flood flows (with allowance for climate change) are outlined in Table 3 below.

Table 3. Determination of flood flows for selected return periods

Peak Flow Estimation Method	1 in 100 Year Predicted Flow (m^3/s)	1 in 1000 Year Predicted Flow (m^3/s)	Growth Factor (Climate Change Allowance)	Plus Climate Change Allowance	
				1 in 100 Year Predicted Flow (m^3/s)	1 in 1000 Year Predicted Flow (m^3/s)
FSU	3.96	5.29	1.2	4.75	6.35
FSSR 6	2.47	3.28	1.2	2.96	3.94
IH 124	2.21	2.94	1.2	2.65	3.53

6.2.6 Recommended Design Flow

There was a relatively strong agreement between the design flows calculated using the FSSR 6 and IH 124 estimation methods. However, a more stringent 1 in 100-year design flow was estimated using the FSU methodology. Whilst not always utilised in catchments of <25km^2, in this instance this more rigorous design flow estimated from the FSU was used in the hydraulic model.

6.3 Hydraulic Modelling Assessment

In order to assess the extent of fluvial flooding in relation to the 1 in 100-year flood event, a 1-Dimensional (1D) steady flow hydraulic model of the stream was constructed using the HEC-RAS hydraulic modelling software (latest version 5.0.7). The model was used to simulate the water level at different points along the stream under different flow regimes (see model outputs in Appendices 3 & 4). The model was compiled using the cross-sections surveyed on the 05th October 2021 and 19th January 2022.

When constructing a 1D Steady Flow Hydraulic Model using HEC-RAS software, a number of user defined parameters are required to complete the computational procedure. This includes Manning's 'n-Values' (i.e. roughness coefficient) of the stream banks and channel at each cross-section. Contraction and expansion coefficients are also required to evaluate the amount of energy loss that occurs because of a flow contraction or expansion at each cross-section. The values used in the model are detailed in Table 4. The downgradient boundary condition of the model was determined using the 'Normal Depth' application of the software, whereby the channel slope was defined as 0.02m/m (i.e. relatively steep channel gradient). The 'Critical Depth' function was selected to model the upgradient boundary condition.

Table 4. Summary of roughness, contraction and expansion coefficients used in the hydraulic model

Cross Section No.	Roughness Coefficient (Manning's n Value)	Contraction Coefficient	Expansion Coefficient
Cross Section 1 (L-L) (RS = 212)	Left overbank – 0.035 River channel – 0.033 Right overbank – 0.035	0.1	0.3
Cross Section 2 (K-K) (RS = 211)	Left overbank – 0.035 River channel – 0.033 Right overbank – 0.035	0.1	0.3
Cross Section 3 (J-J) (RS = 210)	Left overbank – 0.035 River channel – 0.033 Right overbank – 0.035	0.1	0.3
Cross Section 4 (I-I) (RS = 209)	Left overbank – 0.035 River channel – 0.033 Right overbank – 0.035	0.1	0.3
Cross Section 5 (H-H) (RS = 208)	Left overbank – 0.035 River channel – 0.033 Right overbank – 0.035	0.1	0.3
Cross Section 6 (G-G) (RS = 207)	Left overbank – 0.035 River channel – 0.033 Right overbank – 0.035	0.3	0.5
Cross Section 7 (F-F) (RS = 206)	Left overbank – 0.035 River channel – 0.033 Right overbank – 0.035	0.3	0.5
Cross Section 8 (E-E) (RS = 205)	Left overbank – 0.035 River channel – 0.033 Right overbank – 0.035	0.3	0.5
Cross Section 9 (D-D) (RS = 204)	Left overbank – 0.035 River channel – 0.033 Right overbank – 0.035	0.3	0.5
Cross Section 10 (C-C) (RS = 203)	Left overbank – 0.035 River channel – 0.033 Right overbank – 0.035	0.3	0.5
Cross Section 11 (B-B) (RS = 202)	Left overbank – 0.035 River channel – 0.033 Right overbank – 0.035	0.3	0.5

Table 5. Water levels predicted for the stream in relation to the proposed infill site

Cross Section No.	Water Level Predicted (1% AEP)	Water Level Predicted (1% AEP (plus C.C allowance)
CS 1 (L-L)	141.98m AOD	142.04m AOD
CS 2 (K-K)	141.01m AOD	141.20m AOD
CS 3 (J-J)	136.92m AOD	136.98m AOD
CS 4 (I-I)	136.70m AOD	136.75m AOD
CFRAM Node Location	135.84m AOD	135.89m AOD
CS 5 (H-H)	133.94m AOD	133.98m AOD
CS 6 (G-G)	132.43m AOD	132.48m AOD
CS 7 (F-F)	131.25m AOD	131.36m AOD
CS 8 (E-E)	130.50m AOD	130.55m AOD
CS 9 (D-D)	130.10m AOD	130.15m AOD
CS 10 (C-C)	129.50m AOD	129.61m AOD
Nursing Home Culvert	129.37m AOD	129.46m AOD
CS 11 (B-B)	129.45m AOD	129.54m AOD
CS 12 (A6-A6)	129.15m AOD	129.22m AOD
CS 13 (A5-A5)	127.98m AOD	128.04m AOD
CS 14 (A4-A4)	127.87m AOD	127.90m AOD
CS 15 (A3-A3)	127.07m AOD	127.09m AOD
CS 16 (A2-A2)	123.33m AOD	123.38m AOD
CS 17 (A1-A1)	123.08m AOD	123.11m AOD

LEGEND

- Site Boundary
- 1% Fluvial flood extent (+ Climate Change Allowance)
- Proposed Infill Area
- Contour Lines
- N

HYDREC ENVIRONMENTAL CONSULTING

PROJECT:

Flood Risk Assessment
- Coffey Construction Ltd -
Slade, Saggart, Co. Dublin (Hurley Site)

TITLE:

Area proposed for infilling in relation to 1 in 100-year modelled flood plain

SCALE:	DRAWN BY:
1:600@A3	PMcC
DRAWING NO:	**REV.**
Figure 4.	B

8.0 MITIGATION MEASURES

Following the completion of a site-specific hydraulic model, fluvial flooding is not predicated occur within the project site. Thus, the lands under focus can be classified as being located within a 'Flood Zone C'[1]. Thus, compensatory storage (or alternative measures) to mitigate against a loss of floodplain are not required.

Figure 5, demonstrates how a minimum 10m buffer distance from the proposed infill area and the Camac Stream, as requested by the Local Authority can be achieved.

In order to mimic existing greenfield runoff rates onsite, post infilling works, it is proposed to deposit differing soil types within different areas of the infill site (see Figure 6). A minimum of 300mm of topsoil will be reinstated across the site once all infilling activities have ceased. This will compensate for any loss of infiltration / rainwater storage afforded by existing topsoil conditions.

The Ground Investigation completed Causeway Geotech in 2018 (Ref: 17-1375) for the neighbouring waterworks site, recorded glacial till (i.e. firm brown sandy gravelly CLAY) within the upper 1 – 2m horizons at a number of locations within the site. Stiffer glacial tills typically characterised as grey / black CLAY were encountered at lower depths in places. It is proposed that infilling within the majority of the site (i.e. area categorised as TLPSsS subsoil of low permeability, is suitable for infilling with both the firm brown sandy gravelly CLAY and stiffer boulder CLAY, below the topsoil horizon (see Figure 2 & 6). Where higher permeability subsoils is mapped in the northern corner of the site, fill dominated by sands and gravels / cobbles with a lower silt and clay content should be deposited (see Figure 2 & 6).

[1] Lands can be classified as Flood Zone C as flooding under the 1 in 1000-year event was not predicted to encroach onto the proposed infill site either.

LEGEND

- Top of Riverbank
- Proposed Infill Area
- 10m Set Back Distance.
- Watercourse

HYDREC
ENVIRONMENTAL CONSULTING

PROJECT:

Flood Risk Assessment
- Coffey Construction Ltd -
Slade, Saggart, Co. Dublin (Hurley Site)

TITLE:

Plan view map demonstrating the set back distances from infill area and river bank.

SCALE:	DRAWN BY:
1:900@A3	PMcC
DRAWING NO:	**REV.**
Figure 5.	A

SITE CONDITIONS POST INFILLING WORKS

HYDREC ENVIRONMENTAL CONSULTING

LEGEND:

- Indigenous Ground (Low Permeability)
- Indigenous Ground (High Permeability)
- Stiff / Very Stiff Glacial Till Fill
- Predominantly Sand & Gravel Fill

Project:	Flood Risk Assessment - Coffey Construction Ltd. - Slade, Saggart, Co. Dublin
Title:	Cross section detailing soil infill types to be deposited onsite. (Please note vertical scale exaggerated for demonstration purposes).

Figure 6.	**Drawn By: PMcC**
Scale: 1:400 @ A1	**REV. 0**

9.0 VULNERABILITY & JUSTIFICTION TEST

Table 3.1 of the guidelines provides three vulnerability categories, based on the type of development that may be appropriate to each flood zone. In summary:

- **Zone A - High probability of flooding:** Most types of development would be considered inappropriate in this zone. Development in this zone should be avoided and/or only considered in exceptional circumstances, such as in city and town centres, or in the case of essential infrastructure that cannot be located elsewhere, and where the Justification Test has been applied. Only water-compatible development, such as docks and marinas, dockside activities that require a waterside location, amenity open space, outdoor sports and recreation, would be considered appropriate in this zone;

- **Zone B - Moderate probability of flooding:** Highly vulnerable development, such as hospitals, residential care homes, Garda, fire and ambulance stations, dwelling houses and primary strategic transport and utilities infrastructure, would generally be considered inappropriate in this zone, unless the requirements of the Justification Test can be met. Less vulnerable development, such as retail, commercial and industrial uses, sites used for short-let for caravans and camping and secondary strategic transport and utilities infrastructure, and water-compatible development might be considered appropriate in this zone;

- **Zone C - Low probability of flooding:** Development in this zone is appropriate from a flood risk perspective (subject to assessment of flood hazard from sources other than rivers and the coast) but would need to meet the normal range of other proper planning and sustainable development considerations

A Justification Test is an assessment of whether a development proposal within an area at risk of flooding meets specific criteria for proper planning and sustainable development and demonstrates that it will not be subject to unacceptable risk nor increase flood risk elsewhere. Table 3.2 of the guidelines illustrates those types of development that would be required to meet the Justification Test (see Plate 5). On the basis that the infill site is located within 'Flood Zone C', the project can be deemed appropriate from a flood risk perspective and can proceed without the need for a Justification Test. Notwithstanding that the criterion set out in Section 5.15 of the Flood Risk Management Guidelines has been considered as a mean of ensuring that the project will not have an *'adverse impacts or impede access to a watercourse, floodplain or flood protection and management facilities'* (see Table 5).

Table 7. Development Management Justification Test (Box 5.1 of the 'Guidelines')

Criterion	Response
5.1.1. The subject lands have been zoned or otherwise designated for the particular use or form of development in an operative development plan, which has been adopted or varied taking account of these Guidelines.	The RU zoning objective of the application site, seeks to protect and improve rural amenity and to provide for the development of agriculture.
5.1.2 (i) The development proposed will not increase flood risk elsewhere and, if practicable, will reduce overall flood risk.	The Flood Risk Assessment shows that the development will be positioned outside of the modelled 'Flood Zone A'. Consequently, the proposed development will not displace flood water to adjoining lands and thus will not increase flood risk in the vicinity of the site or wider environment.
5.1.2 (ii) The development proposal includes measures to minimise flood risk to people, property, the economy and the environment as far as reasonably possible.	Given that no loss of floodplain storage will occur, a heightened risk of flood damage to surrounding properties or the local road infrastructure is not anticipated under the 1 in 100-year event. Additionally, the 1% AEP modelled flood levels take account of climate change (i.e. Mid-Range Future Scenario).
5.1.2 (iii) The development proposed includes measures to ensure that residual risks to the area and/or development can be managed to an acceptable level as regards the adequacy of existing flood protection measures or the design, implementation and funding of any future flood risk management measures and provisions for emergency services access.	The proposed development does not impact on any existing flood protection measures and will not prevent any potential future flood risk management measures, as a sufficient buffer between the infill area and watercourse will exist. Similarly, the proposed development will not cause an obstruction to any future OPW arterial drainage works.
5.1.2 (iv) The development proposed addresses the above in a manner that is also compatible with the achievement of wider planning objectives in relation to development of good urban design and vibrant and active streetscapes.	The RU zoning objective of the application site, seeks to protect and improve rural amenity and to provide for the development of agriculture.

10.0 CONCLUSIONS & RECOMMENDATIONS

In consideration of the findings of this detailed site-specific flood risk assessment, the following conclusions and recommendations can be made:

- The OPW's CFRAM mapping / modelling indicates that a portion of the site is susceptible to fluvial flooding from the Camac Stream under the 1 in 100-year scenario;
- A hydraulic assessment of the Camac Stream, which was extended both upstream and downstream of the site was constructed by Hydrec Environmental Consulting in order to predict the 1 in 100-year flood event relative to the site and based on current stream channel conditions / elevations (i.e. 2021 / 2022);
- This model produced by Hydrec Environmental Consulting includes a 20% climate change allowance in relation to the Flood Zone A;
- The model shows that there is sufficient capacity within the nursing home culvert to convey the 1 in 100-year flood event. This finding is consistent with the 1 in 100-year flood level calculated to support the Section 50 Application submitted to the OPW in relation to the installation of the nursing home culvert;
- However, under the 1% AEP (+C.C Allowance) fluvial flooding from the Camac Stream was predicated to occur downstream from the proposed infill site;
- The 1% AEP flood level at the overspill point was modelled at 127.90m AOD;
- Given that all lands within the proposed infill site are >130.4m AOD, fluvial flooding from the Camac Stream under the 1 in 100-year event will not occur;
- As no flooding is predicted to occur within the confines of the proposed development site, it can be described as being located within 'Flood Zone C and therefore deemed acceptable from a flood risk perspective. Additionally, the Justification test criterion set out in the Flood Risk Management Guidelines have been considered and adhered too;
- In order to mimic existing subsoil permeability / greenfield runoff rates onsite, it is proposed to deposit differing soil types as identified in the Causeway Geotech Ground Investigation at the inert soil origin site, within different areas of the infill site. These areas were selected on the basis of the GSI's subsoil permeability mapping (see Figure 6);

- **To conclude the project will not be at risk from flooding nor will it block flood flow paths or exacerbate flooding in the immediate vicinity or wider area as no infilling within a 'Flood Zone A' or 'Flood Zone B' will occur.**

Signed:

Patrick McCabe

Patrick McCabe B.Sc., M.Sc.

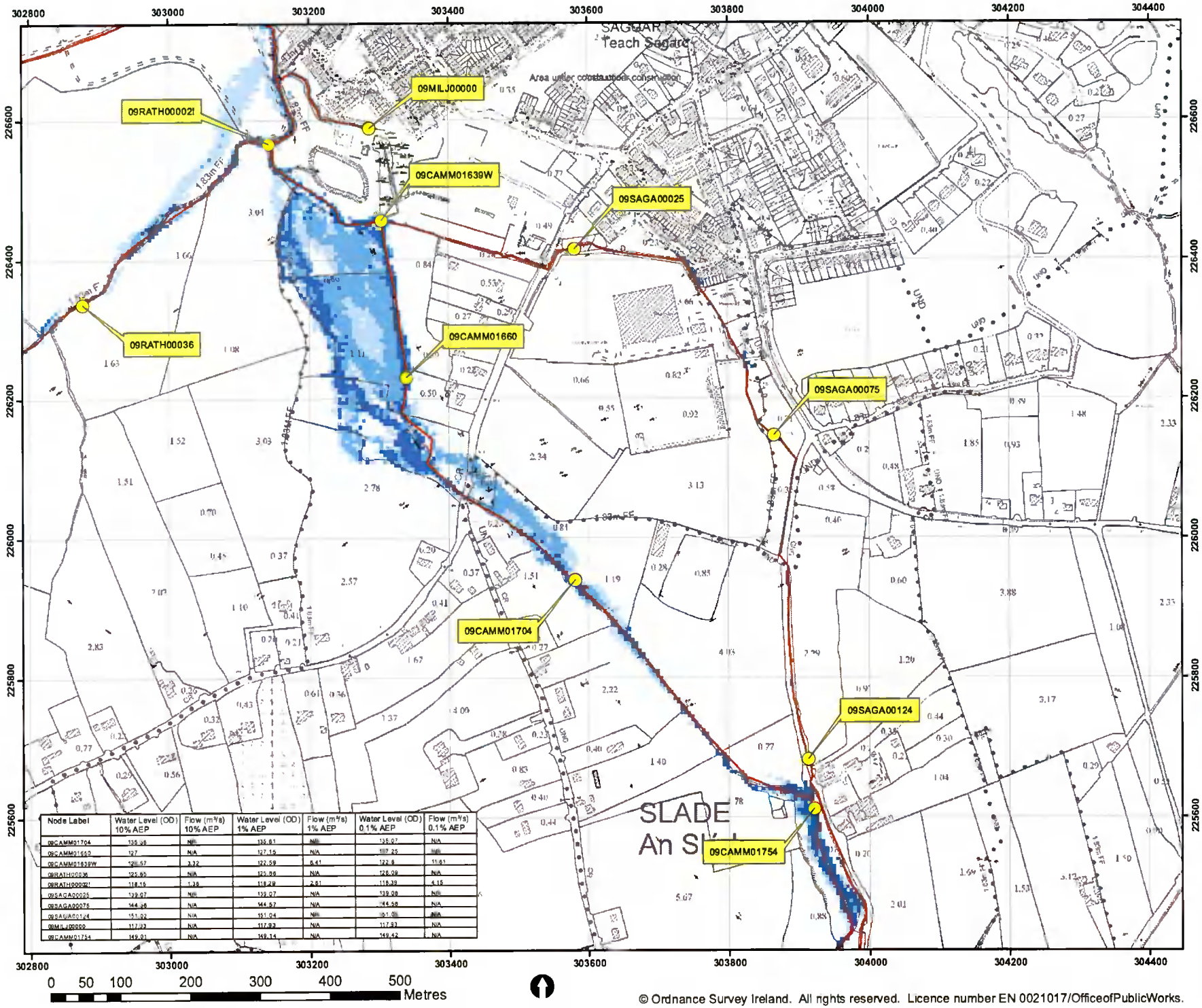
Hydrec Environmental Consulting

(P.I. Available on Request).

APPENDIX 1

CFRAM MAPPING – CAMAC FLUVIAL FLOOD EXTENTS

(ALL POSSIBILITIES)



Node Label	Water Level (OD) 10% AEP	Flow (m³/s) 10% AEP	Water Level (OD) 1% AEP	Flow (m³/s) 1% AEP	Water Level (OD) 0.1% AEP	Flow (m³/s) 0.1% AEP
09CAMM01704	135.98	N/A	135.81	N/A	135.07	N/A
09CAMM01660	127	N/A	127.15	N/A	127.25	N/A
09CAMM01639W	125.57	3.32	122.59	6.41	122.8	11.61
09RATH00036	125.65	N/A	125.56	N/A	125.08	N/A
09RATH00002!	118.15	1.36	118.29	2.61	118.39	4.15
09SAGA00025	139.07	N/A	139.07	N/A	139.08	N/A
09SAGA00075	144.98	N/A	144.57	N/A	144.58	N/A
09SAGA00124	151.02	N/A	151.04	N/A	151.08	N/A
09MILJ00000	117.03	N/A	117.93	N/A	117.93	N/A
09CAMM01754	149.01	N/A	149.14	N/A	149.42	N/A

IMPORTANT USER NOTE:
THE VIEWER OF THIS MAP SHOULD REFER TO THE DISCLAIMER, GUIDANCE NOTES AND CONDITIONS OF USE THAT ACCOMPANY THIS MAP.

Legend

- 10% Fluvial AEP Event
- 1% Fluvial AEP Event
- 0.1% Fluvial AEP Event
- Modelled River Centreline
- AFA Extents
- Embankment
- Wall
- Defended Area
- Standard of Protection of Flood Defence (Walls / Embankments)
- Node Point
- Node ID: Node Label

FINAL

REV:	NOTE	DATE:
01	BOP label updated (Pg 21) Removal of Def. Area (Pg 21)	13/11/2017

The Office of Public Works, Jonathan Swift Street, Trim, Co Meath
Elmwood House, 74 Boucher Road, Belfast, BT12 6RZ
T +44(0) 28 90 667914, F +44(0) 28 90 668286, W www.rpsgroup.com, E ireland@rpsgroup.com

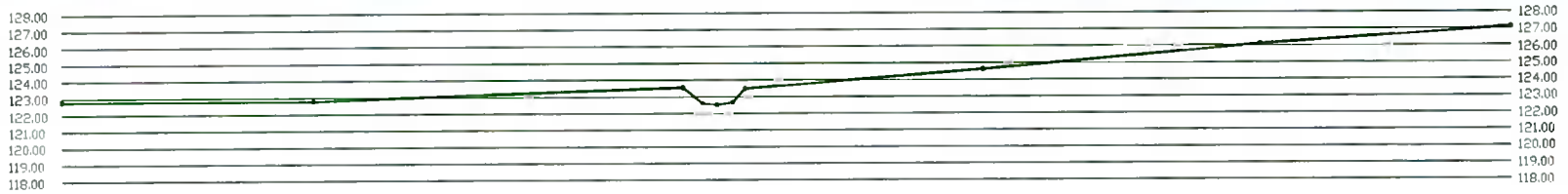
Map: Carnac Fluvial Flood Extents

Map Type:	EXTENT
Source:	FLUVIAL
Map Area:	HPW
Scenario:	CURRENT
Drawn By:	C.McG. Date: 13 November 2017
Checked By:	A.S. Date: 13 November 2017
Approved By:	S.P. Date: 13 November 2017
Drawing No.:	E09CAM_EXFCD_F1_03
Map Series:	Page 3 of 24
Drawing Scale:	1:5,000 @A3

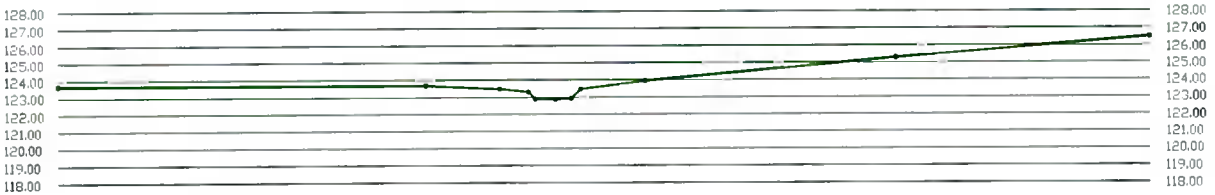
APPENDIX 2

HORIZON SURVEYS LTD – TOPOGRAPHICAL CROSS SECTIONS

NOTES:
1. All levels are relative to Ordnance Datum Malin Head
2. 50m sq grid relative to Irish Transverse Mercator Co-ordinate reference system
3. Contours are at .25m intervals



Section A1 - A1



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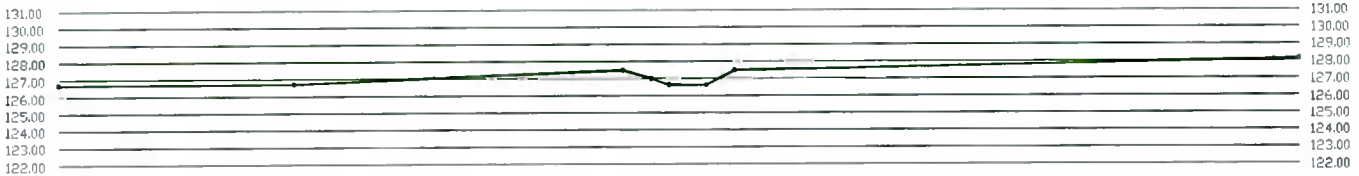

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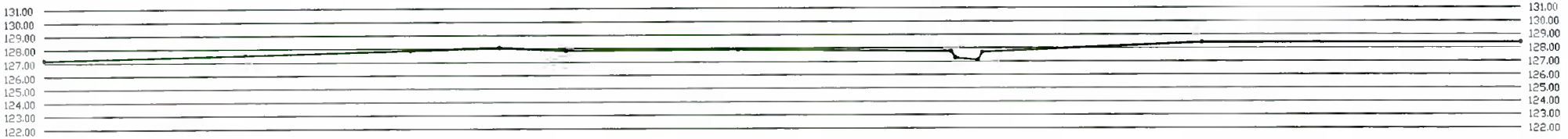

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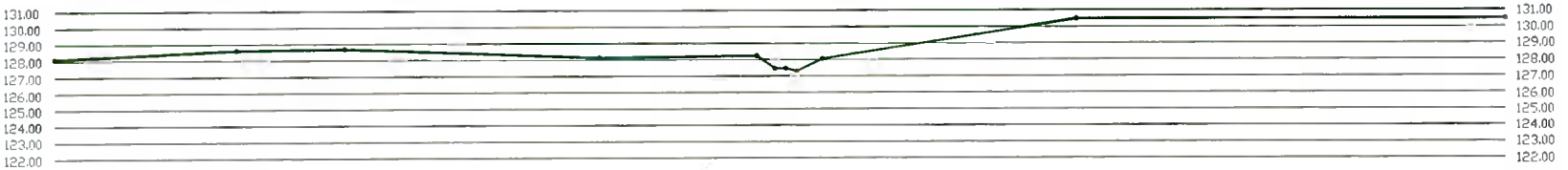


Section A5 - A5

LINE TYPE LEGEND

	Site		Electricity Box
	Boundary		Fire Hydrant
EP	Electricity Pole		Pres Station
GATE	Gate		Inspection Cover
	Gully		Invert Level
	Gas Valve		Lamp Post
	Gas Cover		Manhole
	Finished Floor Level	O WAT	Post
	Electricity Cover	FCA	Pillar
	Manhole Cover	OTP	Telegraph pole
	Ridge	TL	Telecom Cover
	Road Level	CPA	Tree
	Sign		Water Meter

LINE TYPE LEGEND

	Boundary		Surface Change
	Building		Shed
	Road Top		Vegetation Line
	Back Batter		Verge
	Channel		Telecom Cover
	Fence		Wall
	Kerb		Railing
	Path		Verge
	Overhead Electricity Line		Road Edge

REVISIONS

No.	Date	Description

Market Square, Castleblayney, Monaghan, Ireland
Tel: 042 9746871 Mobile: 087 6840802 / 087 7933035
Website: www.horizon-group.ie

- Topographical Surveys
- Measured Building Surveys
- Legal Mapping
- RICS Condition Reports
- Site Suitability For Waste Water Treatment
- As Built Surveys
- GPS Surveys
- Setting Out
- Assigned Cadastral Services

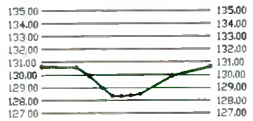
Client:
XX

Professional:
Hydrec

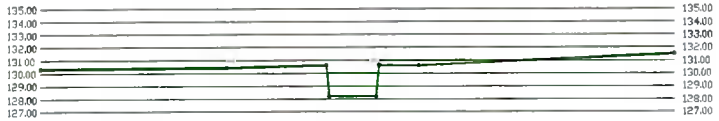
Project Title:
River survey in Saggart

Drawn:	TD	Dwg No:	01/001
Scale:	1/150	Date:	21/01/2022

A1



Section A6 - A6



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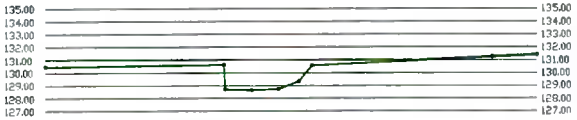
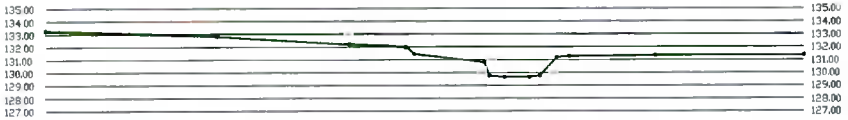
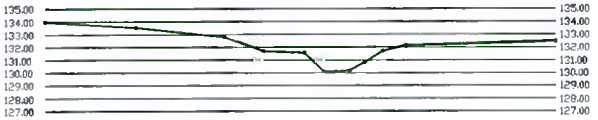


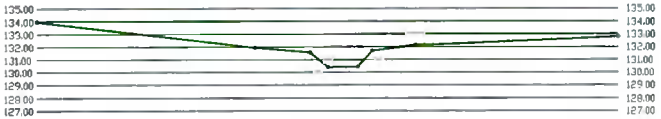
Section C-C



Section D-D



Section E-E



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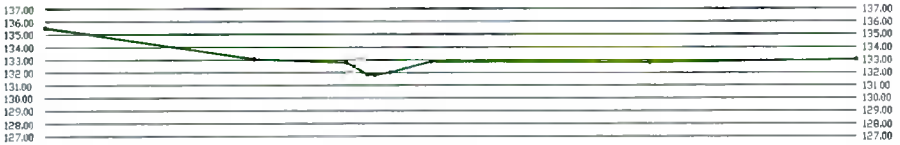
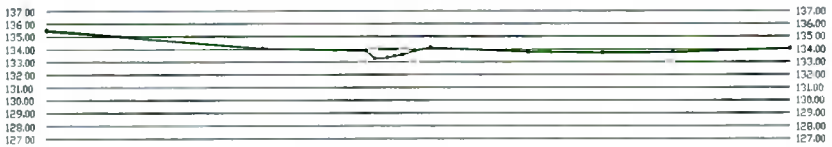


Section G-G



Section H-H

NOTES:
1. All levels are relative to Ordnance Datum Malin Head
2. 50m sq grid relative to Irish Transverse Mercator Co-ordinate reference system
3. Contours are at .25m intervals

LINE TYPE LEGEND

	Boundary		Surface Change
	Building		Step
	Bank Top		Vegetation Line
	Bank Bottom		Verge
	Channel		Telecom Cover
	Fence		Wall
	Kerb		Railing
	Path		Verge
	Overhead Electricity Line		Road Edge

REVISIONS

No.	Date	Description

Horizon Group
Market Square, Castleblayney, Monaghan, Ireland
Tel: 042 9740071 Mobile: 087 6640982 / 087 7939036
Website: www.horizon-group.ie

- Topographical Surveys
- Measured Building Surveys
- Legal Mapping
- RICS Condition Reports
- Site Suitability For Waste Water Treatment
- As Built Surveys
- CPS Surveys
- Setting Out
- Assigned Certifier Services

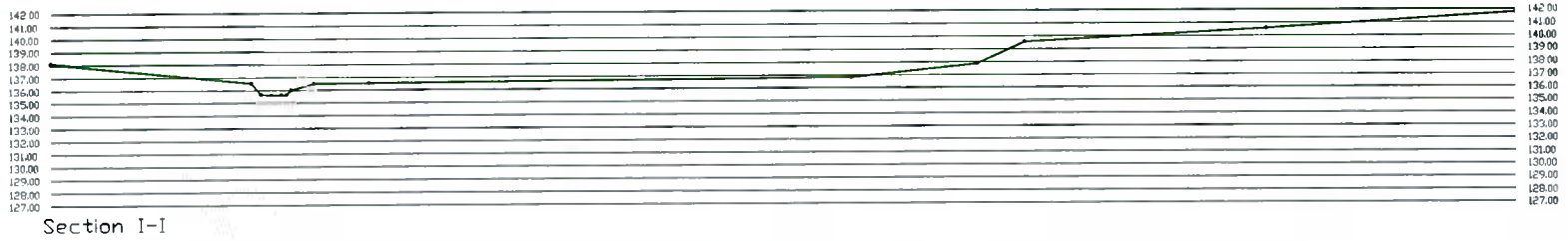
Client: XX

Professional: Hydrec

Project Title: River Survey at Saggart

Drawn:	TD	Dwg No.:	01/001
Scale:	1/200	Date:	XX

A1



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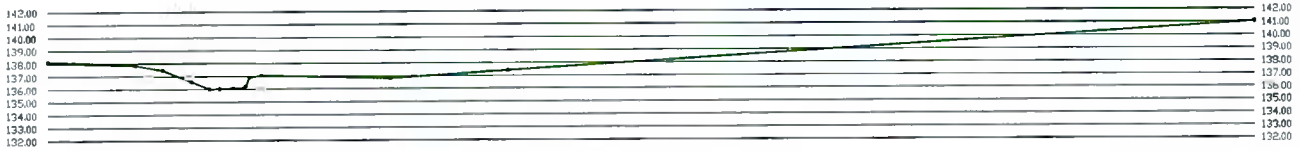
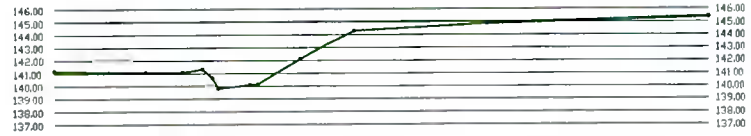
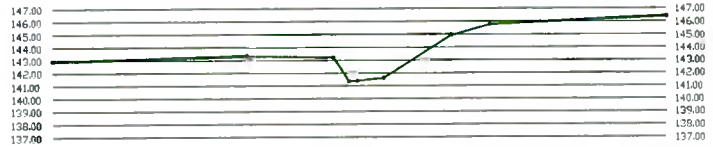


Section J-J



Section K-K



Section L-L

NOTES:

1. All levels are relative to Ordnance Datum Malin Head
2. 50m sq grid relative to Irish Transverse Mercator Co-ordinate reference system
3. Contours are at .25m intervals

LINE TYPE LEGEND

	Boundary		Bottom Change
	Building		Step
	Bank Top		Vegetation Line
	Bank Bottom		Verge
	Channel		Tarmack Cover
	Fence		Wall
	Kerb		Railing
	Path		Verge
	Overhead Electricity Line		Road Edge

LINE TYPE LEGEND

	Soil		Electricity Box
UP	Downpipe		Fire Hydrant
EP	Electricity Pole		Free Station
GATE	Gate	BLAU	Inspection Cover
	Gully	BLAU	Invert Level
	Gas Valve		Lamp Post
	Gas Cover		Manhole
	Finished Floor Level	O PIPE	Post
	Electricity Cover	PLA	Pillar
	Manhole Cover	Chr	Telegraph pole
	Ridge	TELECOM	Telecom Cover
	Spot Level	Om	Tree
	Sign		Water Meter

REVISIONS

No.	Date	Description

RICS Horizon Group Cabe

Meelan Square, Castleblayney, Monaghan, Ireland
Tel: 042 9740471 Mobile: 087 6640882 / 087 7853035
Website: www.horizon-group.ie

- Topographical Surveys
- Measured Building Surveys
- Legal Mapping
- RICS Condition Reports
- Site Suitability For Waste Water Treatment
- As Built Surveys
- GPS Surveys
- Setting Out
- Assigned Certifier Services

Client:
XX

Professional:
Hydrec

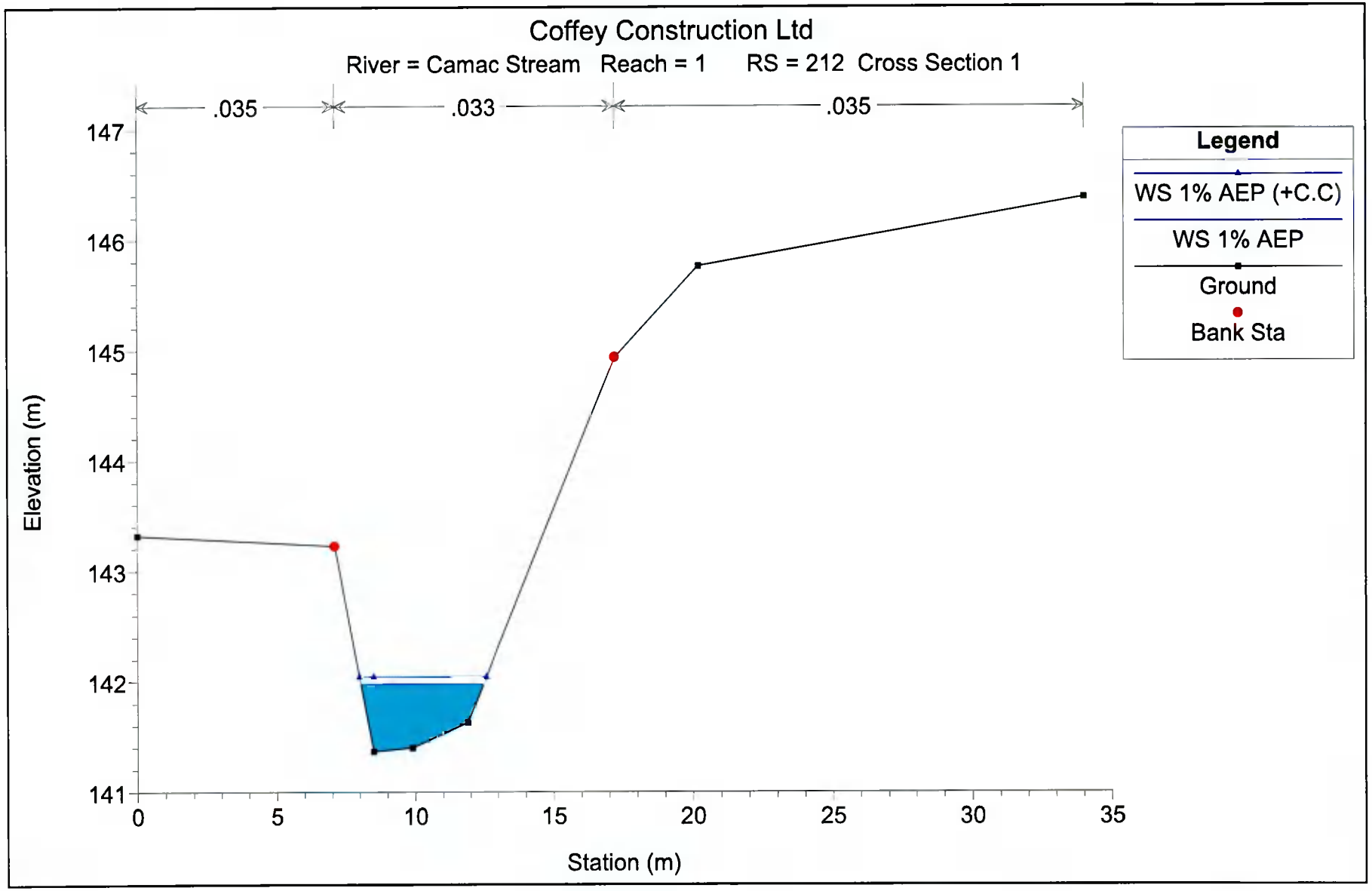
Project Title:
River Survey at Saggart

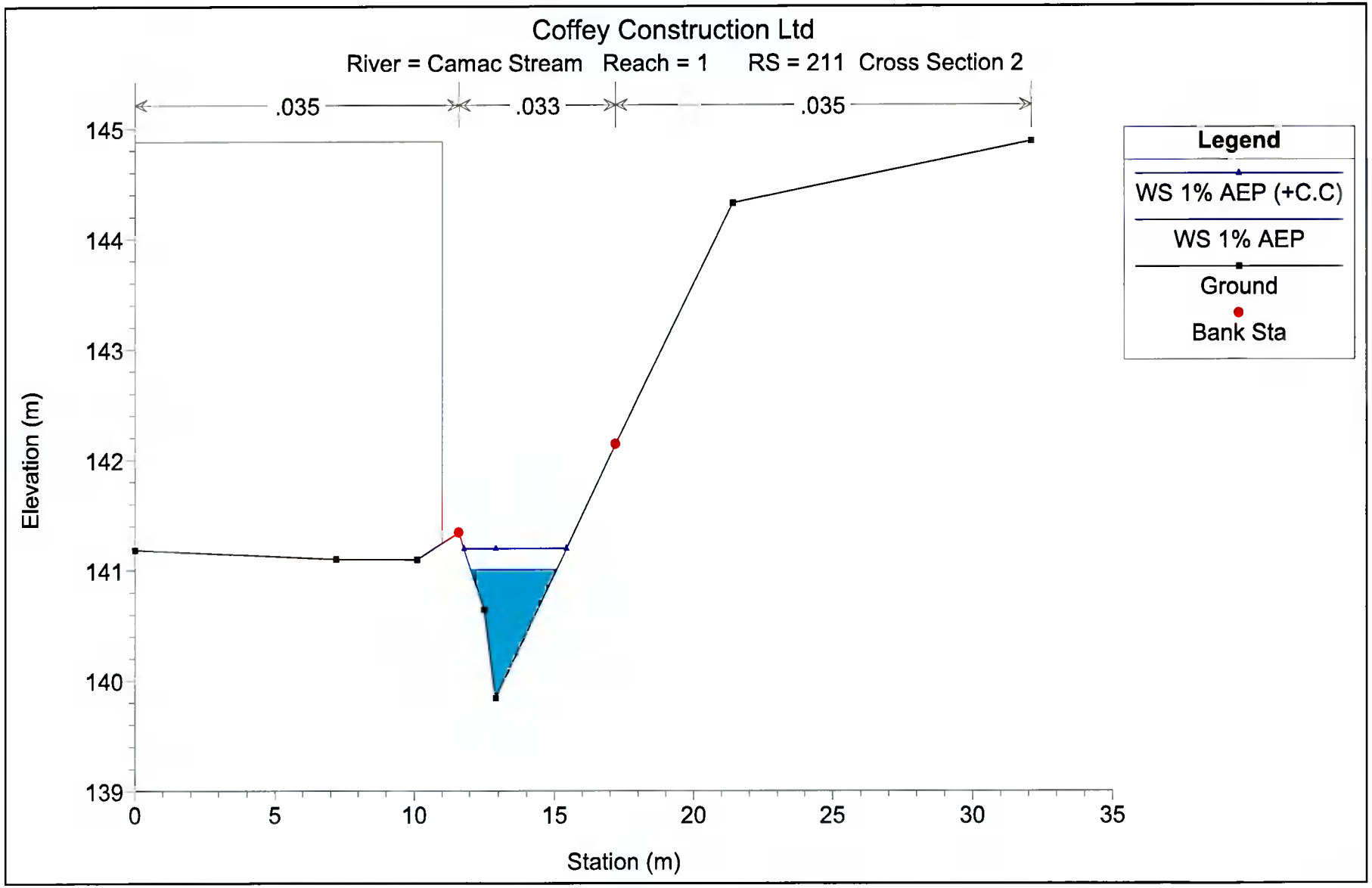
Drawn:	TD	Dwg No:	01/001
Scale:	1/200	Date:	XX

A1

APPENDIX 3

HEC-RAS CROSS SECTION PROFILES


Coffey Construction Ltd
River = Camac Stream Reach = 1 RS = 212 Cross Section 1
.035
.033
.035
147
146
145
144
143
142
141
Elevation (m)
0
5
10
15
20
25
30
35
Station (m)
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta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.033
.035
145
144
143
142
141
140
139
Elevation (m)
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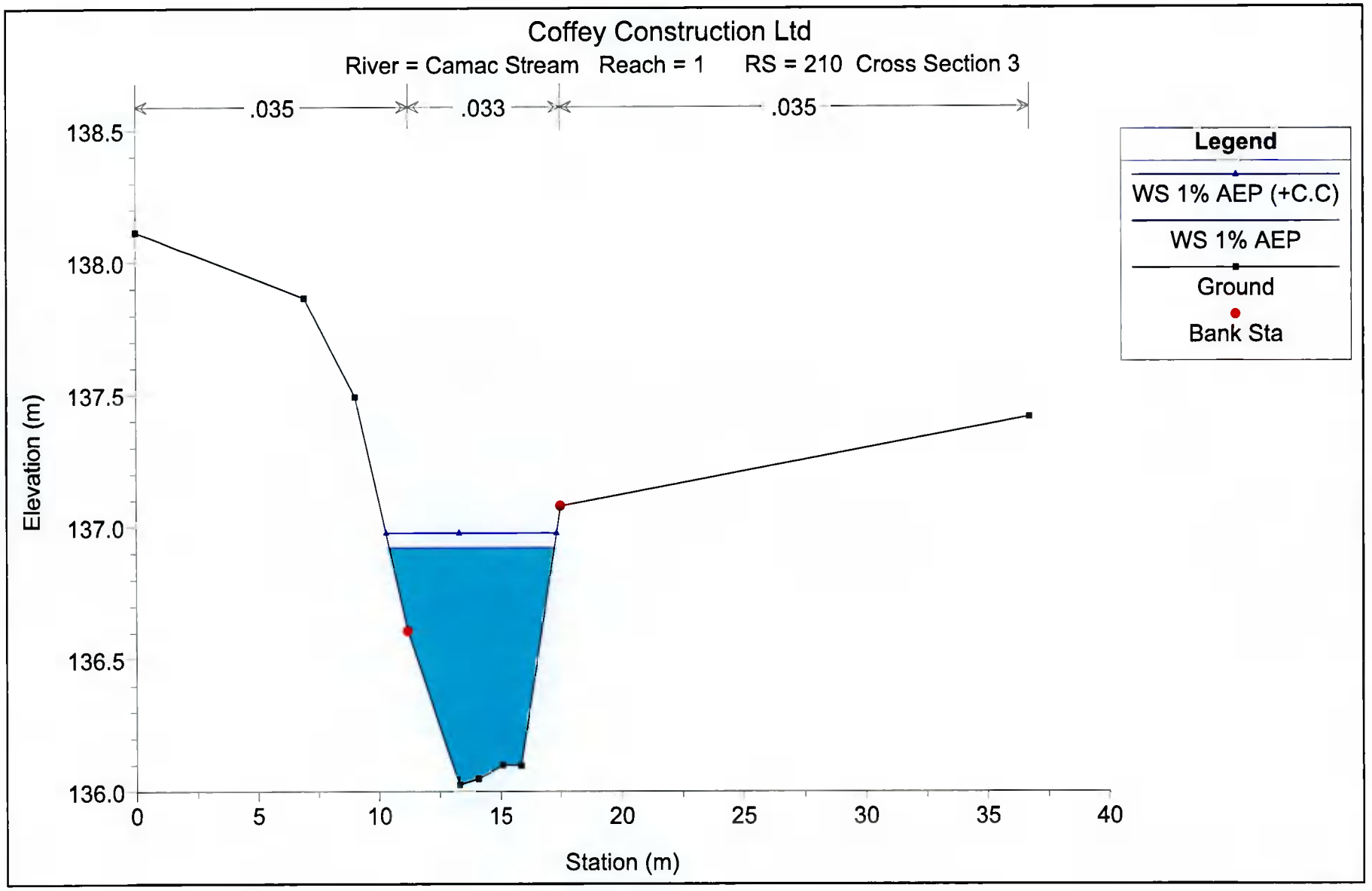
20
25
30
35
Station (m)
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta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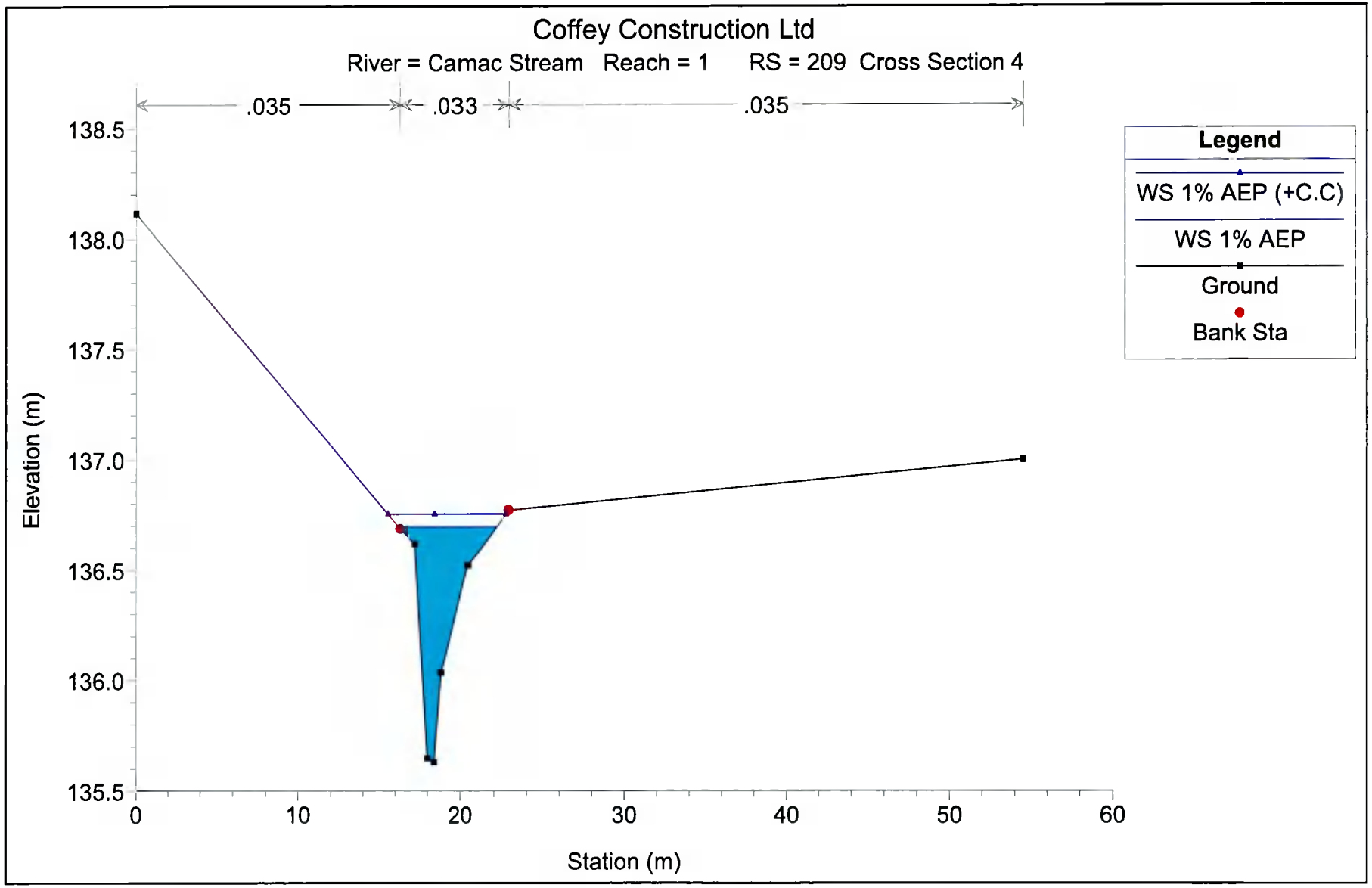
.033
.035
138.5
138.0
137.5
137.0
136.5
136.0
Elevation (m)
0
5
10
15
20
25
30
35
40
Station (m)
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta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.033
.035
138.5
138.0
137.5
137.0
136.5
136.0
135.5
Elevation (m)
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10
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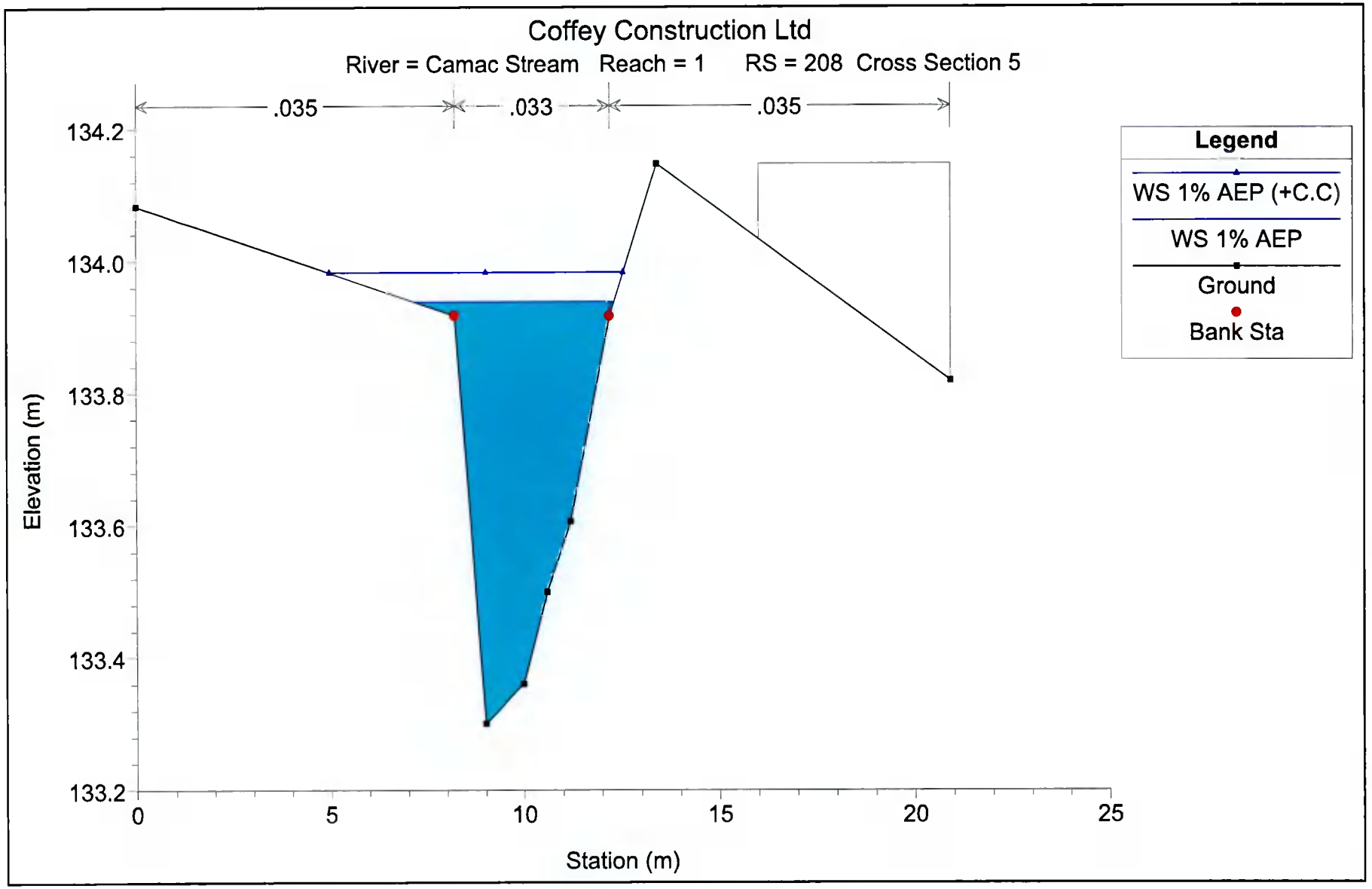
30
40
50
60
Station (m)
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta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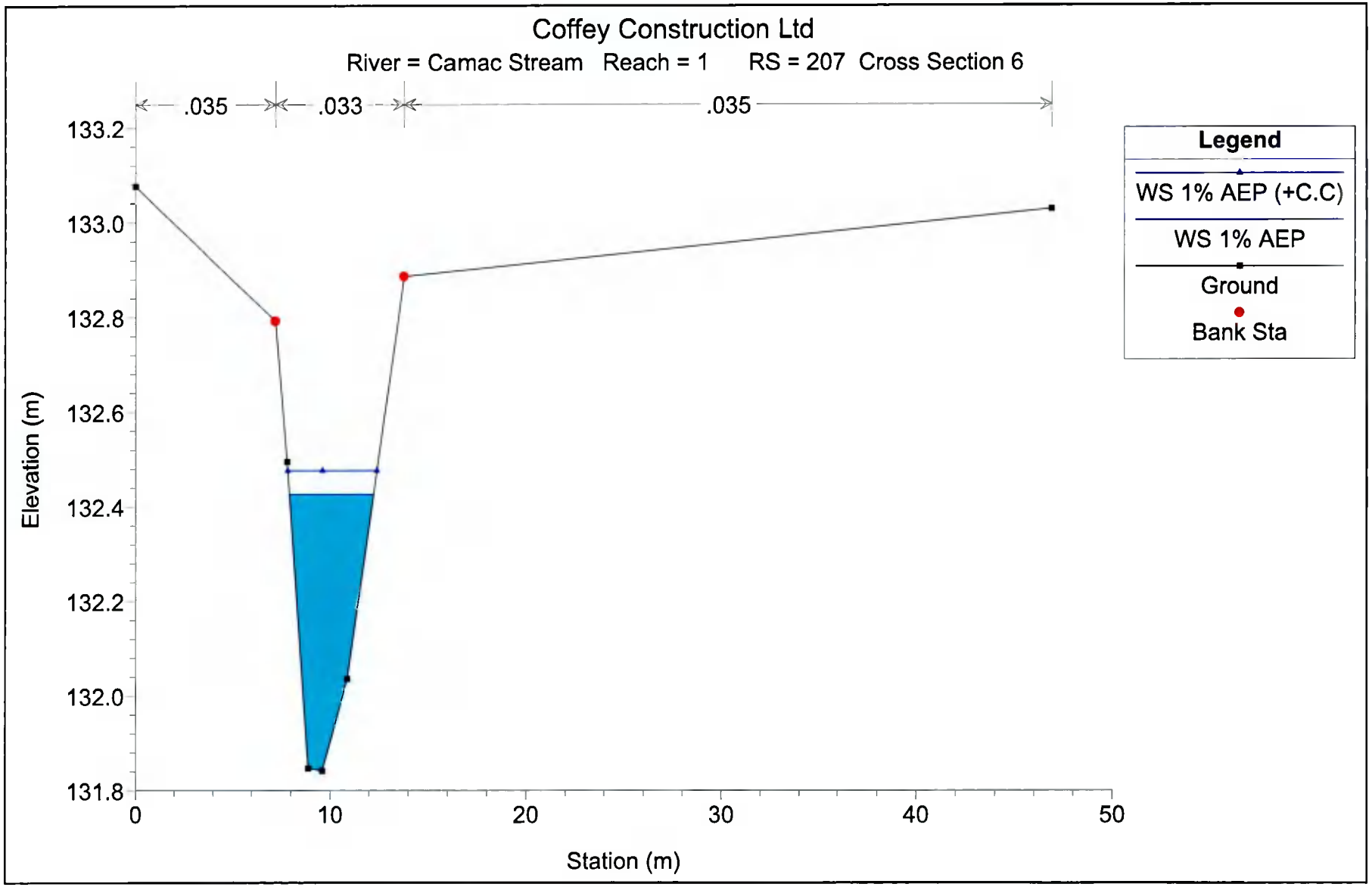
.033
.035
134.2
134.0
133.8
133.6
133.4
133.2
Elevation (m)
0
5
10
15
20
25
Station (m)
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta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River = Camac Stream Reach = 1 RS = 207 Cross Section 6
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.033
.035
133.2
133.0
132.8
132.6
132.4
132.2
132.0
131.8
Elevation (m)
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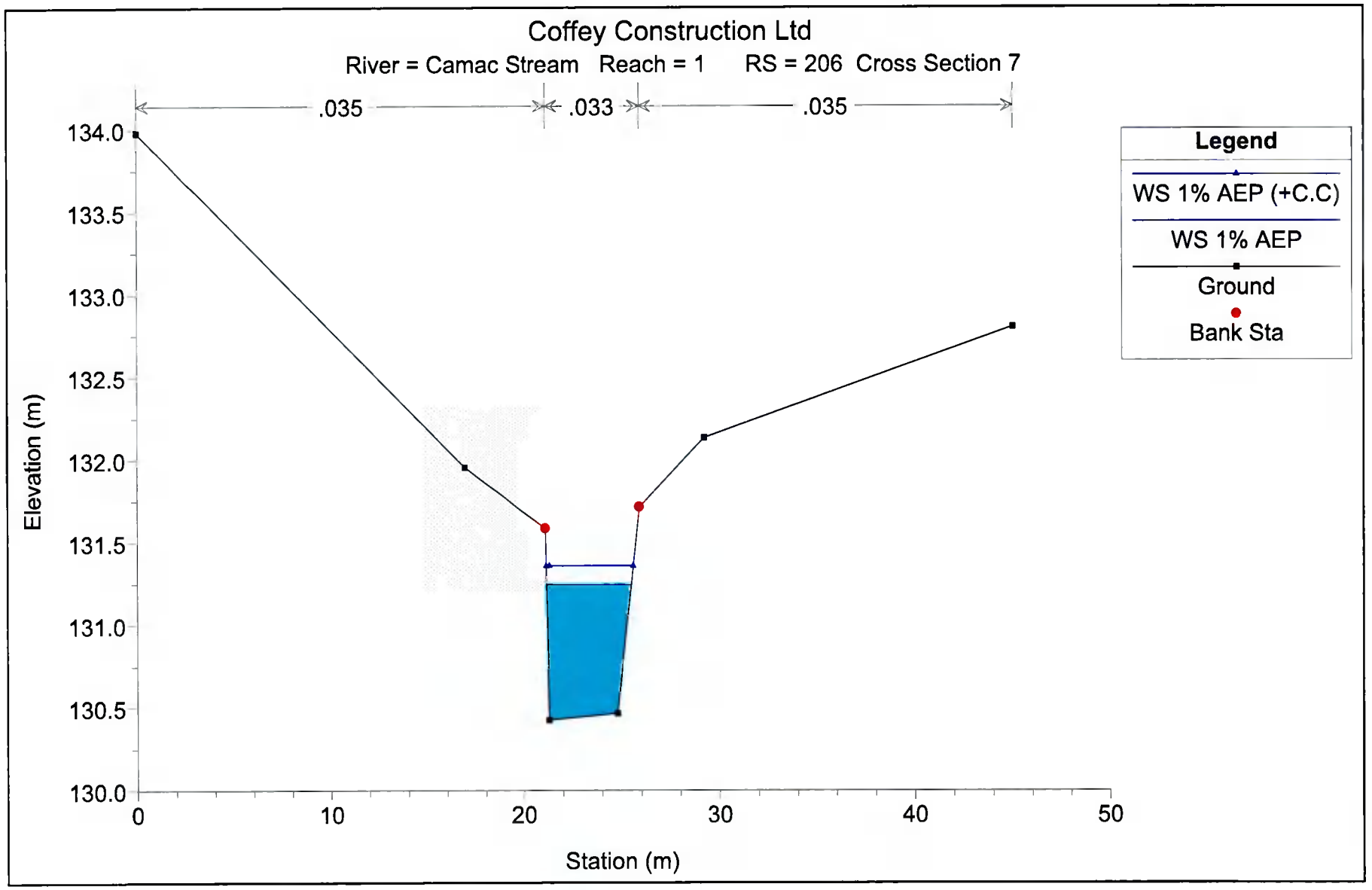
10
20
30
40
50
Station (m)
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta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River = Camac Stream Reach = 1 RS = 206 Cross Section 7
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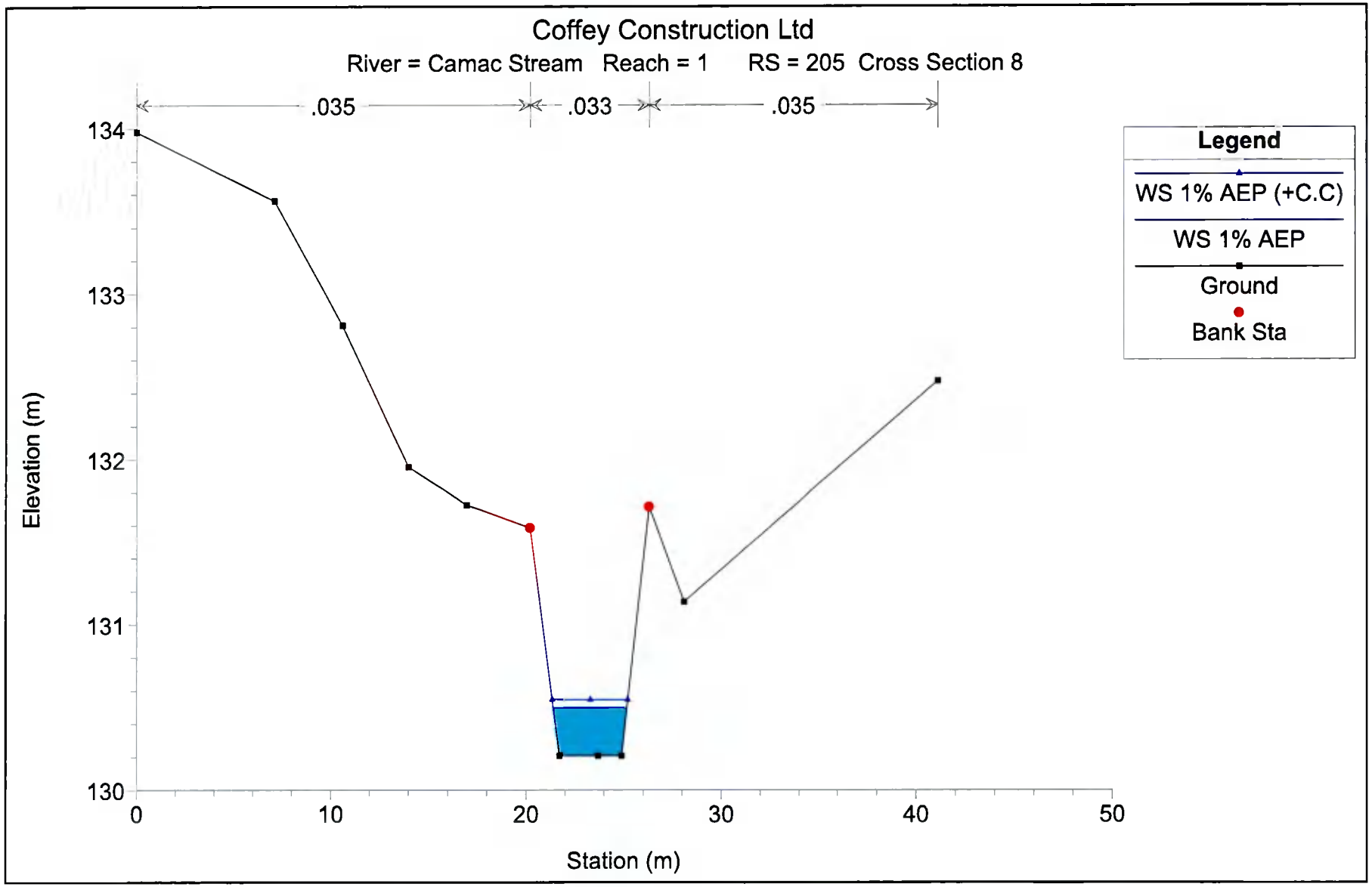
.033
.035
134.0
133.5
133.0
132.5
132.0
131.5
131.0
130.5
130.0
Elevation (m)
0
10
20
30
40
50
Station (m)
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta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River = Camac Stream Reach = 1 RS = 205 Cross Section 8
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.033
.035
134
133
132
131
130
Elevation (m)
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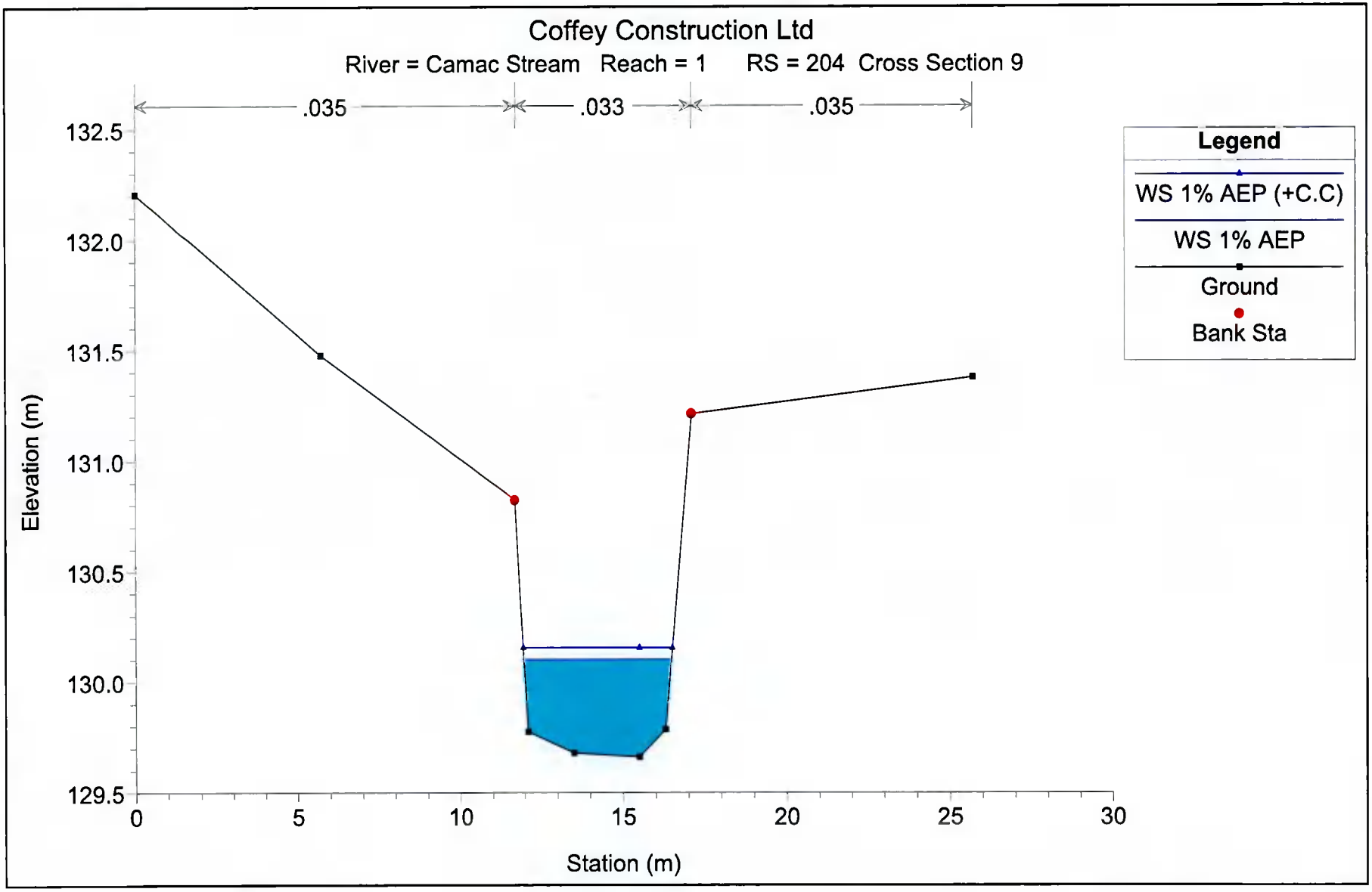
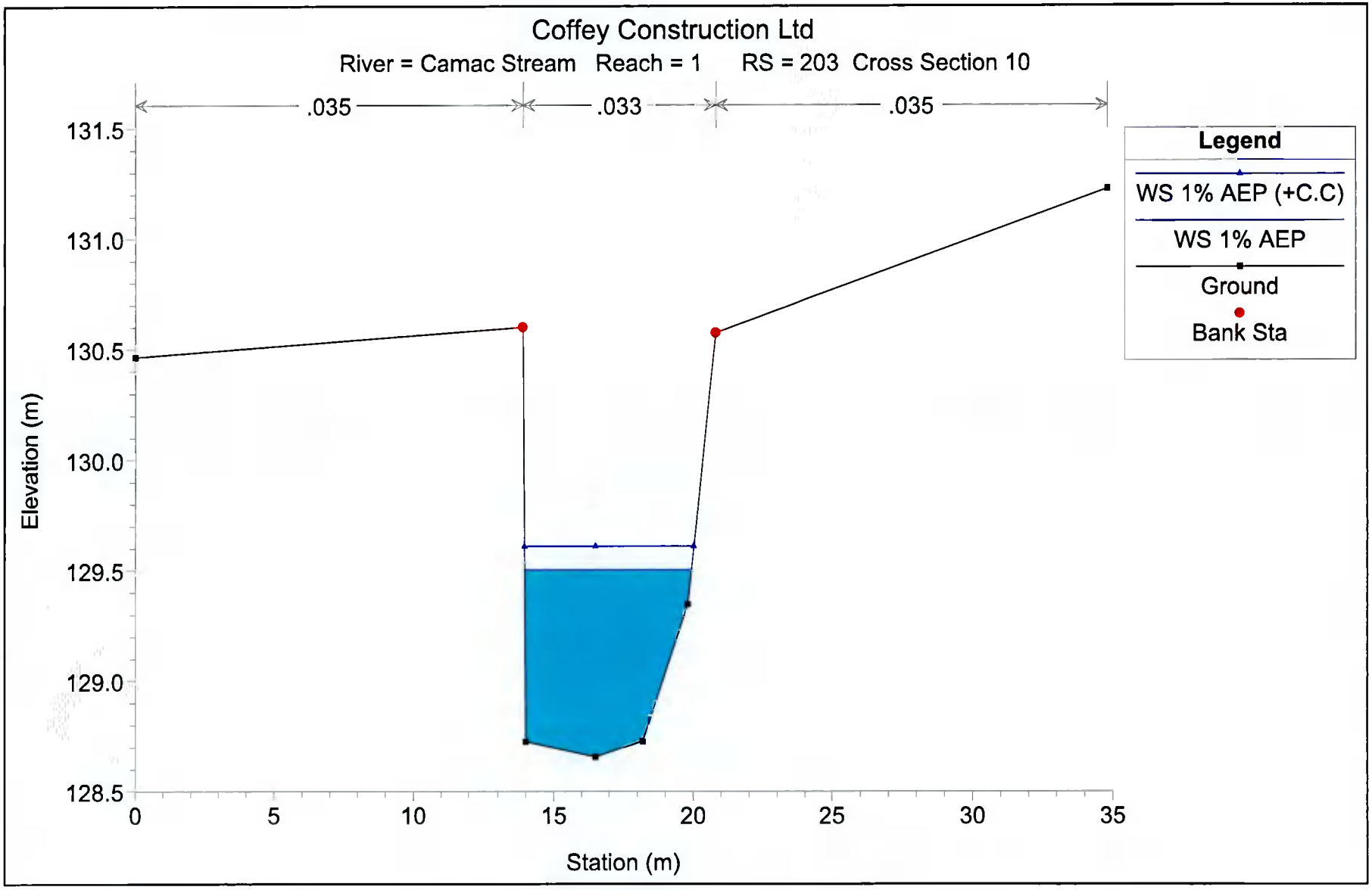
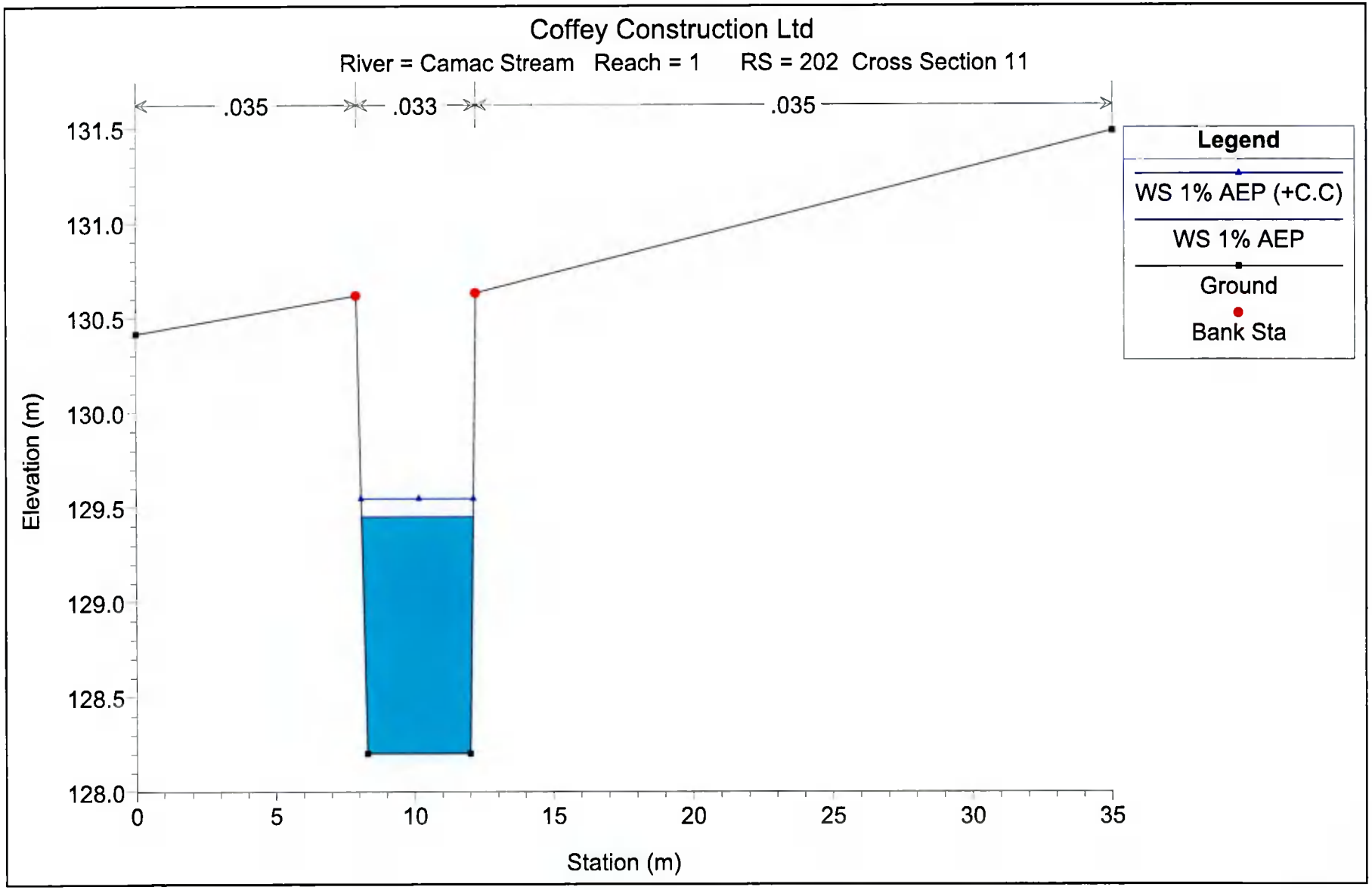
10
20
30
40
50
Station (m)
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta


Coffey Construction Ltd
River = Camac Stream Reach = 1 RS = 204 Cross Section 9
.035
.033
.035
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta
Elevation (m)
132.5
132.0
131.5
131.0
130.5
130.0
129.5
0
5
10
15
20
25
30
Station (m)


Coffey Construction Ltd
River = Camac Stream Reach = 1 RS = 203 Cross Section 10
.035
.033
.035
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta
Elevation (m)
131.5
131.0
130.5
130.0
129.5
129.0
128.5
0
5
10
15
20
25
30
35
Station (m)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River = Camac Stream Reach = 1 RS = 202 Cross Section 11
.035
.033
.035
131.5
131.0
130.5
130.0
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129.0
128.5
128.0
Elevation (m)
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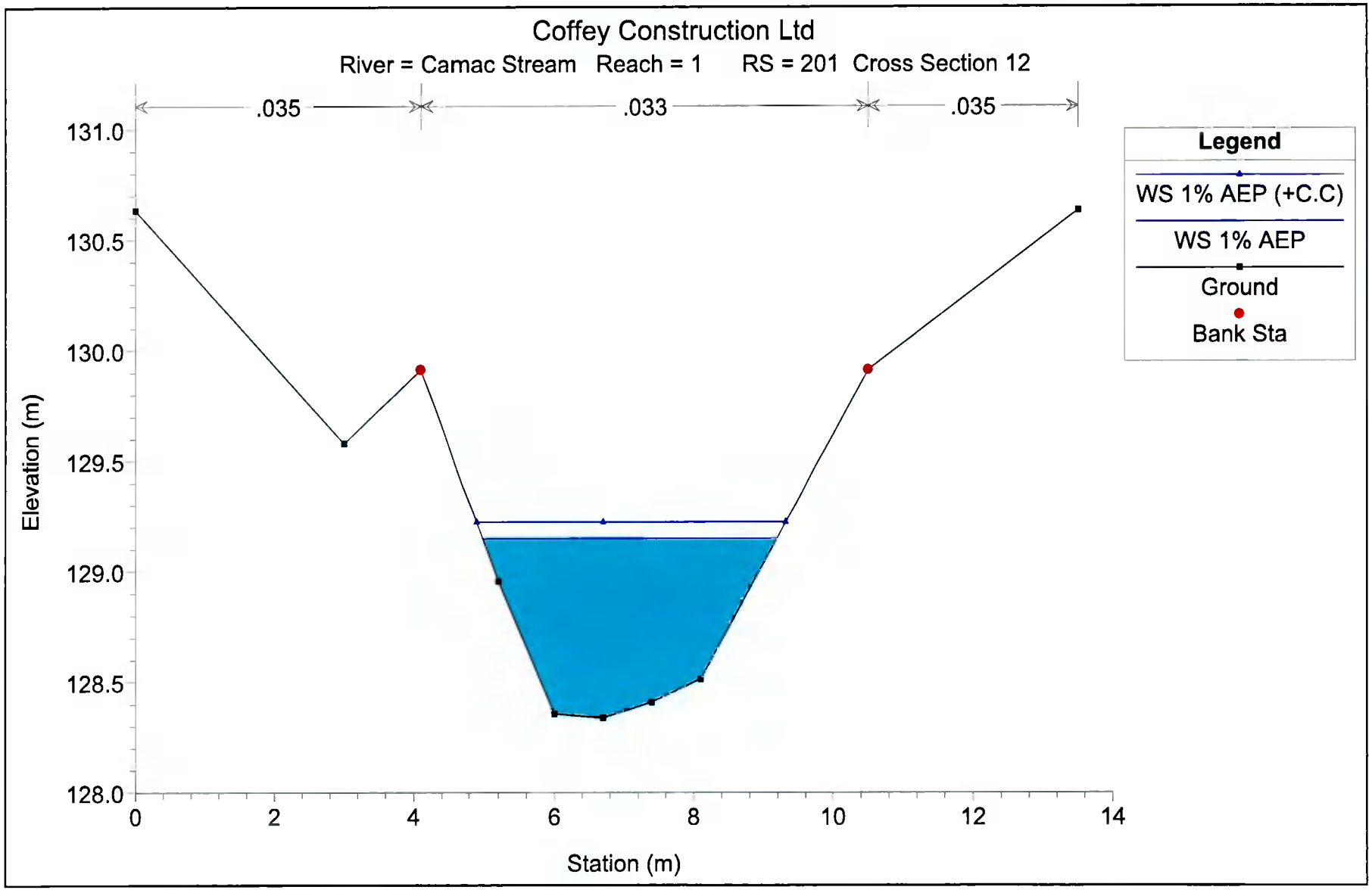
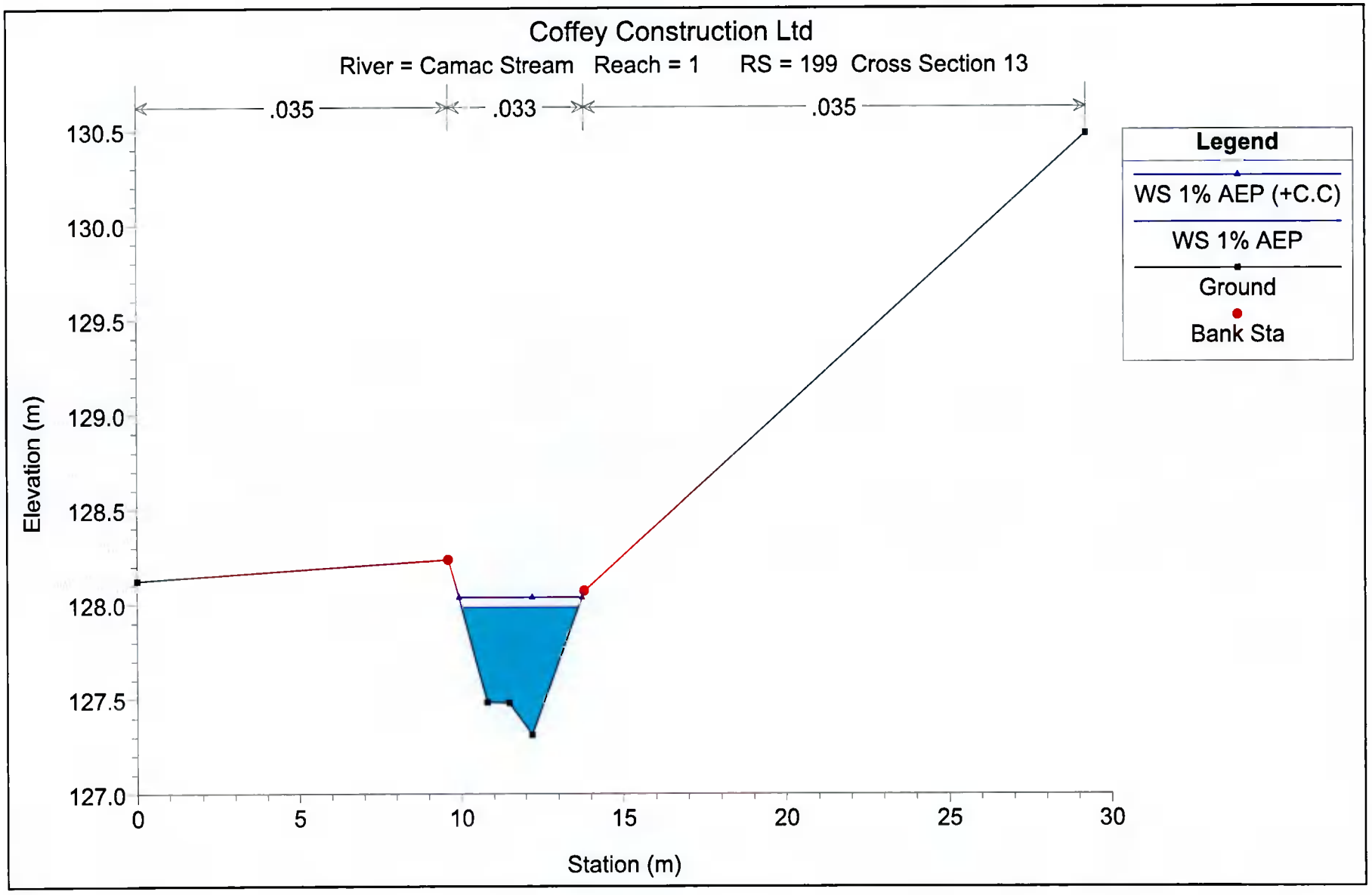
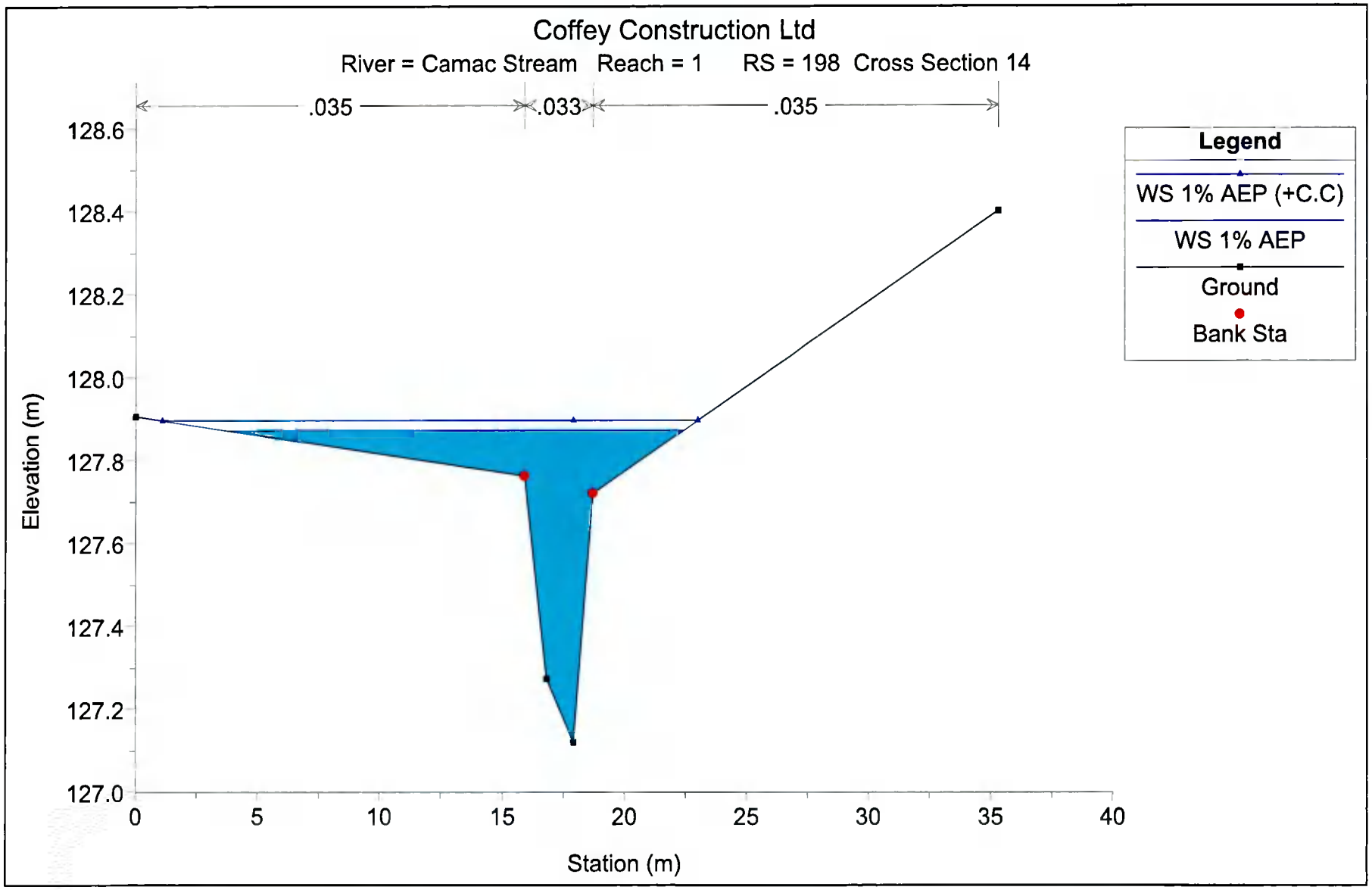
5
10
15
20
25
30
35
Station (m)
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta


Coffey Construction Ltd
River = Camac Stream Reach = 1 RS = 201 Cross Section 12
.035
.033
.035
131.0
130.5
130.0
129.5
129.0
128.5
128.0
Elevation (m)
0
2
4
6
8
10
12
14
Station (m)
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta


Coffey Construction Ltd
River = Camac Stream Reach = 1 RS = 199 Cross Section 13
.035
.033
.035
130.5
130.0
129.5
129.0
128.5
128.0
127.5
127.0
Elevation (m)
0
5
10
15
20
25
30
Station (m)
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta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River = Camac Stream Reach = 1 RS = 198 Cross Section 14
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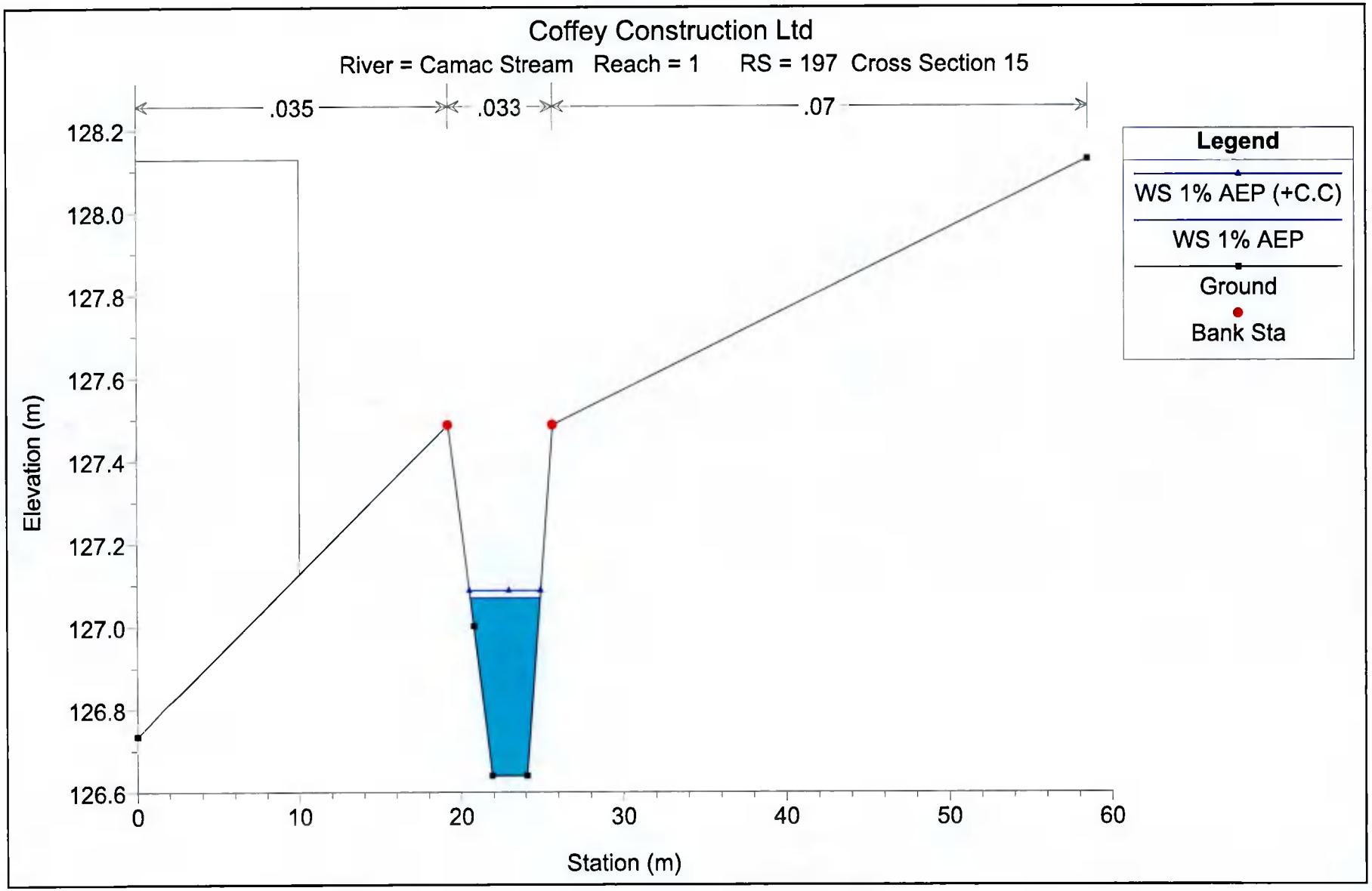
.033
.035
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta
Elevation (m)
128.6
128.4
128.2
128.0
127.8
127.6
127.4
127.2
127.0
0
5
10
15
20
25
30
35
40
Station (m)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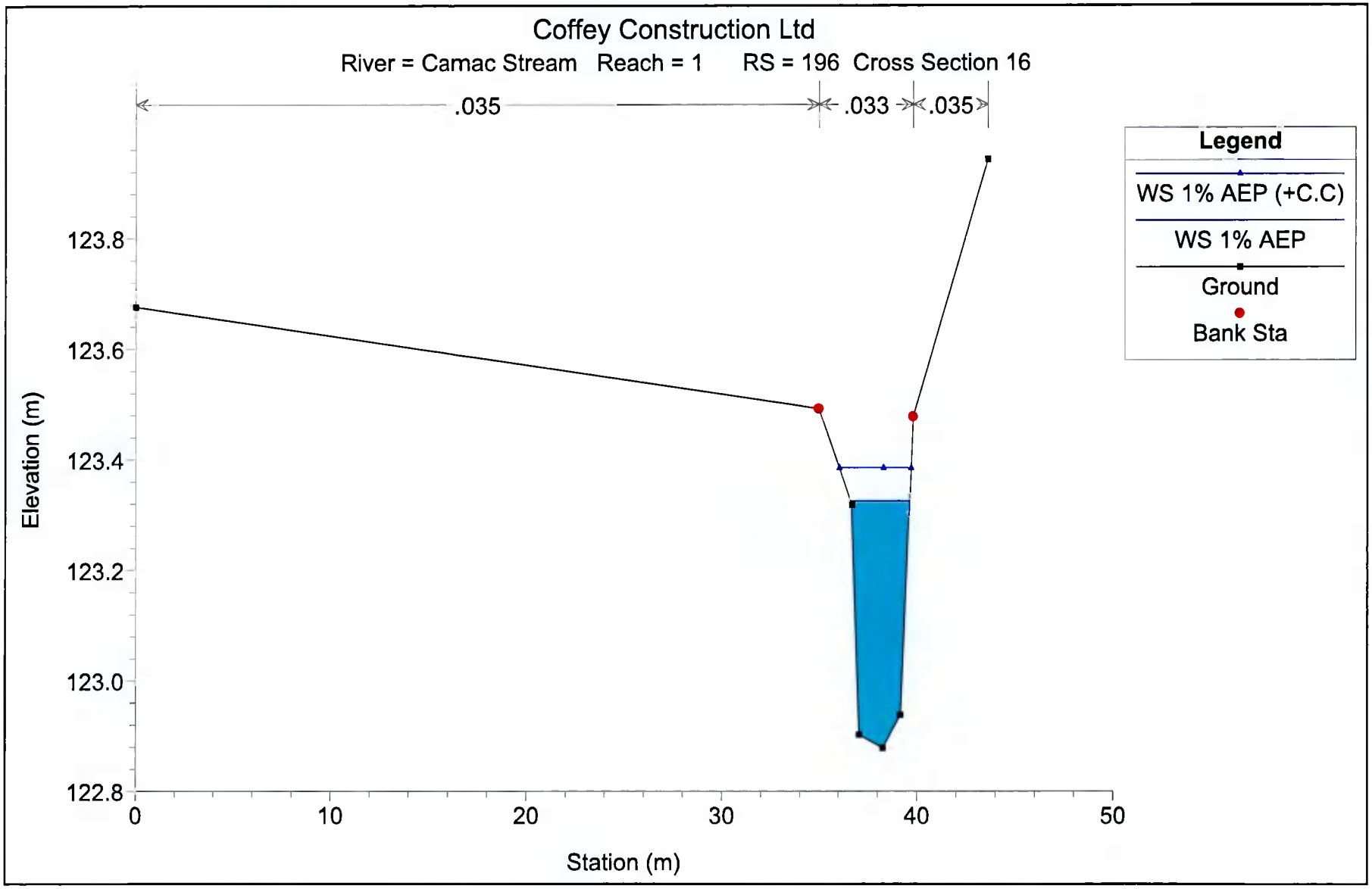
River = Camac Stream Reach = 1 RS = 197 Cross Section 15
.035
.033
.07
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta
Elevation (m)
128.2
128.0
127.8
127.6
127.4
127.2
127.0
126.8
126.6
0
10
20
30
40
50
60
Station (m)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River = Camac Stream Reach = 1 RS = 196 Cross Section 16
.035
.033
.035
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta
123.8
123.6
123.4
123.2
123.0
122.8
Elevation (m)
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10
20
30
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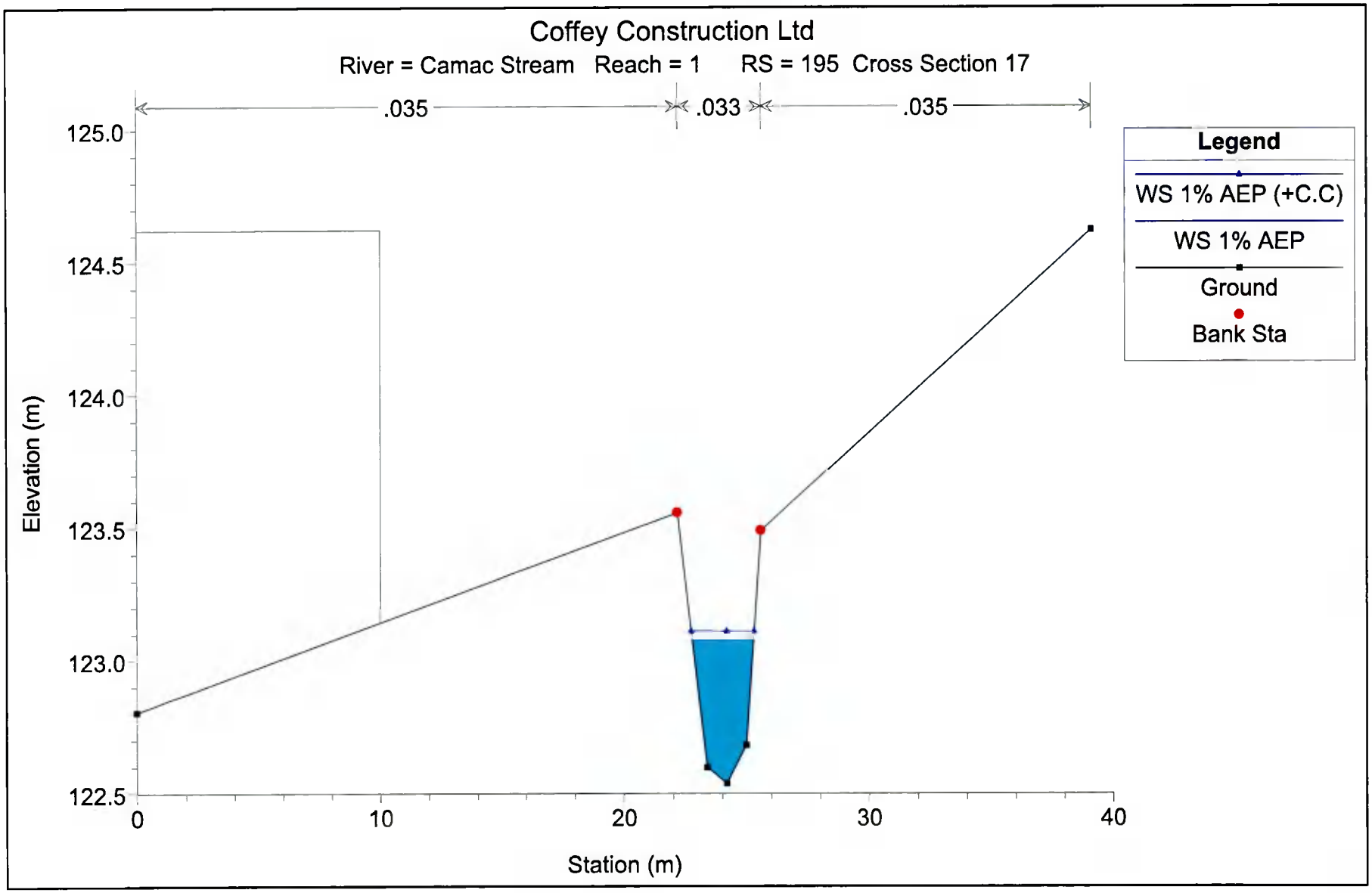
50
Station (m)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River = Camac Stream Reach = 1 RS = 195 Cross Section 17
.035
.033
.035
125.0
124.5
124.0
123.5
123.0
122.5
Elevation (m)
0
10
20
30
40
Station (m)
Legend
WS 1% AEP (+C.C)
WS 1% AEP
Ground
Bank Sta

APPENDIX 4

HEC-RAS HYDRAULIC MODEL OUTPUTS

Plan: Plan 02 Camac Stream 1 RS: 212 Profile: 1% AEP

E.G. Elev (m)	142.18	Element	Left OB	Channel	Right OB
Vel Head (m)	0.20	Wt. n-Val.		0.033	
W.S. Elev (m)	141.98	Reach Len. (m)	2.00	2.00	2.00
Crit W.S. (m)	141.96	Flow Area (m2)		2.01	
E.G. Slope (m/m)	0.013734	Area (m2)		2.01	
Q Total (m3/s)	3.96	Flow (m3/s)		3.96	
Top Width (m)	4.43	Top Width (m)		4.43	
Vel Total (m/s)	1.97	Avg. Vel. (m/s)		1.97	
Max Chl Dpth (m)	0.61	Hydr. Depth (m)		0.45	
Conv. Total (m3/s)	33.8	Conv. (m3/s)		33.8	
Length Wtd. (m)	2.00	Wetted Per. (m)		4.85	
Min Ch El (m)	141.37	Shear (N/m2)		55.78	
Alpha	1.00	Stream Power (N/m s)		110.08	
Frctn Loss (m)	0.03	Cum Volume (1000 m3)	0.08	1.51	0.01
C & E Loss (m)	0.00	Cum SA (1000 m2)	1.13	3.35	0.17

Plan: Plan 02 Camac Stream 1 RS: 212 Profile: 1% AEP (+C.C)

E.G. Elev (m)	142.26	Element	Left OB	Channel	Right OB
Vel Head (m)	0.22	Wt. n-Val.		0.033	
W.S. Elev (m)	142.05	Reach Len. (m)	2.00	2.00	2.00
Crit W.S. (m)	142.02	Flow Area (m2)		2.30	
E.G. Slope (m/m)	0.013329	Area (m2)		2.30	
Q Total (m3/s)	4.75	Flow (m3/s)		4.75	
Top Width (m)	4.58	Top Width (m)		4.58	
Vel Total (m/s)	2.07	Avg. Vel. (m/s)		2.07	
Max Chl Dpth (m)	0.68	Hydr. Depth (m)		0.50	
Conv. Total (m3/s)	41.1	Conv. (m3/s)		41.1	
Length Wtd. (m)	2.00	Wetted Per. (m)		5.05	
Min Ch El (m)	141.37	Shear (N/m2)		59.45	
Alpha	1.00	Stream Power (N/m s)		123.02	
Frctn Loss (m)	0.03	Cum Volume (1000 m3)	0.12	1.71	0.02
C & E Loss (m)	0.00	Cum SA (1000 m2)	1.47	3.49	0.35

Plan: Plan 02 Camac Stream 1 RS: 211 Profile: 1% AEP

E.G. Elev (m)	141.30	Element	Left OB	Channel	Right OB
Vel Head (m)	0.29	Wt. n-Val.		0.033	
W.S. Elev (m)	141.01	Reach Len. (m)	1.70	1.70	1.70
Crit W.S. (m)	141.01	Flow Area (m2)		1.67	
E.G. Slope (m/m)	0.019500	Area (m2)		1.67	
Q Total (m3/s)	3.96	Flow (m3/s)		3.96	
Top Width (m)	3.05	Top Width (m)		3.05	
Vel Total (m/s)	2.37	Avg. Vel. (m/s)		2.37	
Max Chl Dpth (m)	1.17	Hydr. Depth (m)		0.55	
Conv. Total (m3/s)	28.4	Conv. (m3/s)		28.4	
Length Wtd. (m)	1.70	Wetted Per. (m)		3.97	
Min Ch El (m)	139.84	Shear (N/m2)		80.36	
Alpha	1.00	Stream Power (N/m s)		190.80	
Frctn Loss (m)	0.04	Cum Volume (1000 m3)	0.08	1.39	0.01
C & E Loss (m)	0.01	Cum SA (1000 m2)	1.13	3.11	0.17

Plan: Plan 02 Camac Stream 1 RS: 211 Profile: 1% AEP (+C.C)

E.G. Elev (m)	141.37	Element	Left OB	Channel	Right OB
Vel Head (m)	0.18	Wt. n-Val.	0.035	0.033	
W.S. Elev (m)	141.20	Reach Len. (m)	1.70	1.70	1.70
Crit W.S. (m)	141.23	Flow Area (m2)	0.70	2.29	
E.G. Slope (m/m)	0.010444	Area (m2)	0.70	2.29	
Q Total (m3/s)	4.75	Flow (m3/s)	0.33	4.42	

Plan: Plan 02 Camac Stream 1 RS: 211 Profile: 1% AEP (+C.C) (Continued)

Top Width (m)	14.35	Top Width (m)	10.71	3.64	
Vel Total (m/s)	1.59	Avg. Vel. (m/s)	0.47	1.93	
Max Chl Dpth (m)	1.35	Hydr. Depth (m)	0.07	0.63	
Conv. Total (m3/s)	46.5	Conv. (m3/s)	3.2	43.2	
Length Wtd. (m)	1.70	Wetted Per. (m)	10.73	4.67	
Min Ch El (m)	139.84	Shear (N/m2)	6.67	50.30	
Alpha	1.38	Stream Power (N/m s)	3.15	96.96	
Frctn Loss (m)	0.02	Cum Volume (1000 m3)	0.12	1.56	0.02
C & E Loss (m)	0.01	Cum SA (1000 m2)	1.44	3.24	0.35

Plan: Plan 02 Camac Stream 1 RS: 210 Profile: 1% AEP

E.G. Elev (m)	136.97	Element	Left OB	Channel	Right OB
Vel Head (m)	0.05	Wt. n-Val.	0.035	0.033	
W.S. Elev (m)	136.92	Reach Len. (m)	1.82	1.82	1.82
Crit W.S. (m)		Flow Area (m2)	0.12	4.04	
E.G. Slope (m/m)	0.001875	Area (m2)	0.12	4.04	
Q Total (m3/s)	3.96	Flow (m3/s)	0.04	3.92	
Top Width (m)	6.82	Top Width (m)	0.78	6.04	
Vel Total (m/s)	0.95	Avg. Vel. (m/s)	0.34	0.97	
Max Chl Dpth (m)	0.90	Hydr. Depth (m)	0.16	0.67	
Conv. Total (m3/s)	91.4	Conv. (m3/s)	1.0	90.5	
Length Wtd. (m)	1.82	Wetted Per. (m)	0.84	6.36	
Min Ch El (m)	136.02	Shear (N/m2)	2.69	11.69	
Alpha	1.03	Stream Power (N/m s)	0.92	11.33	
Frctn Loss (m)	0.00	Cum Volume (1000 m3)	0.08	1.13	0.01
C & E Loss (m)	0.00	Cum SA (1000 m2)	1.13	2.48	0.17

Plan: Plan 02 Camac Stream 1 RS: 210 Profile: 1% AEP (+C.C)

E.G. Elev (m)	137.03	Element	Left OB	Channel	Right OB
Vel Head (m)	0.06	Wt. n-Val.	0.035	0.033	
W.S. Elev (m)	136.98	Reach Len. (m)	1.82	1.82	1.82
Crit W.S. (m)		Flow Area (m2)	0.17	4.38	
E.G. Slope (m/m)	0.002091	Area (m2)	0.17	4.38	
Q Total (m3/s)	4.75	Flow (m3/s)	0.07	4.68	
Top Width (m)	7.05	Top Width (m)	0.92	6.13	
Vel Total (m/s)	1.04	Avg. Vel. (m/s)	0.40	1.07	
Max Chl Dpth (m)	0.95	Hydr. Depth (m)	0.19	0.71	
Conv. Total (m3/s)	103.9	Conv. (m3/s)	1.5	102.4	
Length Wtd. (m)	1.82	Wetted Per. (m)	0.99	6.46	
Min Ch El (m)	136.02	Shear (N/m2)	3.53	13.90	
Alpha	1.04	Stream Power (N/m s)	1.43	14.85	
Frctn Loss (m)	0.00	Cum Volume (1000 m3)	0.12	1.26	0.02
C & E Loss (m)	0.00	Cum SA (1000 m2)	1.40	2.57	0.35

Plan: Plan 02 Camac Stream 1 RS: 209 Profile: 1% AEP

E.G. Elev (m)	136.87	Element	Left OB	Channel	Right OB
Vel Head (m)	0.18	Wt. n-Val.	0.035	0.033	
W.S. Elev (m)	136.70	Reach Len. (m)	1.68	1.68	1.68
Crit W.S. (m)	136.70	Flow Area (m2)	0.00	2.11	
E.G. Slope (m/m)	0.017503	Area (m2)	0.00	2.11	
Q Total (m3/s)	3.96	Flow (m3/s)	0.00	3.96	
Top Width (m)	5.98	Top Width (m)	0.11	5.88	
Vel Total (m/s)	1.88	Avg. Vel. (m/s)	0.10	1.88	
Max Chl Dpth (m)	1.07	Hydr. Depth (m)	0.00	0.36	
Conv. Total (m3/s)	29.9	Conv. (m3/s)	0.0	29.9	
Length Wtd. (m)	1.68	Wetted Per. (m)	0.11	6.59	
Min Ch El (m)	135.63	Shear (N/m2)	0.79	54.99	

Plan: Plan 02 Camac Stream 1 RS: 209 Profile: 1% AEP (Continued)

Alpha	1.00	Stream Power (N/m s)	0.08	103.21	
Frctn Loss (m)	0.03	Cum Volume (1000 m3)	0.08	1.06	0.01
C & E Loss (m)	0.00	Cum SA (1000 m2)	1.11	2.36	0.16

Plan: Plan 02 Camac Stream 1 RS: 209 Profile: 1% AEP (+C.C)

E.G. Elev (m)	136.94	Element	Left OB	Channel	Right OB
Vel Head (m)	0.19	Wt. n-Val.	0.035	0.033	
W.S. Elev (m)	136.75	Reach Len. (m)	1.68	1.68	1.68
Crit W.S. (m)	136.75	Flow Area (m2)	0.03	2.46	
E.G. Slope (m/m)	0.016728	Area (m2)	0.03	2.46	
Q Total (m3/s)	4.75	Flow (m3/s)	0.01	4.74	
Top Width (m)	7.19	Top Width (m)	0.76	6.43	
Vel Total (m/s)	1.91	Avg. Vel. (m/s)	0.38	1.93	
Max Chl Dpth (m)	1.12	Hydr. Depth (m)	0.03	0.38	
Conv. Total (m3/s)	36.7	Conv. (m3/s)	0.1	36.7	
Length Wtd. (m)	1.68	Wetted Per. (m)	0.76	7.14	
Min Ch El (m)	135.63	Shear (N/m2)	5.41	56.53	
Alpha	1.01	Stream Power (N/m s)	2.06	108.90	
Frctn Loss (m)	0.03	Cum Volume (1000 m3)	0.11	1.19	0.02
C & E Loss (m)	0.00	Cum SA (1000 m2)	1.37	2.45	0.30

Plan: Plan 02 Camac Stream 1 RS: 208 Profile: 1% AEP

E.G. Elev (m)	134.23	Element	Left OB	Channel	Right OB
Vel Head (m)	0.29	Wt. n-Val.	0.035	0.033	0.035
W.S. Elev (m)	133.94	Reach Len. (m)	1.96	1.96	1.96
Crit W.S. (m)	134.06	Flow Area (m2)	0.01	1.59	0.16
E.G. Slope (m/m)	0.024180	Area (m2)	0.01	1.59	0.16
Q Total (m3/s)	3.96	Flow (m3/s)	0.00	3.85	0.11
Top Width (m)	7.90	Top Width (m)	1.06	4.00	2.84
Vel Total (m/s)	2.25	Avg. Vel. (m/s)	0.22	2.43	0.66
Max Chl Dpth (m)	0.64	Hydr. Depth (m)	0.01	0.40	0.06
Conv. Total (m3/s)	25.5	Conv. (m3/s)	0.0	24.8	0.7
Length Wtd. (m)	1.96	Wetted Per. (m)	1.06	4.28	2.96
Min Ch El (m)	133.30	Shear (N/m2)	2.54	87.74	13.11
Alpha	1.14	Stream Power (N/m s)	0.55	213.08	8.60
Frctn Loss (m)	0.05	Cum Volume (1000 m3)	0.08	0.84	0.00
C & E Loss (m)	0.00	Cum SA (1000 m2)	1.06	1.78	0.08

Plan: Plan 02 Camac Stream 1 RS: 208 Profile: 1% AEP (+C.C)

E.G. Elev (m)	134.29	Element	Left OB	Channel	Right OB
Vel Head (m)	0.31	Wt. n-Val.	0.035	0.033	0.035
W.S. Elev (m)	133.98	Reach Len. (m)	1.96	1.96	1.96
Crit W.S. (m)	134.10	Flow Area (m2)	0.11	1.76	0.32
E.G. Slope (m/m)	0.022785	Area (m2)	0.11	1.76	0.32
Q Total (m3/s)	4.75	Flow (m3/s)	0.05	4.46	0.25
Top Width (m)	11.32	Top Width (m)	3.24	4.00	4.08
Vel Total (m/s)	2.17	Avg. Vel. (m/s)	0.44	2.53	0.78
Max Chl Dpth (m)	0.68	Hydr. Depth (m)	0.03	0.44	0.08
Conv. Total (m3/s)	31.5	Conv. (m3/s)	0.3	29.5	1.6
Length Wtd. (m)	1.96	Wetted Per. (m)	3.24	4.28	4.25
Min Ch El (m)	133.30	Shear (N/m2)	7.33	91.89	16.64
Alpha	1.28	Stream Power (N/m s)	3.24	232.44	12.92
Frctn Loss (m)	0.04	Cum Volume (1000 m3)	0.11	0.95	0.01
C & E Loss (m)	0.00	Cum SA (1000 m2)	1.24	1.85	0.12

Plan: Plan 02 Camac Stream 1 RS: 207 Profile: 1% AEP

E.G. Elev (m)	132.74	Element	Left OB	Channel	Right OB
Vel Head (m)	0.32	Wt. n-Val.		0.033	
W.S. Elev (m)	132.43	Reach Len. (m)	1.97	1.97	1.97
Crit W.S. (m)	132.51	Flow Area (m2)		1.59	
E.G. Slope (m/m)	0.027648	Area (m2)		1.59	
Q Total (m3/s)	3.96	Flow (m3/s)		3.96	
Top Width (m)	4.31	Top Width (m)		4.31	
Vel Total (m/s)	2.50	Avg. Vel. (m/s)		2.50	
Max Chl Dpth (m)	0.58	Hydr. Depth (m)		0.37	
Conv. Total (m3/s)	23.8	Conv. (m3/s)		23.8	
Length Wtd. (m)	1.97	Wetted Per. (m)		4.54	
Min Ch El (m)	131.84	Shear (N/m2)		94.62	
Alpha	1.00	Stream Power (N/m s)		236.33	
Frctn Loss (m)	0.04	Cum Volume (1000 m3)	0.08	0.76	0.00
C & E Loss (m)	0.05	Cum SA (1000 m2)	1.06	1.56	0.06

Plan: Plan 02 Camac Stream 1 RS: 207 Profile: 1% AEP (+C.C)

E.G. Elev (m)	132.83	Element	Left OB	Channel	Right OB
Vel Head (m)	0.35	Wt. n-Val.		0.033	
W.S. Elev (m)	132.48	Reach Len. (m)	1.97	1.97	1.97
Crit W.S. (m)	132.57	Flow Area (m2)		1.81	
E.G. Slope (m/m)	0.027727	Area (m2)		1.81	
Q Total (m3/s)	4.75	Flow (m3/s)		4.75	
Top Width (m)	4.57	Top Width (m)		4.57	
Vel Total (m/s)	2.63	Avg. Vel. (m/s)		2.63	
Max Chl Dpth (m)	0.63	Hydr. Depth (m)		0.40	
Conv. Total (m3/s)	28.5	Conv. (m3/s)		28.5	
Length Wtd. (m)	1.97	Wetted Per. (m)		4.82	
Min Ch El (m)	131.84	Shear (N/m2)		102.04	
Alpha	1.00	Stream Power (N/m s)		267.87	
Frctn Loss (m)	0.04	Cum Volume (1000 m3)	0.11	0.85	0.01
C & E Loss (m)	0.06	Cum SA (1000 m2)	1.22	1.61	0.08

Plan: Plan 02 Camac Stream 1 RS: 206 Profile: 1% AEP

E.G. Elev (m)	131.33	Element	Left OB	Channel	Right OB
Vel Head (m)	0.08	Wt. n-Val.		0.033	
W.S. Elev (m)	131.25	Reach Len. (m)	13.00	13.00	13.00
Crit W.S. (m)	130.94	Flow Area (m2)		3.13	
E.G. Slope (m/m)	0.003573	Area (m2)		3.13	
Q Total (m3/s)	3.96	Flow (m3/s)		3.96	
Top Width (m)	4.33	Top Width (m)		4.33	
Vel Total (m/s)	1.26	Avg. Vel. (m/s)		1.26	
Max Chl Dpth (m)	0.82	Hydr. Depth (m)		0.72	
Conv. Total (m3/s)	66.3	Conv. (m3/s)		66.3	
Length Wtd. (m)	13.00	Wetted Per. (m)		5.38	
Min Ch El (m)	130.42	Shear (N/m2)		20.42	
Alpha	1.00	Stream Power (N/m s)		25.81	
Frctn Loss (m)		Cum Volume (1000 m3)	0.08	0.65	0.00
C & E Loss (m)		Cum SA (1000 m2)	1.06	1.30	0.06

Plan: Plan 02 Camac Stream 1 RS: 206 Profile: 1% AEP (+C.C)

E.G. Elev (m)	131.45	Element	Left OB	Channel	Right OB
Vel Head (m)	0.09	Wt. n-Val.		0.033	
W.S. Elev (m)	131.36	Reach Len. (m)	13.00	13.00	13.00
Crit W.S. (m)	131.00	Flow Area (m2)		3.63	
E.G. Slope (m/m)	0.003353	Area (m2)		3.63	
Q Total (m3/s)	4.75	Flow (m3/s)		4.75	

Plan: Plan 02 Camac Stream 1 RS: 206 Profile: 1% AEP (+C.C) (Continued)

Top Width (m)	4.45	Top Width (m)		4.45	
Vel Total (m/s)	1.31	Avg. Vel. (m/s)		1.31	
Max Chl Dpth (m)	0.94	Hydr. Depth (m)		0.82	
Conv. Total (m3/s)	82.0	Conv. (m3/s)		82.0	
Length Wtd. (m)	13.00	Wetted Per. (m)		5.64	
Min Ch El (m)	130.42	Shear (N/m2)		21.16	
Alpha	1.00	Stream Power (N/m s)		27.68	
Frctn Loss (m)		Cum Volume (1000 m3)	0.11	0.73	0.01
C & E Loss (m)		Cum SA (1000 m2)	1.22	1.35	0.08

Plan: Plan 02 Camac Stream 1 RS: 205 Profile: 1% AEP

E.G. Elev (m)	131.28	Element	Left OB	Channel	Right OB
Vel Head (m)	0.78	Wt. n-Val.		0.033	
W.S. Elev (m)	130.50	Reach Len. (m)	1.94	1.94	1.94
Crit W.S. (m)	130.72	Flow Area (m2)		1.01	
E.G. Slope (m/m)	0.105747	Area (m2)		1.01	
Q Total (m3/s)	3.96	Flow (m3/s)		3.96	
Top Width (m)	3.78	Top Width (m)		3.78	
Vel Total (m/s)	3.92	Avg. Vel. (m/s)		3.92	
Max Chl Dpth (m)	0.29	Hydr. Depth (m)		0.27	
Conv. Total (m3/s)	12.2	Conv. (m3/s)		12.2	
Length Wtd. (m)	1.94	Wetted Per. (m)		4.02	
Min Ch El (m)	130.21	Shear (N/m2)		260.31	
Alpha	1.00	Stream Power (N/m s)		1020.74	
Frctn Loss (m)	0.11	Cum Volume (1000 m3)	0.08	0.62	0.00
C & E Loss (m)	0.20	Cum SA (1000 m2)	1.06	1.25	0.06

Plan: Plan 02 Camac Stream 1 RS: 205 Profile: 1% AEP (+C.C)

E.G. Elev (m)	131.35	Element	Left OB	Channel	Right OB
Vel Head (m)	0.80	Wt. n-Val.		0.033	
W.S. Elev (m)	130.55	Reach Len. (m)	1.94	1.94	1.94
Crit W.S. (m)	130.78	Flow Area (m2)		1.20	
E.G. Slope (m/m)	0.089347	Area (m2)		1.20	
Q Total (m3/s)	4.75	Flow (m3/s)		4.75	
Top Width (m)	3.89	Top Width (m)		3.89	
Vel Total (m/s)	3.95	Avg. Vel. (m/s)		3.95	
Max Chl Dpth (m)	0.34	Hydr. Depth (m)		0.31	
Conv. Total (m3/s)	15.9	Conv. (m3/s)		15.9	
Length Wtd. (m)	1.94	Wetted Per. (m)		4.17	
Min Ch El (m)	130.21	Shear (N/m2)		252.71	
Alpha	1.00	Stream Power (N/m s)		999.21	
Frctn Loss (m)	0.09	Cum Volume (1000 m3)	0.11	0.69	0.01
C & E Loss (m)	0.20	Cum SA (1000 m2)	1.22	1.29	0.08

Plan: Plan 02 Camac Stream 1 RS: 204 Profile: 1% AEP

E.G. Elev (m)	130.37	Element	Left OB	Channel	Right OB
Vel Head (m)	0.26	Wt. n-Val.		0.033	
W.S. Elev (m)	130.10	Reach Len. (m)	1.88	1.88	1.88
Crit W.S. (m)	130.14	Flow Area (m2)		1.74	
E.G. Slope (m/m)	0.022691	Area (m2)		1.74	
Q Total (m3/s)	3.96	Flow (m3/s)		3.96	
Top Width (m)	4.50	Top Width (m)		4.50	
Vel Total (m/s)	2.28	Avg. Vel. (m/s)		2.28	
Max Chl Dpth (m)	0.44	Hydr. Depth (m)		0.39	
Conv. Total (m3/s)	26.3	Conv. (m3/s)		26.3	
Length Wtd. (m)	1.88	Wetted Per. (m)		4.92	
Min Ch El (m)	129.66	Shear (N/m2)		78.52	

Plan: Plan 02 Camac Stream 1 RS: 204 Profile: 1% AEP (Continued)

Alpha	1.00	Stream Power (N/m s)		178.97	
Frctn Loss (m)	0.05	Cum Volume (1000 m3)	0.08	0.56	0.00
C & E Loss (m)	0.01	Cum SA (1000 m2)	1.06	1.11	0.06

Plan: Plan 02 Camac Stream 1 RS: 204 Profile: 1% AEP (+C.C)

E.G. Elev (m)	130.45	Element	Left OB	Channel	Right OB
Vel Head (m)	0.30	Wt. n-Val.		0.033	
W.S. Elev (m)	130.15	Reach Len. (m)	1.88	1.88	1.88
Crit W.S. (m)	130.20	Flow Area (m2)		1.97	
E.G. Slope (m/m)	0.021993	Area (m2)		1.97	
Q Total (m3/s)	4.75	Flow (m3/s)		4.75	
Top Width (m)	4.55	Top Width (m)		4.55	
Vel Total (m/s)	2.41	Avg. Vel. (m/s)		2.41	
Max Chl Dpth (m)	0.49	Hydr. Depth (m)		0.43	
Conv. Total (m3/s)	32.0	Conv. (m3/s)		32.0	
Length Wtd. (m)	1.88	Wetted Per. (m)		5.04	
Min Ch El (m)	129.66	Shear (N/m2)		84.49	
Alpha	1.00	Stream Power (N/m s)		203.28	
Frctn Loss (m)	0.04	Cum Volume (1000 m3)	0.11	0.62	0.01
C & E Loss (m)	0.01	Cum SA (1000 m2)	1.22	1.15	0.08

Plan: Plan 02 Camac Stream 1 RS: 203 Profile: 1% AEP

E.G. Elev (m)	129.55	Element	Left OB	Channel	Right OB
Vel Head (m)	0.05	Wt. n-Val.		0.033	
W.S. Elev (m)	129.50	Reach Len. (m)	21.00	21.00	21.00
Crit W.S. (m)	129.12	Flow Area (m2)		4.18	
E.G. Slope (m/m)	0.001906	Area (m2)		4.18	
Q Total (m3/s)	3.96	Flow (m3/s)		3.96	
Top Width (m)	5.97	Top Width (m)		5.97	
Vel Total (m/s)	0.95	Avg. Vel. (m/s)		0.95	
Max Chl Dpth (m)	0.85	Hydr. Depth (m)		0.70	
Conv. Total (m3/s)	90.7	Conv. (m3/s)		90.7	
Length Wtd. (m)	21.00	Wetted Per. (m)		6.90	
Min Ch El (m)	128.65	Shear (N/m2)		11.33	
Alpha	1.00	Stream Power (N/m s)		10.73	
Frctn Loss (m)		Cum Volume (1000 m3)	0.08	0.49	0.00
C & E Loss (m)		Cum SA (1000 m2)	1.06	0.95	0.06

Plan: Plan 02 Camac Stream 1 RS: 203 Profile: 1% AEP (+C.C)

E.G. Elev (m)	129.66	Element	Left OB	Channel	Right OB
Vel Head (m)	0.05	Wt. n-Val.		0.033	
W.S. Elev (m)	129.61	Reach Len. (m)	21.00	21.00	21.00
Crit W.S. (m)	129.17	Flow Area (m2)		4.83	
E.G. Slope (m/m)	0.001774	Area (m2)		4.83	
Q Total (m3/s)	4.75	Flow (m3/s)		4.75	
Top Width (m)	6.06	Top Width (m)		6.06	
Vel Total (m/s)	0.98	Avg. Vel. (m/s)		0.98	
Max Chl Dpth (m)	0.96	Hydr. Depth (m)		0.80	
Conv. Total (m3/s)	112.8	Conv. (m3/s)		112.8	
Length Wtd. (m)	21.00	Wetted Per. (m)		7.15	
Min Ch El (m)	128.65	Shear (N/m2)		11.76	
Alpha	1.00	Stream Power (N/m s)		11.56	
Frctn Loss (m)		Cum Volume (1000 m3)	0.11	0.54	0.01
C & E Loss (m)		Cum SA (1000 m2)	1.22	0.98	0.08