UNESCO/IHA research project on the

GHG status of freshwater reservoirs

The GHG Reservoir Tool *(G-res)*

User Guide

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1. INTRODUCTION TO THE G-RES TOOL

1.1. Overview of Tool Purpose, Development Process and Applicability

Climate change mitigation is one of the most important goals towards achieving sustainable development. Although reservoir systems are generally considered to be a source of carbon to the atmosphere, there are large differences in emission rates depending on reservoir location, hydrology, configuration, operation, and many other factors. Certain reservoir systems may be an important source of greenhouse gas (GHG) emissions while others may not; or may even be a sink of GHG emissions.

There is an increasing need to understand and manage the uncertainties around GHG emissions from reservoirs in an environment coming under greater scrutiny from governments, authorities, lenders, developers, and other stakeholders.

By estimating the GHG impact of reservoir formation, appropriate actions can be taken for reservoirs vulnerable to high emissions. This may include introducing emissions mitigation measures to existing reservoirs, or adjusted reservoir characteristics for planned reservoirs. In the case of an estimation of low net emissions, the tool could avoid costly and protracted GHG emissions monitoring campaigns.

Reliable and consistent approaches are required to evaluate GHG emissions for all types of assets and activities at different stages of development. The G-res tool addresses this knowledge gap by estimating net GHG footprint from reservoirs.

1.2. Description of Tool

The G-res tool aims to facilitate enhanced decision making throughout the development process of creating a reservoir. It is a tool which aims to increase the ability to communicate potential impacts and identify projects where there may be a need for mitigation. To increase its applicability, the G-res tool uses input data that do not require onsite measurements to be undertaken for either the pre- or post-impoundment conditions; instead, it uses parameters and data that should be known by project developers and environmental professionals; for example, when planning new reservoirs or assessing existing reservoirs.

The G-res tool estimates ‘net GHG footprint’ from the creation of a reservoir. This approach is based on the recommendation from the Intergovernmental Panel on Climate Change (IPCC, 2011) that net emissions should be evaluated in determining the impact of reservoir systems. Thus, a realistic portrait of the net impact of a reservoir should consider the GHG balance of the pre-impounded area and remove, or add, it to the GHG balance of the reservoir itself post impoundment.

In addition, the G-res tool considers the possibility that some reservoir emissions could be the result of human activity unrelated to the creation of the reservoir itself needs to be accounted for. The tool further includes the indirect GHG emissions attributed to the manufacture, transportation, and installation of reservoir infrastructure construction. This provides a more comprehensive estimation of the overall emissions associated with a reservoir.

The calculation of net GHG footprint in the G-res tool is defined by the following equation:

Net GHG footprint =

[Post-impoundment GHG balance of the reservoir]

– [Pre-impoundment GHG balance of the reservoir area before its introduction]

+ [GHG due to construction (Optional)]

A full description of how the G-res tool models GHG emissions from reservoir formation can be found in the *G-res Tool Technical documentation*, which is available from within the G-res tool and on the IHA website.

> Prairie YT, Alm J, Harby A, Mercier-Blais S, Nahas R. 2017. The GHG Reservoir Tool (G-res) Technical documentation, UNESCO/IHA research project on the GHG status of freshwater reservoirs. Updated version 3.2 (19-12-2022). Joint publication of the UNESCO Chair in Global Environmental Change and the International Hydropower Association. 74 pages.

A summary is presented here.

The G-res tool models GHG emissions using a series of modules which estimate emissions based on user inputs and calculated parameters based on those inputs. The modules address each part of the net GHG footprint calculation (Equation 1), namely pre-impoundment, post-impoundment, UAS and construction. Each of these modules can be summarised as:

- Pre-impoundment – the GHG balance associated with the area subsequently occupied by the reservoir, which is calculated based on the land-cover and a set of emission factors which represent the flux of emissions for land cover at the location of the reservoir.

- Post-impoundment – the GHG balance associated with the reservoir after inundation, which is calculated using a semi-empirical model based on a comprehensive dataset collated from the published peer-reviewed literature on measured GHG fluxes for diffusive, bubbling, and degassing emission pathways.

- Unrelated anthropogenic sources – the GHG emissions that can be attributed to activities within the catchment calculated based on the proportions of sources of nutrients and carbon flowing into the reservoir (Optional Allocation).

- Construction – the GHG emission associated with materials, plant and transport required to construct the dam and other infrastructure to form the reservoir, calculated based on the use of materials and emission factors (Optional).

The results for each module are presented in terms of annual emissions, total emissions, and areal emissions. Furthermore, the G-res tool includes a methodology for apportioning those emissions to the economic, social, and environmental services that the reservoir provides. This provides an indication of the relative contribution to the net GHG impact of each of the services.

2. USING G-RES

2.1. How to access G-res

G-res is an online system. The tool and supporting guidance and documentation can be accessed at:

www.hydropower.org/gres-tool

This includes access to G-res, the *G-res Tool Technical documentation* and this user guide.

More information on the G-res Tool is available at: g-res.hydropower.org

Before using G-res, users should note that:

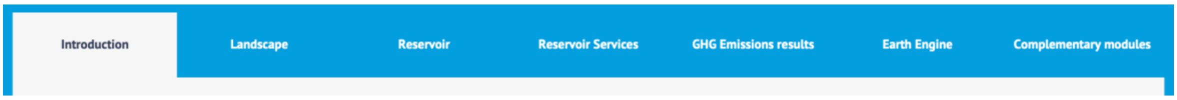
- This web page will disconnect automatically after 1 hour of inactivity.
- G-res works only with the following supported browsers: Safari 13.x, Chrome 80 or later, Microsoft Edge 44 or later.

Your collaboration on G-res is welcomed. Please send any comments and suggestions to ghg@hydropower.org.

If you have technical issues accessing or using G-res, please contact techsupport@grestool.org

2.2. Components of G-res

The G-res tool is a complex suite of interconnected components, each of which carries its own concepts, assumptions, and methodologies. G-res is divided into several worksheets where users input information about the reservoir of interest. These inputs and then used within the calculations included in G-res to make predictions about the GHG emissions of that reservoir. These worksheets can be accessed by clicking on the tabs within G-res:



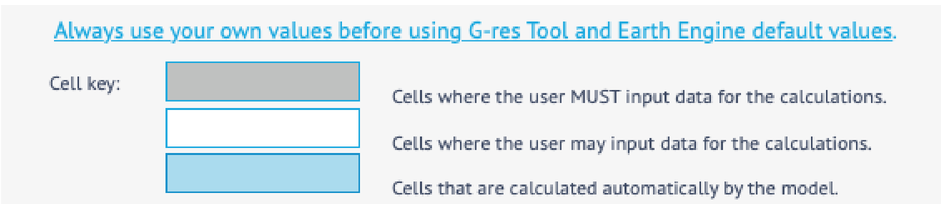
Each of the worksheets within G-res is described below:

Worksheet		Description
Introduction		Provides access to key information, the ability to save and import data and make a printable report
Landscape		Input data screen for details about the reservoir's catchment and landscape
Reservoir		Input data screen for details about the reservoir itself
Reservoir Services		Input data screen for details about the services that the reservoir provides
GHG emissions results	Total footprint	Information worksheet which presents the GHG footprint for the reservoir and construction, apportioned to the reservoir services
	Reservoir Emissions by Pathway	Information screen which presents the calculated GHG emissions of the reservoir
	Temporal Emissions	Annual net emissions, and annual emissions by pathways
Earth Engine		Access to the Earth Engine feature, which can help to provide some of the required inputs to G-res
Complementary modules	Construction GHG	Input data screen for details on the construction of the dam and supporting infrastructure
	Land Cover Factors	Input data worksheet where the user can adjust pre-defined emission factors and phosphorus load.
	UAS	Information screen about the calculations made for Unrelated Anthropogenic Sources of GHG emissions

Each of these worksheets is described in Section 3 to 0 of this user guide.

2.3. Types of user inputs

G-res requires information from the user that describes the reservoir. Depending on whether an existing or new reservoir is of interest, the source of that information will vary. Some parameters in G-res can be calculated based on other inputs. G-res uses a common color-coding of cell which indicate how the user can interact with them. These are summarised in Box below.



If a question mark (?) appears in one field, it means that you included too many decimals to your number. In most case, one (1) to two (2) decimal is enough to use the G-res Tool.

2.4. Google Earth Engine

To provide useful estimates of net GHG footprint from reservoirs, the G-res tool requires information concerning the physical, geographical, climatic, soil and land cover attributes of the reservoir itself as well as its catchment.

This information is obtained from several sources and entered in to G-res. To facilitate this process, G-res provides an additional functionality to help the user extract the information in a globally consistent manner and import it into G-res. This functionality was developed using Earth Engine platform of Google and it thus termed the Earth Engine (EE) functionality in the G-res tool.

Prairie YT, Alm J, Harby A, Mercier-Blais S, Nahas R. 2017. The GHG Reservoir Tool (G-res) User guidelines for the Earth Engine functionality v3 (Updated 19-12-2022), UNESCO/IHA research project on the GHG status of freshwater reservoirs. Joint publication of the UNESCO Chair in Global Environmental Change and the International Hydropower Association. 24 pages.

To take advantage of this option, users should read the accompanying 'User guide for the Earth Engine functionality' which details the steps required.

Once used, users should still manually review the data from Earth Engine to make sure it is applicable to the reservoir of interest.

2.5. If the G-res Tool is slow to open

If the G-res Tool takes longer than previously to open, it might help to clear your browsing data. Here is an example of how to clear browsing data in Google Chrome (Mac and PC):

Click on the 3 vertical points of *Customized and Control Google Chrome* button in the top right of your browser→ *History* → Advanced → *Clear browsing data* → Check *Cookies and other side data* and *Cached image and files* →*Clear data*

****WARNING: This will erase any passwords and pre-setting you have saved in Google Chrome****

2.6. About your data

Information that is entered into G-res is not permanently stored. When using G-res, all information is stored within that session and not stored on a server. This means that users must save their information using the "*save input parameters*" option within the tool, which will record the inputs within a downloadable file available to that user only. Users must then import that saved data to continue working on that reservoir at another time.

3. INTRODUCTION

Upon accessing the tool, users are invited to read this guidance document and the *G-res tool technical documentation*. Please take the time to do so carefully, as many parameters request specific information.

Options dropdown menu

Validate your Results

Access the G-res Tool website to learn more about the Validation of results process.

Save Data and Import Saved Data

At any time, you can save the work you have done and reload it later in the tool.

When you click the **Save Input Parameters** Button in the top left dropdown menu, you will be able to produce a file in Mailing format (.mer). Please save this file in a folder where you will be able to access it back when you want to restart to work on the Tool. The file name will have the following format:

G-res Tool_<Dam name>.mer

When you want to load your data later, select the '**Import Saved Parameters**' Button in the top left dropdown menu of the *G-res* tool and select the file that was previously saved on your computer. Please be patient while all your data are loaded in the tool as it can take a few minutes.

When loaded, the Reservoir Name will appear on Introduction the page.

Printable Reports (PDF files)

When you have input all the data required to make a prediction of GHG emissions, you can produce by clicking on the Printable Reports button a quick Printable Reports including:

Inputs Report
Reservoir GHG results Report
Total GHG Footprint Results Report
Construction Report

This functionality can also be used when comparing different reservoirs. In case of new reservoir, it is also possible to use the Printable Report to assess different options.

Export to .txt file (Comma delimited text file)

If you want to export the input variables and all the results obtained with the G-res, you can export the data to a comma delimited text file (Saved as .txt). If you want to view this file in Excel, you will need to convert the data using the comma delimited option.

Technical Support

In case of any technical problems, questions, or comments, please contact our Technical Support by clicking on the Technical Support button and follow the instructions or send an email directly to techsupport@grestool.org

Download Technical Document and User guidelines

Click on the button to download a pdf version of the documents on your computer.

Restart Analysis with a New Reservoir

Located on the Introduction tab, this button allows the user to erase all the work that has been done to restart with a new reservoir.

4. LANDSCAPE

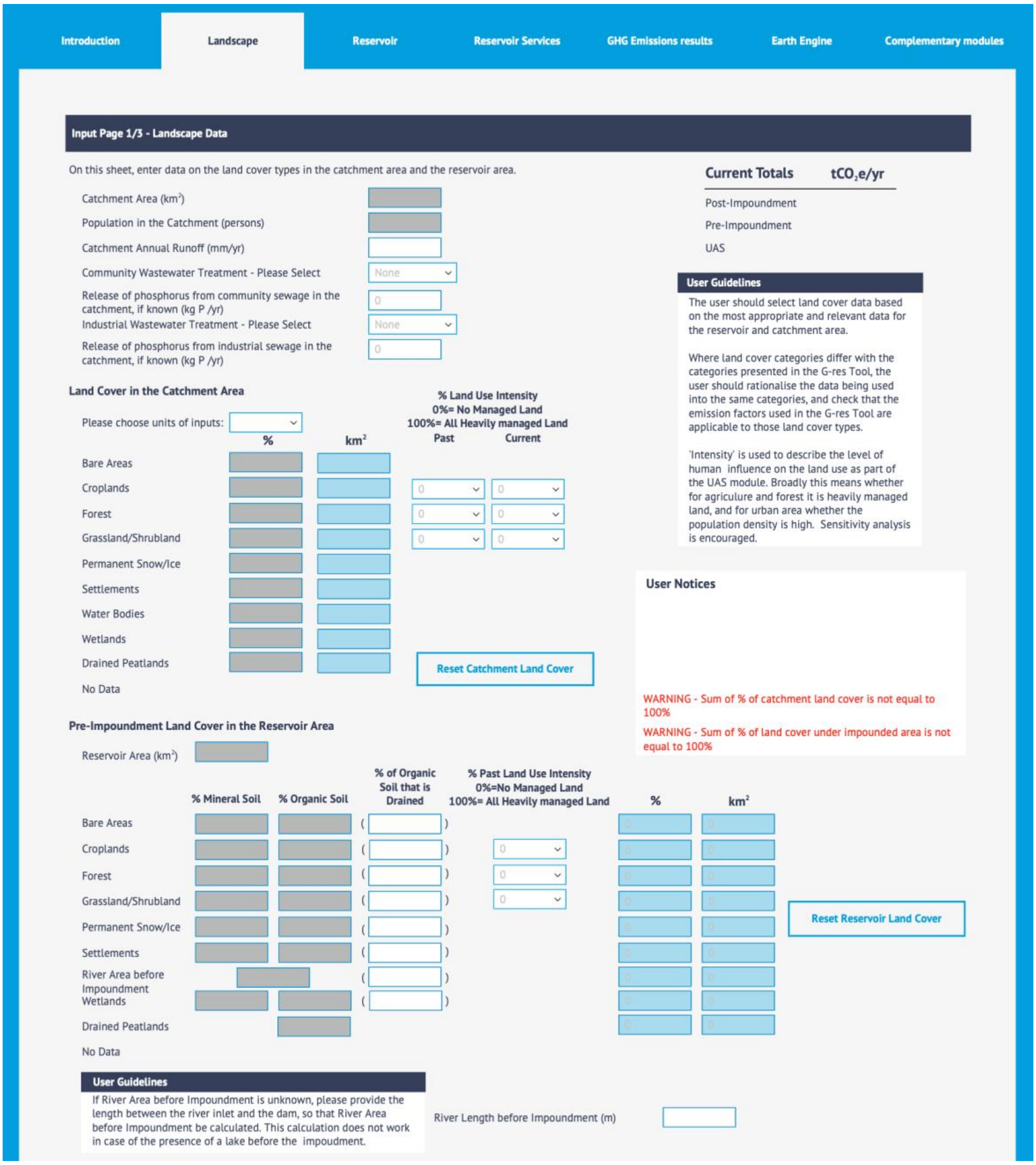
The Landscape worksheet contains the required inputs that describe the catchment within which the reservoir being assessed is located.

G-res is not designed to model complex cascade systems. Where a cascade system it to be modelled using G-res, users should note that the model assumes that the system is a single, unconnected system. In particular, it does not account for changes in flows of water and sediment between systems. Where users intend to model a reservoir within a cascade system, they are encouraged to undertake sensitivity analysis.

The data input page for Catchment and Landscape parameters is shown in Figure 4 below. The subsequent table provides a description of each data parameter listed. Please note that users need not provide data for every parameter, but just the parameters which are coloured in grey.

Please be sure to include a value for each grey cell. If no value is available, type "0" so that all cells become white.

Parameters coloured in blue in the Landscape worksheet are shown as a reference for the user but cannot be changed.



Introduction
Landscape
Reservoir
Reservoir Services
GHG Emissions results
Earth Engine
Complementary modules
Input Page 1/3 - Landscape Data
On this sheet, enter data on the land cover types in the catchment area and the reservoir area.
Catchment Area (km²)
Population in the Catchment (persons)
Catchment Annual Runoff (mm/yr)
Community Wastewater Treatment - Please Select
None
Release of phosphorus from community sewage in the catchment, if known (kg P /yr)
Industrial Wastewater Treatment - Please Select
Release of phosphorus from industrial sewage in the catchment, if known (kg P /yr)
Current Totals
tCO₂e/yr
Post-Impoundment
Pre-Impoundment
UAS
User Guidelines
The user should select land cover data based on the most appropriate and relevant data for the reservoir and catchment area.
Where land cover categories differ with the categories presented in the G-res Tool, the user should rationalise the data being used into the same categories, and check that the emission factors used in the G-res Tool are applicable to those land cover types.
'Intensity' is used to describe the level of human influence on the land use as part of the UAS module. Broadly this means whether for agriculure and forest it is heavily managed land, and for urban area whether the population density is high. Sensitivity analysis is encouraged.
Land Cover in the Catchment Area
Please choose units of inputs:
%
km²
% Land Use Intensity
0%= No Managed Land
100%= All Heavily managed Land
Past
Current
Bare Areas
Croplands
Forest
Grassland/Shrubland
Permanent Snow/Ice
Settlements
Water Bodies
Wetlands
Drained Peatlands
No Data
Reset Catchment Land Cover
User Notices
WARNING - Sum of % of catchment land cover is not equal to 100%
WARNING - Sum of % of land cover under impounded area is not equal to 100%
Pre-Impoundment Land Cover in the Reservoir Area
Reservoir Area (km²)
% Mineral Soil
% Organic Soil
% of Organic Soil that is Drained
% Past Land Use Intensity
0%=No Managed Land
100%= All Heavily managed Land
%
km²
Bare Areas
Croplands
Forest
Grassland/Shrubland
Permanent Snow/Ice
Settlements
River Area before Impoundment
Wetlands
Drained Peatlands
No Data
Reset Reservoir Land Cover
User Guidelines
If River Area before Impoundment is unknown, please provide the length between the river inlet and the dam, so that River Area before Impoundment be calculated. This calculation does not work in case of the presence of a lake before the impoundment.
River Length before Impoundment (m)

Landscape data	Unit	Overview
Catchment Area	km^2	The area of the catchment of interest upstream of the dam, in square kilometres.
Population in the Catchment	person	Population within the catchment areas upstream of the dam, in number of persons, reference can be made to CIESIN (Center for International Earth Science Information Network), Columbia University; and Centro Internacional de Agricultura Tropical (CIAT). (2020). Gridded Population of the World Version 4 (GPWv4): Population Density Grids. Palisades, NY: Socioeconomic Data and Applications Center (SEDAC), Columbia University. Available online at: http://sedac.ciesin.columbia.edu/gpw
Catchment Annual Runoff	mm/yr	Annual runoff is the amount of water in millimetres that flows from the catchment at the surface of the soil to a water body per year.
Community Wastewater Treatment	n/a	Specify whether there is any wastewater treatment activity upstream of the dam, which may affect the water quality in the reservoir. Wastewater treatment is the level of purification that is applied to the water in the catchment. The options range from none to primary (mechanical removal), secondary (biological treatment) and tertiary (where additional treatment above primary and secondary is applied). **Default Wastewater treatment:** None for least developed country and Secondary for developed country (UNDESA 2018)
Release of phosphorous form community sewage in the catchment	kgP/yr	The release of phosphorus from community sewage in the catchment in kilograms of phosphorus per year.
Industrial wastewater treatment	n/a	Specify whether there is any wastewater treatment activity of industrial sewage in the catchment upstream of the dam, which may affect the water quality in the reservoir. Wastewater treatment is the level of purification that is applied to the release of industrial sewage in the catchment. The options range from none to primary (mechanical removal), secondary (biological treatment) and tertiary (where additional treatment above primary and secondary is applied).
Release of phosphorous form industrial sewage in the catchment	kgP/yr	The release of phosphorus from industrial sewage in the catchment in kilograms of phosphorus per year.

Landscape data	Unit	Overview
Catchment land cover	%	The land cover category of the catchment first needs to be identified. Then, each category needs to be represented as a percent of the total catchment area. The nine catchment land cover categories are(a): 1) Bare Areas 2) Croplands 3) Forest 4) Grassland/Shrubland 5) Permanent Snow/Ice 6) Settlements 7) Water Bodies 8) Wetlands 9) Drained Peatland Further details are presented in Section 15.1 on the definition of these classifications. Land cover is entered as % of the study area and the km^2 is calculated. For some land cover categories, the Land Use Intensity should also be entered. This reflects whether the land is 'unmanaged' (low intensity, natural land cover) or 'heavily managed' (high intensity land cover with human influence)
Pre-impoundment land cover in the reservoir area (%)	%	The land cover category of the impounded land under the reservoir area needs first to be identified. Then, each category needs to be represented as a percent of the total impounded area. The eight reservoir land cover categories are(a): 1) Bare Areas 2) Croplands 3) Forest 4) Grassland/Shrubland 5) Permanent Snow/Ice 6) Settlements 7) Wetlands 8) River Area before Impoundment 9) Drained Peatland (Sum of % Organic Soil that is drained) Further details are presented in Section 15.1 on the definition of these classifications. Land cover is entered as % of the study area and the km^2 is calculated. The percentage of mineral and organic soils should also be specified as well as the % of the organic soil that is drained. For some land cover categories, the Land Use Intensity should also be entered. This reflects the land use from only 'unmanaged' (0%) to only ' heavily managed' (100%).
Land Use Intensity	%	Used to describe the level of human influence on the land use. Broadly this means whether for Cropland, Grassland/Shrubland and Forest, the percentage of heavily managed land, and for settlements the percentage of highly populated area. The intensity applies to each specific land cover category. This variable is used to estimate the Risk factor for the GHG emissions (UAS section, all 4 categories) and to apply specific phosphorus load factors (Cropland, Grassland/Shrubland and Forest).

Landscape data	Unit	Overview
River Length before Impoundment (m)		The length between the river inlet and the dam, used to estimate River Area before Impoundment if not available.

(a): We have included a table in Section 8.4 of ANNEX 1 that provides the detailed land cover categories from the European Space Agency (ESA) – Climate Change Initiative (CCI) and the corresponding categories included in the *G-res* tool

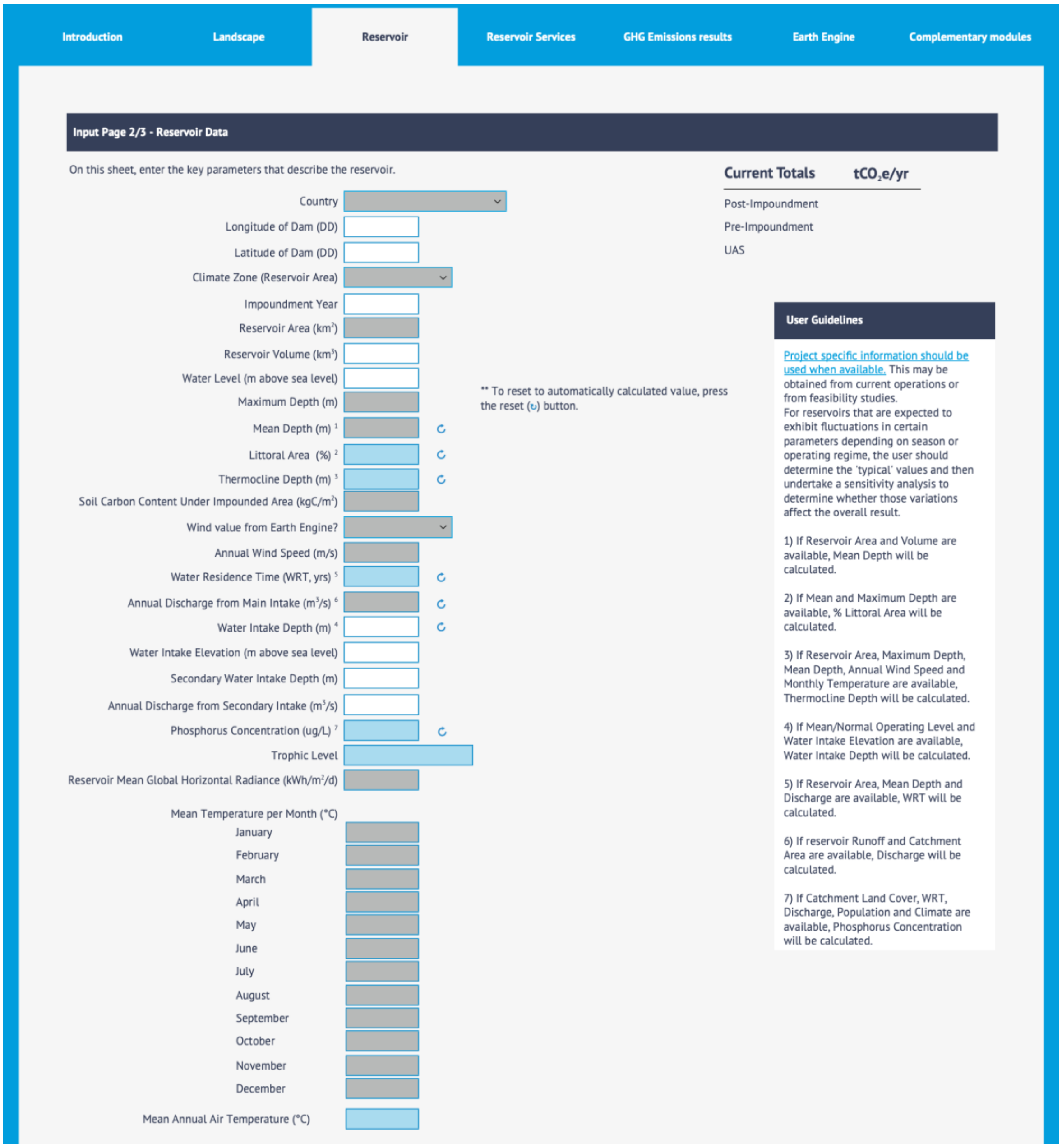
Other notes

Users can access the 'Land Cover Factors' tab in the Complementary modules to take them to the Land Cover Factors worksheet. On this worksheet, the emission factors and phosphorus load associated with land cover types can be adjusted if the user has more accurate, local data available.

The 'Reset Catchment Cover' and 'Reset Reservoir Land Cover' buttons will clear the data in their respective tables.

5. RESERVOIR

The data input page for the Reservoir parameters is shown in Figure 5 below. The subsequent table provides a description of each data parameter listed. Please note that users do not need to provide data for every parameter; parameters in grey are mandatory, but parameters in blue can be calculated by G-res. However, if the user also knows specific values for the blue parameters, they can be entered.

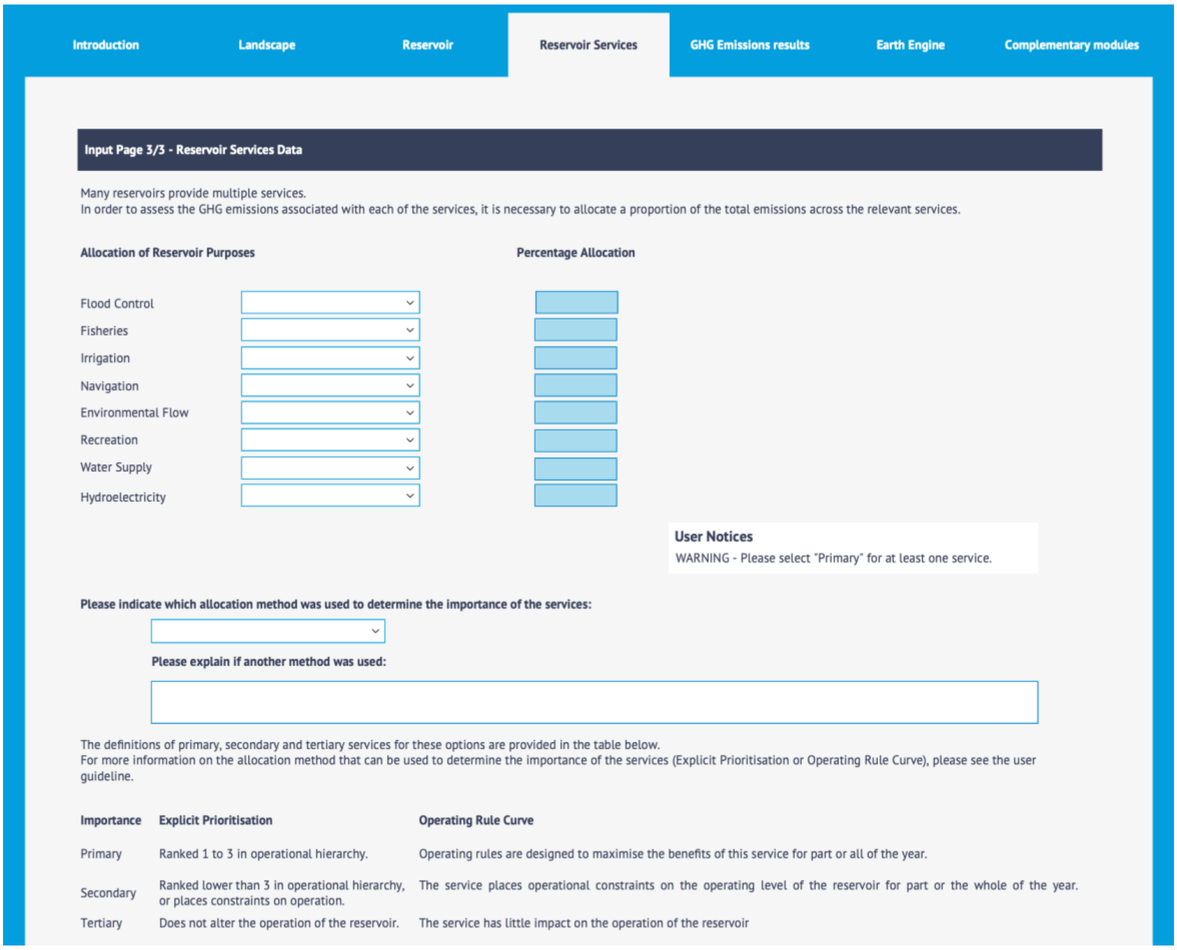


Reservoir data	Unit	Overview
Country		Location of the reservoir (or for cross-border schemes, the country from which the reservoir is managed)
Longitude of dam	DD	Longitude of point location of dam, in decimal degrees (DD).
Latitude of dam	DD	Latitude of point location of dam, in decimal degrees (DD).
Climate zone (reservoir area)	choice	The appropriate climate category considering the following categories used in the model: Tropical, subtropical, temperate and boreal. Refer to the world maps of Köppen-Geiger climate classification for more details: http://koeppen-geiger.vu-wien.ac.at/shifts.htm. The most representative choice should be used (where a reservoir is located across two zones, the zone with the largest proportion should be used).
Impoundment year	year	The year in which the flooding of land that formed the reservoir was completed.
Reservoir area	km^2	To obtain more conservative emissions, we suggest using the surface area occupied by the reservoir at full supply water level, in square kilometres. The Tool can also be run using surface area occupied by the reservoir at normal (average) water level, in square kilometres. This should be defined based on mean operating level over the course of a year. **Tip:** Reservoir mean depth, maximum depth, volume, discharge should also be estimated at the same chosen water level.
Reservoir volume	km^3	The total volume of water in the reservoir. This should be defined relative to water level of the reservoir (full water supply or mean operating level), in cubic kilometres.
Water level	m a.s.l.	The full water supply or mean operating level of the reservoir in meters above sea level, depending on the reservoir area used.
Maximum depth	m	The maximum depth of the reservoir relative to water level of the reservoir (full water supply or mean operating level), in metres.
Mean depth	m	The average depth of the reservoir relative to water level of the reservoir (full water supply or mean operating level), in metres. This can be estimated by taking reservoir volume and dividing by reservoir area.
Littoral area	%	The littoral area represents the surface area of the reservoir between the shore and the distance to the shore at 3m depth, where the water is shallower and the water temperature warmer than the rest of the reservoir. In the *G-res* tool, the percent littoral area is defined as the percentage of the reservoir area that has a depth less than 3m. Where a GIS model is available, the littoral area can be calculated by calculating the area of the reservoir and the topographic profile of the reservoir area, or estimated by using the area of the maximum and minimum levels, comparing the reservoir area and the depth
Thermocline depth	m	The depth from the surface of the reservoir to the mean level of the thermocline.

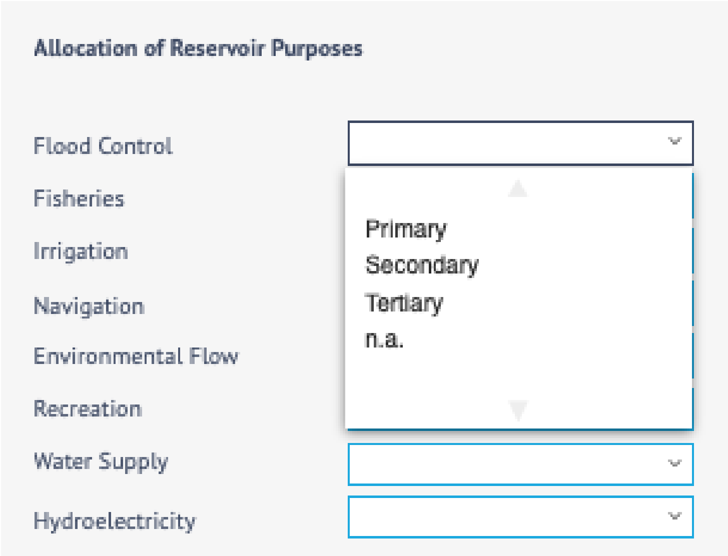
Reservoir data	Unit	Overview
Soil carbon content under impounded area	kgC/m^2	The typical carbon content of soils found beneath the flooded area of the reservoir (0-30cm), in kilograms of carbon per square metre.
Annual Wind Speed	m/s	The average wind speed above the reservoir surface, in metres per second. Where measurements at the reservoir are not available, local weather station data could be used if available.
Wind value from Earth Engine?	n/a	Please choose Yes or No if your Annual wind speed value is coming from Earth Engine
Wind measurements heigh	m	Height above the reservoir surface at which the wind speed measurements were taken, in meter. If the annual wind speed from Earth Engine is used, this information is not required.
Water residence time	years	The water residence time represents the average amount of time that a molecule of water spends in the reservoir, in years.
Annual discharge from Main Intake	m^3/s	Annual average rate of discharge from the main dam outlet for chosen water level of the reservoir (full water supply or mean operating level), in cubic meters per second.
Water intake depth	m	The depth from the surface of the reservoir to the level of the dam intake
Water intake elevation	m a.s.l.	Elevation of the water intake of the reservoir in metres above sea level
Annual discharge from Secondary Intake	m^3/s	Annual average rate of discharge from the secondary dam outlet for chosen water level of the reservoir (full water supply or mean operating level), in cubic meters per second
Secondary Water intake depth	m	The depth from the surface of the reservoir to the level of any secondary dam intake
Phosphorus concentration	µg/L	Mean phosphorus concentration within the reservoir
Trophic level		The tropic state of the reservoir. There are four states to select from, and users should note the following thresholds: • Oligotrophic = Less than 10 µg L^{-1} • Mesotrophic = Between 10 and 30 µ g L^{-1} • Eutrophic = Between 30 and 100 µ g L^{-1} • Hyper-eutrophic = More than 100 µ g L^{-1}
Reservoir mean global horizontal radiance	$kWh/m^2/d$	5.1.1. The annual or ice-free average amount of the total solar radiation incident on a horizontal surface at the surface of the earth. See Annex III of the *G-res tool technical documentation* to convert to Cumulative global horizontal radiance (kWh/m^2/period).
Mean air temperature per month at reservoir site	°C	The mean air temperature for each month at the reservoir site. Please provide data only if multi-year monthly mean air temperature (°C) are available for all months from local data taken on the reservoir itself or from a nearby weather station. If no air temperature data are available, the G-res tool will use a monthly mean air temperature average of 50 years (1950-2000).

6. RESERVOIR SERVICES

Many reservoirs provide multiple services; to assess the GHG emissions associated with each of the services, it is necessary to allocate a proportion of the total emissions across the relevant services. Allocation of GHG emissions in the G-res tool is achieved using the 'Reservoir Services' worksheet where there are eight separate reservoir services to choose from (Figure 6 below); these are defined in the subsequent table.



Users must choose whether each service is a Primary, Secondary or Tertiary service, or not a service at all, by selecting from the drop-down menus next to each service. Note at least one service should be selected as 'Primary'.



Two Operating Regime Approaches

To allocate emissions associated with the reservoir across the different services, the first step is to indicate the relative importance of each service. A number of approaches to allocation have been proposed in the literature; however, there is currently no consensus. The approach to allocation in the current version of the G-res tool is to base the importance of the service on the operating regime of the reservoir.

The operating regimes for reservoirs throughout the world are influenced by a multitude of socio-political, economic, financial and environmental factors. The means by which operating regimes are determined are by explicit prioritisation or operating rule curve. These are the approaches the user is advised to base the allocation on in the current version of the G-res tool. The definitions of primary, secondary and tertiary services for these options are provided in the table below.

Importance	Explicit Prioritisation	Operating Rule Curve
Primary	Ranked 1 to 3 in operational hierarchy.	Operating rules are designed to maximise the benefits of this service for part or all of the year.
Secondary	Ranked lower than 3 in operational hierarchy, or places constraints on operation.	The service places operational constraints on the operating level of the reservoir for part or the whole of the year.
Tertiary	Does not alter the operation of the reservoir.	The service has little impact on the operation of the reservoir.

Apportionment

Apportionment for total GHG emission is as follows: 80% for primary, 15% for secondary and 5% for tertiary. If there is more than one service in each level, the apportionment for that level is split equally between them.

There is a maximum of three services in each level. This means a lower level service will never have a greater apportionment than a higher level service.

Where there are no tertiary services, the apportionment (5%) is split between the secondary services. If there is no secondary service, the apportionment (20%) is split between the primary services.

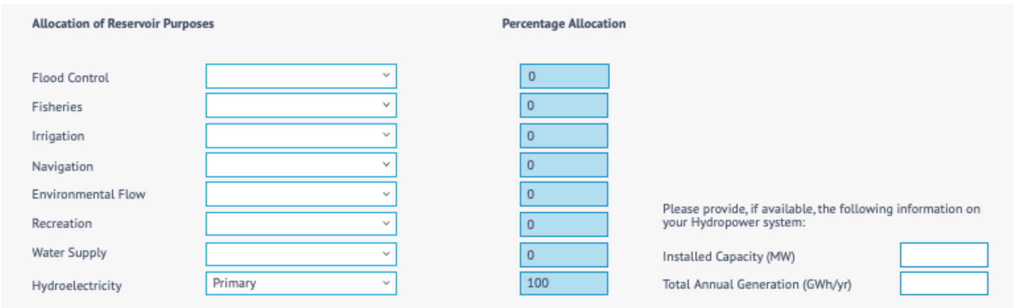
Based on the above apportionment rules, the allocation percentage of GHG emissions will be calculated if the importance of a service is indicated. The apportionment is shown in the column 'Percentage Allocation'.

Information on hydropower system

If hydropower is chosen as one of the service (independent of the importance chosen), some supplemental information on the hydropower system are asked:

Reservoir data	Unit	Overview
Installed Capacity	MW	The maximum capacity that the system is designed to run at, i.e. sum of all turbines, in megawatt. Also known as nameplate capacity or rated capacity
Total Annual Generation	GWh/yr	The intensity of power production generated per year in gigawatt hours per year (five year average recommended).

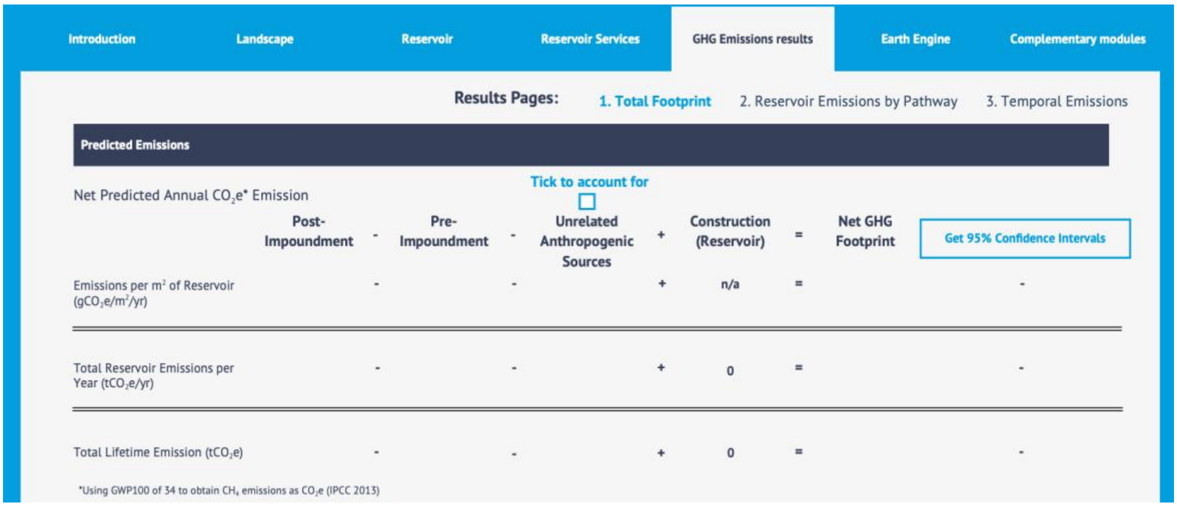
Those two informations are required to estimate Power density (W/m^2) and Allocated GHG emissions intensity (gCO$_2$e/wWh) available in the Total GHG footprint worksheet.



7. TOTAL FOOTPRINT

The Total footprint worksheet presents the summary results of the assessment made in G-res. This worksheet is presented in a number of sections:

Predicted emissions



This section of the summary table expresses the results of each element of the GHG emission prediction in terms of:

- Emissions per m^2 of Reservoir in $gCO_2e/m^2/yr$ (excludes construction);
- Total Reservoir Emissions per year in tCO_2e per year on a 100-year basis; and
- Total lifetime emissions in tCO_2e.

The worksheet provides a simple breakdown of the relative contributions of each part of the assessment in the form of the equation "*Post-Impoundment – Pre-Impoundment – UAS + Construction =Net GHG footprint*". Therefore, within the summary, negative numbers represent a sink of GHG emissions while positive numbers represent a source of GHG emissions.

To include UAS in the footprint calculation, the user needs to tick the Tick to Account for Unrelated Anthropogenic Sources either in the Reservoir GHG or Total GHG Footprint tab.

The 95% Confidence intervals (CI) is calculated using a normal distribution of the Net Reservoir Footprint obtained from the addition of each individual emissions pathways randomly calculated from their own distributions. The CI numbers are only calculated each time the Get 95% Confidence Intervals button is pressed. The CI will be erased each time an input value is changed.

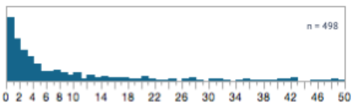
Net GHG Emissions Contribution for Each Reservoir Service, Power density and Allocated GHG emissions intensity

Net GHG Emissions Contribution for Each Reservoir Services

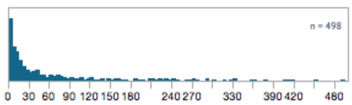
Reservoir Service	GHG Emissions from Reservoir (tCO_2e/yr)	GHG Emissions from Construction (tCO_2e/yr)	GHG Footprint (tCO_2e/yr)	Percentage Allocation (%)
Flood Control	0	0	0	0
Fisheries	0	0	0	0
Irrigation	0	0	0	0
Navigation	0	0	0	0
Environmental Flow	0	0	0	0
Recreation	0	0	0	0
Water Supply	0	0	0	0
Hydroelectricity	0	0	0	100

Hydroelectricity and Net GHG footprint

Power Density (W/m^2) =



Allocated GHG emissions intensity (gCO_2e/kWh) = -



Allocation Method Used:

Emission Factor Used:

Default Emission Factors used

Construction Comments:

This part of the worksheet apportions the total GHG emissions in accordance with the reservoir services specified in the Reservoir Services worksheet. For each service, the contribution to the total GHG emissions is presented terms of total emissions per year equivalent to the allocation of that service.

If hydropower is chosen as one of the service (independent of the importance chosen), Power density (W/m^2) and Allocated GHG emissions intensity (gCO_2e/kWh) will be evaluated in the Total GHG footprint worksheet. The two values are presented as a point in the distribution graph, which compares this reservoir value to the value of other reservoirs that have been quantified by the G-res team (note, this does not include other users' reservoirs).

Reservoir data	Unit	Overview
Power Density	W/m^2	The ratio of installed capacity to total reservoir surface area .
Allocated GHG emissions intensity	gCO_2e/kWh	The emission rate of greenhouse gasses (CO_2 + CH_4) relative to the intensity of power production. In this case, gCO_2eper kWh generated.

RESERVOIR EMISSIONS BY PATHWAY

This section of the summary table expresses the results of each element of the GHG emission prediction for the reservoir only.

The upper part of the worksheet presents the predicted emissions as:

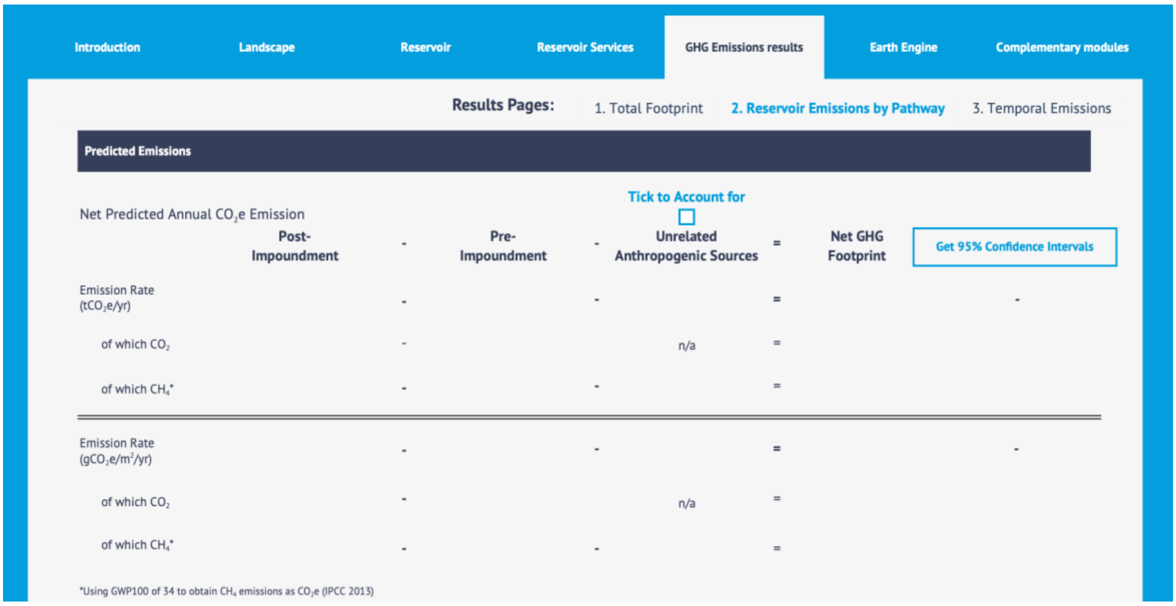
- Reservoir wide emissions in tCO_2e per year on a 100-year basis; and
- Areal emissions in $gCO_2e/m^2/yr$;

The worksheet provides a simple breakdown of the relative contributions of each part of the assessment in the form of the equation "*Post-Impoundment – Pre-Impoundment – UAS = Net GHG footprint*". Therefore, within the summary, negative numbers represent a sink of GHG emissions while positive numbers represent a source of GHG emissions.

The results are expressed in CO_2 equivalents and then separately for CO_2 and methane emissions for each part of the calculation.

To include UAS in the footprint calculation, the user needs to tick the Tick to Account for Unrelated Anthropogenic Sources either in the Reservoir GHG or Total GHG Footprint tab.

The 95% Confidence intervals (CI) is calculated using a normal distribution of the Net Reservoir Footprint obtained from the addition of each individual emissions pathways randomly calculated from their own distributions. The CI numbers are only calculated each time the Get 95% Confidence Intervals button is pressed. The CI will be erased each time an input value is changed.

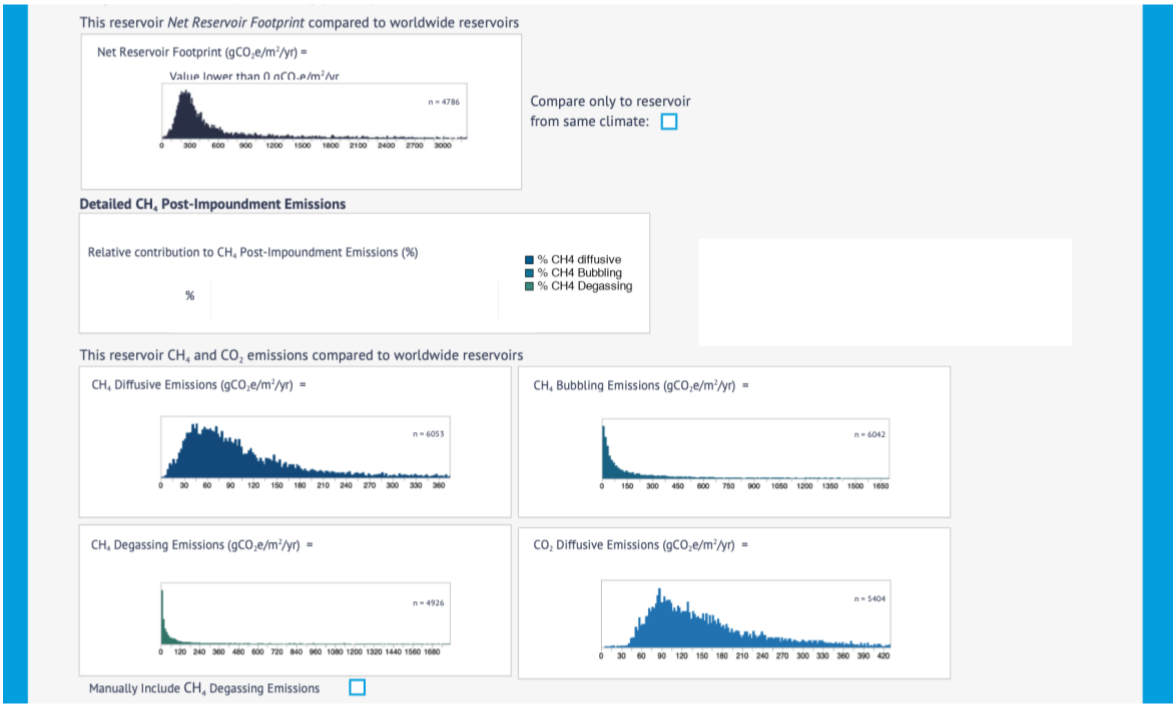


The lower part of the worksheet puts the results into context, based on data gathered from other reservoirs.

This reservoir emission compared to worldwide reservoirs

The dark point in each graph expresses the emissions (Net Reservoir Footprint, CH_4 diffusive, bubbling, or degassing emission, CO_2 emissions) of the assessed reservoir in comparison to the emissions of other reservoirs that have been quantified by the G-res team (note, this does not include other users' reservoirs).

Similarly, the emissions associated with the diffusive flux from the reservoir, the degassing and the bubbling emissions are expressed in a comparative way.



Finally, the contribution of emissions from Unrelated Anthropogenic Sources is presented as a percentage of the total post-impoundment emissions. This indicates the potential significance of emissions due to activities within the catchment that increase GHG emissions in the reservoir. The weighted sum model risk result from the UAS worksheet is also presented.

8. TEMPORAL EMISSIONS

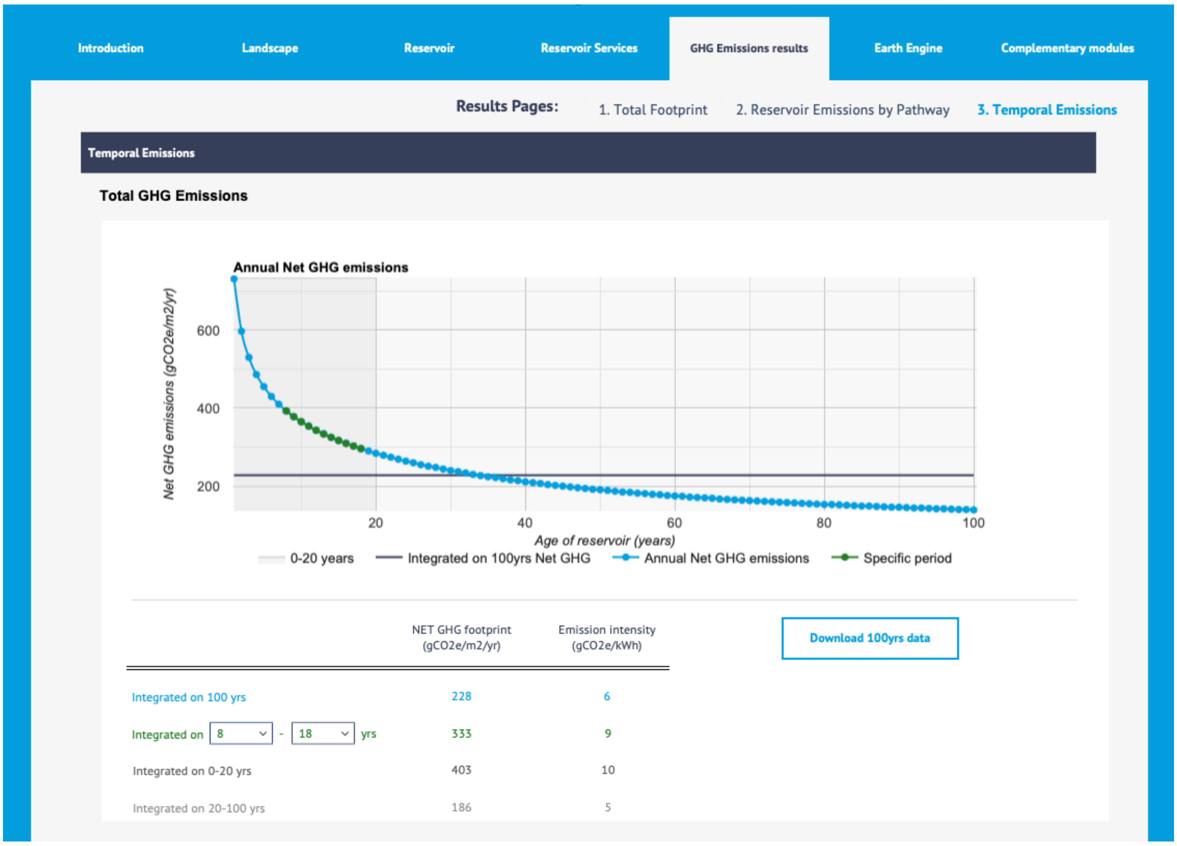
Annual Net GHG emissions over the lifetime of the reservoir

The top figure presents Annual Net GHG emissions over the lifetime of the reservoir. Each value represents the balance between Post and Pre-impoundment emissions and including all four pathways.

- Blue points: Annual Net GHG emissions
- Dark blue line: Net GHG footprint integrated on 100-yrs
- Green points: Annual Net GHG emissions for a specific period (Here age 8 to 18 of the reservoir)
- Dark grey zone: 0-20 years period as used in IPCC
- Pale grey zone: 0-20 years period as used in IPCC

Each coloured elements in the figure have an associated value in the table below and represents the integrated value over the mentioned period.

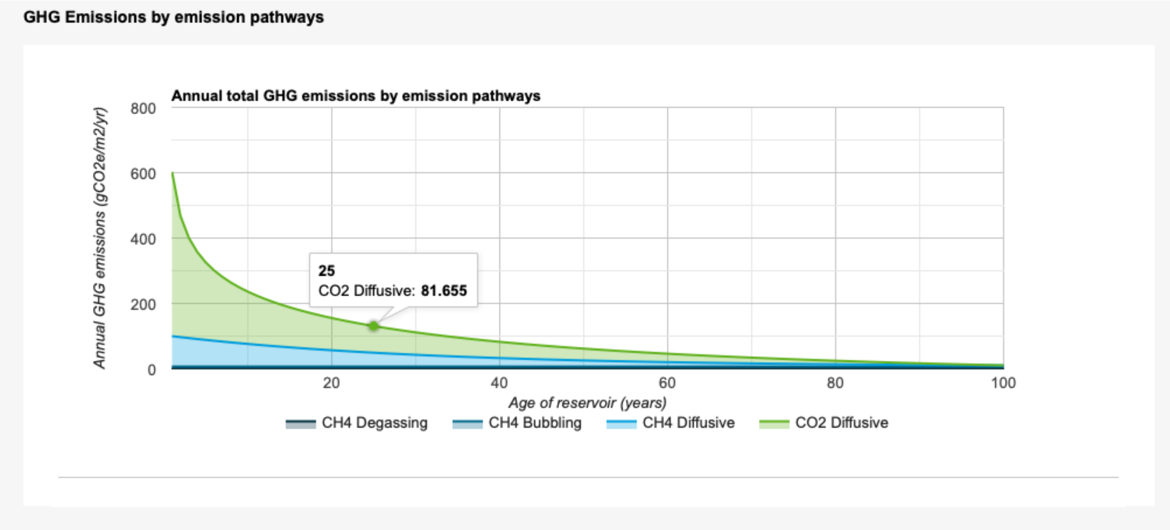
The Download 100yrs data button is available to download the 100-yrs annual values as a csv file.



***** Warning: Potential large interannual variability if only one year is used. We do recommend using multiples years average (e.g., 5 years period).**

GHG Emissions by emissions pathways

This figure presents the gross emissions for each individual pathways (CH4 degassing, CH4 bubbling, CH4 diffusive, and CO2 diffusive). The sum of the 4 pathways is represented by the total height of the curve as Annual total GHG emissions. Hover on the figure to get dynamically individual value for each pathway and each year.



9. EARTH ENGINE

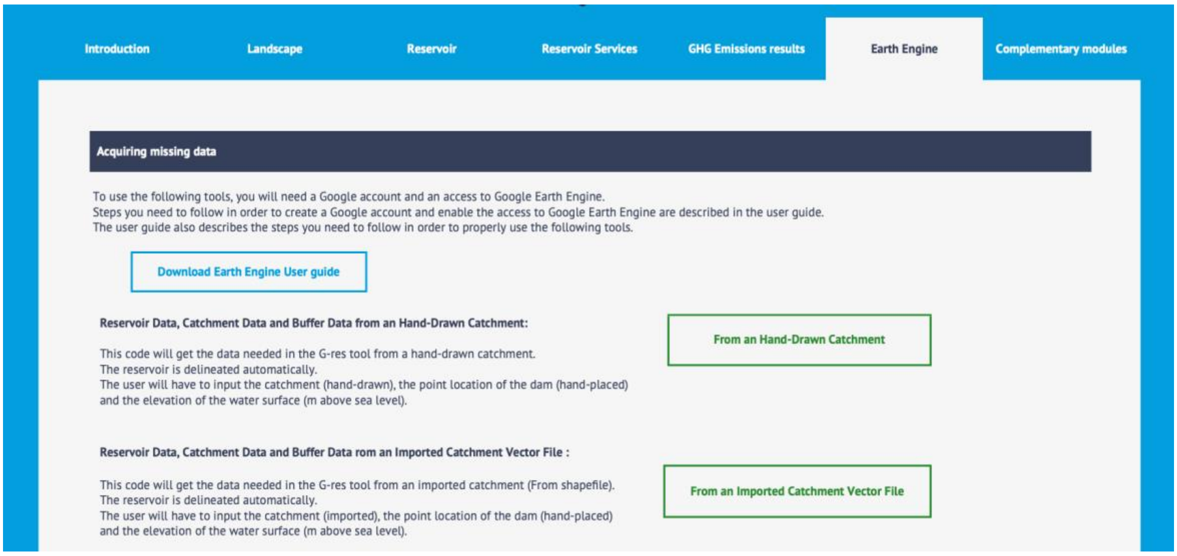
G-res includes a Google Earth Engine functionality which can be used to generate some of the input data required in G-res. To use this feature, you will need an existing or new Google account.

Please use results from the Earth Engine functionality only for missing data.

A detailed explanation of how to use the Earth Engine feature is presented in the *Earth Engine User Guide*, which can be found within G-res and at g-res.hydropower.org.

This worksheet has two buttons on the right-hand side from which the user can select the appropriate way to use the Earth Engine. This allows for the user to hand-draw the catchment in Earth Engine, or to use an existing shapefile from a GIS software, from which the Earth Engine can generate the required inputs.

For further support on this functionality, contact techsupport@grestool.org



11. CONSTRUCTION

Emissions due to dam infrastructure construction are included within the G-res tool. Where they have the information, the user will be able to specify the materials, construction plant and transport associated with the construction of the associated infrastructure.

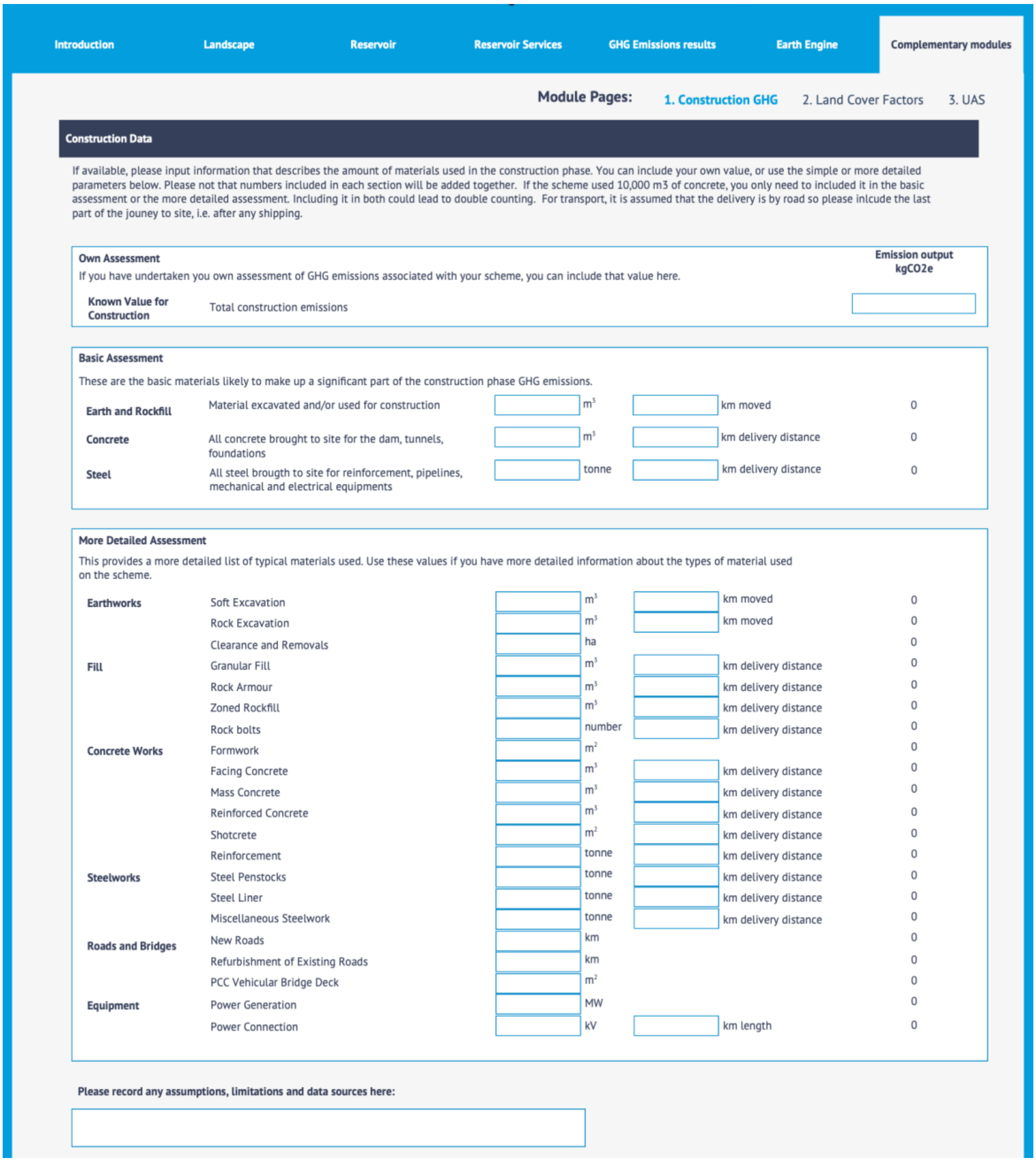
The Construction GHG is split in to three sections:

- Own assessment provides space for the user to input a figure based on their own assessment outside of G-res.
- Basic assessment includes only four key activities and materials that are likely to represent a large proportion of construction phase GHG emissions.
- More detailed assessment includes more granular items to select from in the case that these are known.

Note that users do not need to contribute data for each section – for example, including a value for concrete in the basic assessment *and* the more detailed assessment would result in double counting. Users should take care to make sure the sum of all the materials is equal to those used for the reservoir in the case that inputs are included in both parts of the worksheet. Users can also use the 'own assessment' to include any materials not included on the worksheet and these will be added to the total.

Users should try to include as much of the infrastructure as possible is included in order to make as complete an assessment as possible. This would include the dam(s) and cofferdams, tunnels and water passageways, the spillway, intake structures, powerhouse, roads and any other assets that may be required. Users are encouraged to record the assets included within the text box on the construction worksheet.

Data on the construction phase can often take different forms, and a number of assumptions have been made regarding the type of activities, which are included within G-res. This also includes assumptions on emission factors regarding the materials, transport and plant used during construction.



Introduction | Landscape | Reservoir | Reservoir Services | GHG Emissions results | Earth Engine | Complementary modules

Module Pages: 1. Construction GHG   2. Land Cover Factors   3. UAS

Construction Data

If available, please input information that describes the amount of materials used in the construction phase. You can include your own value, or use the simple or more detailed parameters below. Please not that numbers included in each section will be added together. If the scheme used 10,000 m3 of concrete, you only need to included it in the basic assessment or the more detailed assessment. Including it in both could lead to double counting. For transport, it is assumed that the delivery is by road so please inlcude the last part of the jouney to site, i.e. after any shipping.

Own Assessment

If you have undertaken you own assessment of GHG emissions associated with your scheme, you can include that value here.

			Emission output kgCO2e
Known Value for Construction	Total construction emissions		

Basic Assessment

These are the basic materials likely to make up a significant part of the construction phase GHG emissions.

Earth and Rockfill	Material excavated and/or used for construction		m^3		km moved	0
Concrete	All concrete brought to site for the dam, tunnels, foundations		m^3		km delivery distance	0
Steel	All steel brougth to site for reinforcement, pipelines, mechanical and electrical equipments		tonne		km delivery distance	0

More Detailed Assessment

This provides a more detailed list of typical materials used. Use these values if you have more detailed information about the types of material used on the scheme.

Earthworks	Soft Excavation		m^3		km moved	0
	Rock Excavation		m^3		km moved	0
	Clearance and Removals		ha			0
Fill	Granular Fill		m^3		km delivery distance	0
	Rock Armour		m^3		km delivery distance	0
	Zoned Rockfill		m^3		km delivery distance	0
	Rock bolts		number		km delivery distance	0
Concrete Works	Formwork		m^2			0
	Facing Concrete		m^3		km delivery distance	0
	Mass Concrete		m^3		km delivery distance	0
	Reinforced Concrete		m^3		km delivery distance	0
	Shotcrete		m^2		km delivery distance	0
	Reinforcement		tonne		km delivery distance	0
Steelworks	Steel Penstocks		tonne		km delivery distance	0
	Steel Liner		tonne		km delivery distance	0
	Miscellaneous Steelwork		tonne		km delivery distance	0
Roads and Bridges	New Roads		km			0
	Refurbishment of Existing Roads		km			0
	PCC Vehicular Bridge Deck		m^2			0
Equipment	Power Generation		MW			0
	Power Connection		kV		km length	0

Please record any assumptions, limitations and data sources here:

Further information and a worked example are provided in Section 0.

Simple assessment

Construction	Unit	Description
Earth and rockfill	m^3 and km	All rock, soil, sand, gravel brought to site and/or excavations for use in the construction of the required structures, expressed in m^3. The average delivery/movement distance should be used. This should be balanced based on whether the materials are imported, or site won.
Concrete	m^3 and km	All concrete brought to site for the dam, tunnels, foundations, and other structures, in m^3. This is assumed to be a standard concrete mix. The transport distance can be specified and should be stated as an average of the constituent components (i.e., the weighted distance of concrete, aggregate and sand suppliers).
Steel	tonnes and km	All steel brought to site for reinforcement, pipelines, mechanical and electrical equipment, expressed in tonnes. Note there is likely to be some uncertainty in this due to the difference between steel sections, for example, and finished products that contain steel components. To be conservative, the total mass of steel should be included, but this may require some sensitivity testing.

More detailed assessment

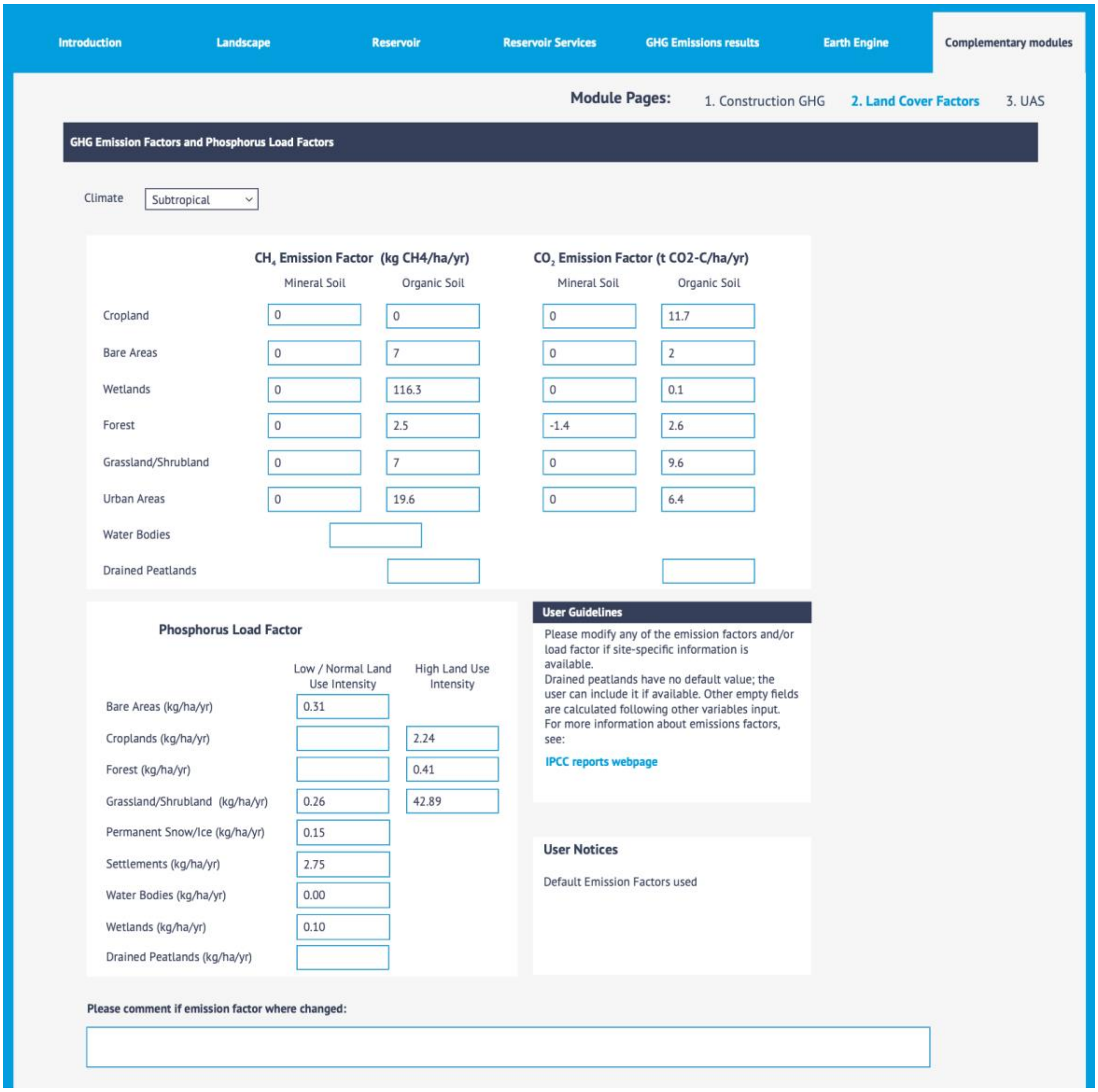
Construction	Unit	Description
Soft excavation	m^3	Excavations using a machine in soft ground, in cubic metres
Rock excavation	m^3	Excavations using a machine in hard ground, in cubic metres
Clearance and removals	ha	Area of vegetation removed in preparation for construction activities, in hectares
Granular fill	m^3	Volume of fill material used within structures, in cubic metres
Rock armour transport and placing (Nom. 1m dia rocks)	m^3	Volume of rock armour used to protect structures, in cubic metres
Zoned Rockfill	m^3	Volume of rockfill used within structures, in cubic metres
Rock bolts, 25mm dia x 4m lg	Nr	Number of steel bolts used to support structures
PVC lined gabion basket	m^3	Gabions used to protect structures, in cubic metres
Formwork	m^2	Area of formwork used to form concrete structures, in square metres
Facing Concrete (C32/40 & 20mm agg. size)	m^3	Volume of concrete used for facing and surfacing, in cubic metres
Mass Concrete (C12/15 & 20mm agg. size)	m^3	Volume of concrete used for mass filling of structures, in cubic metres
Reinforced Concrete (C32/40 & 20mm agg. size)	m^3	Volume of concrete with steel reinforcement used within structures, in cubic metres
Shotcrete 50mm thick	m^2	Concrete used to form a lining or surface, 50mm thickness
Shotcrete 100mm thick	m^2	Concrete used to form a lining or surface, 100mm thickness
Reinforcement	tonne	Steel mesh or bars used within concrete

Construction	Unit	Description
Steel Penstocks (site welded)	tonne	Steel sluice and pipework within the structure of the dam
Steel liner	tonne	Steel lining within tunnels
Miscellaneous Steelwork	tonne	Any other steelwork for structural purposes, including pipelines
New roads	km	New roads built to access the reservoir and dam
Refurbishment of existing roads	km	Refurbishment or upgrading of existing access routes to the reservoir and dam
PCC vehicular bridge deck (10m span)	m^2	Pre-cast concrete bridge deck
Turbine installed capacity	MW	Turbines and supporting equipment used to generate power within the dam
Power connection	kV and km length	Substation and overhead line required to connect hydropower equipment to the electricity grid. The voltage of the line and the length of the line should be specified.
Trashracks, valves, turbines	tonne	Other steel equipment and valves used within the reservoir and dam.

12. LAND COVER FACTORS

The Land Cover Factors worksheet allows the user to modify some of the emission factors and Phosphorus Load within G-res.

At the top of the worksheet, the user can select from a drop-down menu a climate zone. In the worksheet shown below, the 'subtropical' zone is selected. Once a climate zone is selected, the other parts of the worksheet are populated. Drained peatlands have no default value; the user can include it if available. Other empty fields are calculated following other variables input.



The default values within G-res are consistent with the IPCC default values for those zones and land cover types, presented for the mineral and organic soil types. A full description is presented in the *G-res tool technical documentation*. Users can change these values by simply selecting a value and inputting a new value.

Similarly, for phosphorus, the default values can be changed for more specific factors where these are known, expressed for normal and high land use intensity.

Changing these values will modify the results presented by G-res. In particular, for land cover this will affect the Pre-impoundment GHG emissions prediction and changing phosphorous loads will affect some of the calculations in the Post-impoundment and UAS GHG predictions.

Where values are changed from the defaults, a notice will be presented at the top of the worksheet and on the Reservoir GHG worksheet. Users are encouraged to record on the Emission Factor worksheet the reasons and sources of any alternative emission factors used in their assessment.

13. UNRELATED ANTHROPOGENIC SOURCES (UAS)

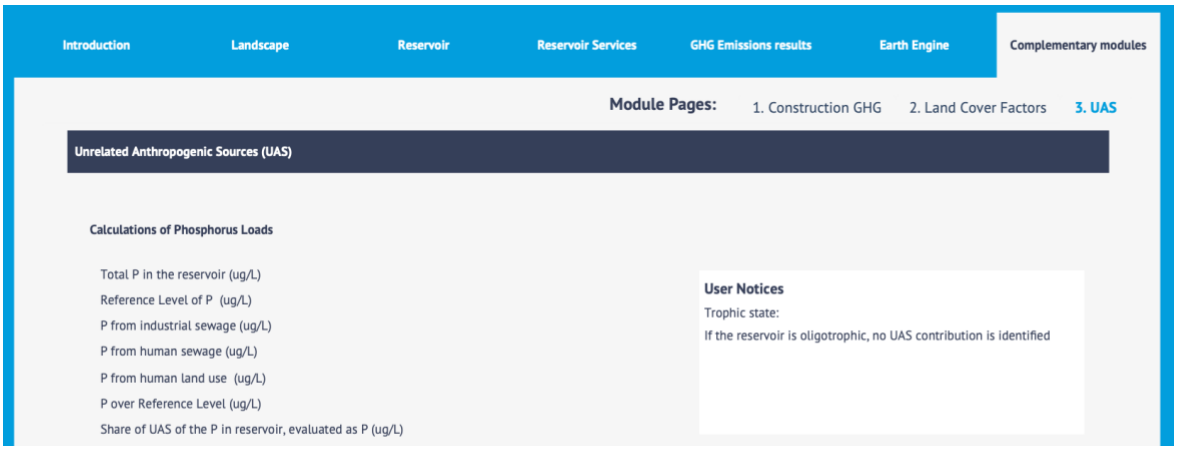
Human activity within the catchment or the reservoir itself may cause an increase in nutrient load to the reservoir. Such activities are intensive land use in agriculture, forestry, fish farming etc. In addition, nutrients leak from settlements and industry through incomplete or missing sewage treatment. The load of nutrients and organic matter that may enrich the trophic state of the reservoir and through the eutrophication ultimately result in increased GHG emissions is called "Unrelated Anthropogenic Sources, UAS".

While it is not possible to directly measure the contribution of UAS to net GHG footprint from the reservoir, we use the share of phosphorus (P) load that exceeds the natural background load as a proxy for the UAS impact. The proportional excess of P load over the estimated natural background thus determines the share of CH_4 resulting from UAS. The distinction of UAS-caused CH_4 emission versus natural background emission in G-res is based on assumptions that are difficult to verify directly in the field. Thus, the interpretation in G-res is only indicative of the possible contribution of UAS to the total CH_4 emission. However, the UAS estimation may be useful in several ways:

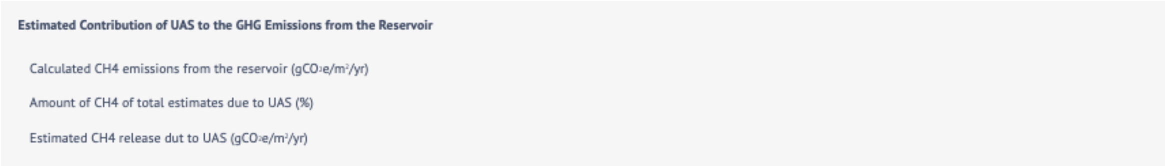
1. Considering the risk of building a reservoir in a catchment that has intensive land use
2. Considering the potential in improving land management and sewage treatment options to prevent eutrophication of the reservoir and thereby mitigating the conditions that may lead to increased GHG emissions. For this purpose, the G-res model could be re-run several times using different sets of land use parameters, including the intensiveness and area of particular land use, or better sewage treatment levels.

The UAS sheet summarises the calculated results for UAS. This is provided to the user for checking and sensitivity analysis.

The upper part of the worksheet presents the calculated phosphorus loads within the reservoir, based on the inputs provided on the Catchment and Reservoir worksheets. This is split based on the assumed source of phosphorus made by G-res. Based on the loads, the trophic state of the reservoir is also identified. The user should check the assumptions in Emission Factors worksheet and compare with any available national or local data where possible.

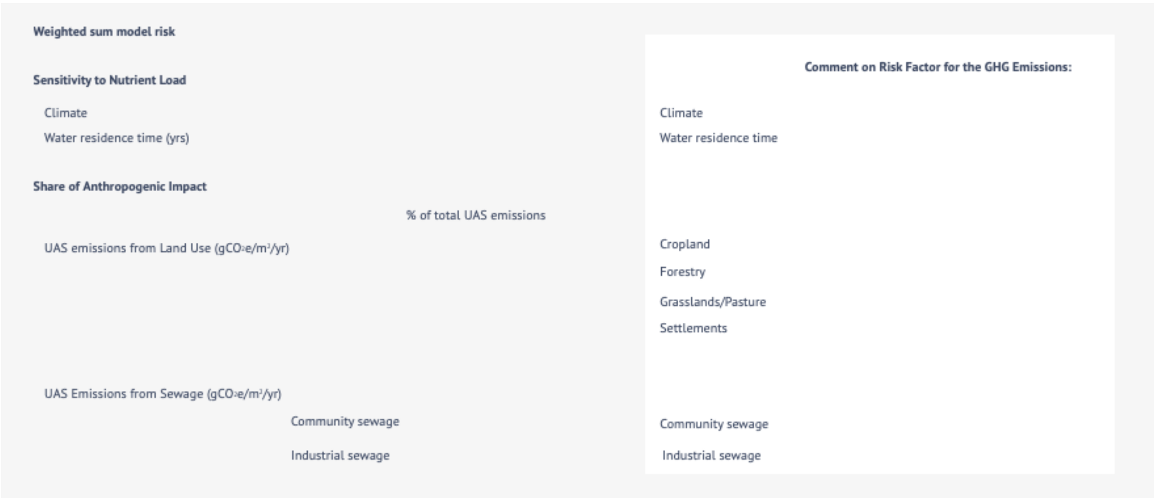


Based on the loads, G-res estimates the contribution of UAS to the GHG footprint from the reservoir. This is presented as the percentage contribution of the gross emissions and the absolute amount of UAS emissions in $gCO_2e/m^2/yr$.



The weighted sum model risk is also reported. This value represents the relative risk that those UAS associated emissions will occur. A full description of how this is calculated is presented in the *G-res tool technical documentation*. This unit is dimensionless and is not comparable between different reservoirs. It can however be used to compare different scenarios for the same reservoir, for example by adjusting the intensity of use for different land cover types or sewage treatment levels. A larger value will then indicate whether the risk of UAS is greater.

The 'Share of Anthropogenic Impact' section presents the percentage of the total GHG emissions that have been attributed to UAS in the model.



The 'Comment on Risk Factor' box notifies the user as to the sensitivity of the land cover types in the catchment to UAS. This signifies if the catchment is prone to producing UAS emissions based on the activities and land cover mix identified. It also indicates, along with the Weighted Sum Model Risk whether further sensitivity analysis might be required.

To include UAS in the footprint calculation, the user needs to tick the Tick to Account for Unrelated Anthropogenic Sources either in the Reservoir GHG or Total GHG Footprint tab.**

14. REFERENCES

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15. ANNEX 1: ADDITIONAL INFORMATION

15.1. Land Cover Categorization of the G-res Tool

The G-res tool uses land cover data for a number of calculations, based on a simplified set of categories. In producing the default values, data from detailed datasets was rationalised into these simplified datasets. Where the user has more detailed land cover data, the below table serves as a guide for how to classify this data into the appropriate, simplified categories used in the G-res tool.

Land cover categories from the European Space Agency (ESA) – Climate Change Initiative (CCI) and the corresponding categories used in the *G-res* tool

ESA – CCI categories	IHA categories
No data	No Data
Cropland, rainfed	Croplands
Cropland, irrigated or post-flooding	Croplands
Tree or shrub cover	Forest
Tree cover, broadleaved, evergreen, closed to open (>15%)	Forest
Tree cover, broadleaved, deciduous, closed to open (>15%)	Forest
Tree cover, broadleaved, deciduous, closed (>40%)	Forest
Tree cover, broadleaved, deciduous, open (15-40%)	Forest
Tree cover, needleleaved, evergreen, closed to open (>15%)	Forest
Tree cover, needleleaved, evergreen, closed (>40%)	Forest
Tree cover, needleleaved, evergreen, open (15-40%)	Forest
Tree cover, needleleaved, deciduous, closed to open (>15%)	Forest
Tree cover, needleleaved, deciduous, closed (>40%)	Forest
Tree cover, needleleaved, deciduous, open (15-40%)	Forest
Tree cover, mixed leaf type (broadleaved and needleleaved)	Forest
Mosaic tree and shrub (>50%) / herbaceous cover (<50%)	Grassland/Shrubland
Mosaic herbaceous cover (>50%) / tree and shrub (<50%)	Grassland/Shrubland
Shrubland	Grassland/Shrubland
Shrubland evergreen	Grassland/Shrubland
Shrubland deciduous	Grassland/Shrubland
Grassland	Grassland/Shrubland
Lichens and mosses	Grassland/Shrubland
Sparse vegetation (tree, shrub, herbaceous cover) (<15%)	Grassland/Shrubland
Sparse shrub (<15%)	Grassland/Shrubland
Sparse herbaceous cover (<15%)	Grassland/Shrubland
Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover) (<50%)	Grassland/Shrubland
Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (<50%)	Grassland/Shrubland
Herbaceous cover	Grassland/Shrubland
Tree cover, flooded, fresh or brakish water	Wetlands
Tree cover, flooded, saline water	Wetlands
Shrub or herbaceous cover, flooded, fresh/saline/brakish water	Wetlands
Urban areas	Settlements
Bare areas	Bare Areas
Consolidated bare areas	Bare Areas
Unconsolidated bare areas	Bare Areas
Water bodies	Water bodies
Permanent snow and ice	Permanent snow and ice

15.2. Construction Module further information

The construction worksheet can be completed in one of three ways:

- Own assessment provides space for the user to input a figure based on their own assessment outside of G-res.
- Basic assessment includes only four key activities and materials that are likely to represent a large proportion of construction phase GHG emissions.
- More detailed assessment includes more granular items to select from in the case that these are known.

Further detail on the meaning of these and how to complete them are described below.

15.2.1. Scoping of assessment

The construction module, in the basic and more detailed assessment sections, calculates the GHG emissions associated with the initial construction materials, the transport of those materials and plant associated with excavation and installation of those materials. In general, users should try to include as much of the infrastructure associated with the reservoir as possible, including the dams and cofferdams, tunnels, powerhouses, intakes, spillways, and any other required infrastructure. Users should note any specific exclusions from their assessment.

The assessment aims to provide an indicative, order-of-magnitude level result which can be used to determine the overall importance of the construction phase. It is not a substitute for a formal assessment of the construction phase. Key activities are included within the basic and more detailed assessment stages however the following are not accounted for:

- Any GHG emissions from site compounds or movement of workers
- Any GHG emissions from maintenance and consumables during operation
- Any GHG emissions associated with deconstruction

Where the user has specific information, they are free to include such source as part of the 'own assessment' method, however it should be noted that when comparing reservoirs that have used different methods within he construction module, there may be slight differences in scope.

G-res uses emission factors that are not specific to any country since the assessment can take place in any location.

15.2.2. Own assessment

In some cases, reservoir schemes may have undertaken their own assessment of the construction phase or some form of life-cycle assessment. Where these are available, this data can be included within G-res.

G-res expects a total $kgCO_2e$ value from the user. This value is then apportioned across a 100-year assumed lifetime of the reservoir. Therefore, the user should make sure than any existing data reflects these parameters. Users should also take note of the scoping noted above. If comparing to another reservoir that has been assessed using the basic or more detailed assessment, it may be necessary to adjust the results of an existing study to match the same scope of activities.

15.2.3. Basic and more detailed assessment

Where no existing GHG studies exist, the user can input specific data about the infrastructure used in the reservoir to create an estimate of the GHG emissions.

G-res expects data to be input based on the amounts of materials used (either in cubic meters, number of or tonnes of) for a range of different items. This data can typically be found from the following types of data sources:

- Bills of quantities or bills of materials; these are typically produced for projects at various stages of development to inform the cost of a scheme. They often provide reasonably detailed information about the key materials and plant required for a given scheme, often in the units that are required in G-res. In some cases, conversion rates might be needed to match the expected input units of G-res (for example, concrete might be included in tonnes, and therefore would need to be converted to cubic meters to be used in G-res, done by dividing by the typical density of that concrete).
- Drawings, which can be used to provide estimates of the dimensions of the various elements of infrastructure which can then be used to determine the volumes and/or masses of each item.
- The Feasibility Study or Environmental Impact Assessment for the scheme may include information on amounts of materials either in a specific GHG section or possibly in the project description, materials, transport, or waste management sections.
- Existing LCA studies could be used and scaled to match a proposed project, which may provide information on the amounts of materials required.
- Asset registers may contain information for existing reservoirs of the assets held and may include sizes, weights, and numbers of various aspects of a reservoir's infrastructure.

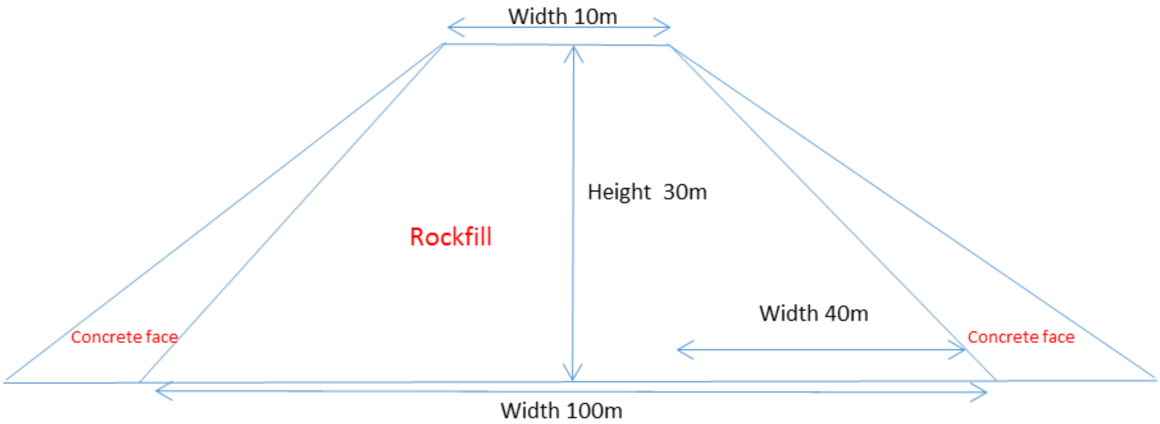
It may be easier to use a mixture of the Basic and More Detailed Assessment approaches, for example it may be easier to estimate the transmission line using the More Detailed Assessment than the Basic Assessment.

15.2.4. Example of how to complete the worksheet

Input example 1: Basic Assessment

In this example, the user would have limited information about the infrastructure required. Three inputs are required: earth and rockfill, concrete and steel, which comprise the most likely materials.

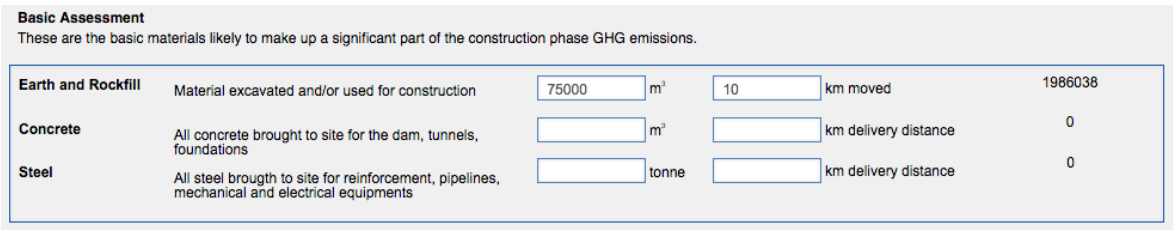
Data may be available from several sources, as noted above. If there is no existing information, the following approach could be used. Assuming that the reservoir was formed using an embankment dam, the user can estimate the approximate volume of material required using the dimensions of the dam. Assuming a uniform shape across the length, the volume of materials can be calculated by taking a cross section, calculating the area of each component (e.g. the bulk materials) and then multiplying by the length.



For example, considering the dam as a structure as per the above, the user can calculate the relative amounts of materials required. For the rockfill, the cross-sectional area can be estimated as:

[10m x 30m] + 2 x [0.5 x 40m x 30m] = 1500m^2

This can then be multiplied by the length of the dam – if it is 50m long, then this would total 75,000m^3 of rockfill material. This can then be input into G-res.


Basic Assessment
These are the basic materials likely to make up a significant part of the construction phase GHG emissions.

Earth and Rockfill	Material excavated and/or used for construction	75000	m³	10	km moved	1986038
Concrete	All concrete brought to site for the dam, tunnels, foundations		m³		km delivery distance	0
Steel	All steel brougth to site for reinforcement, pipelines, mechanical and electrical equipments		tonne		km delivery distance	0

Similarly, this can be done for concrete and steel. Users should consider the approximate amounts of material in the dam, tunnels, powerhouse, and other assets, following a similar approach to the above if information does not exist on the amounts of those materials in the project.

Input example 2: More Detailed Assessment

For a reservoir with a gravity dam and tunnels, the amount of concrete used is know to be 80,000m³ for the dam, and 50,000m³ for the tunnel. Using the basic assessment, this can be combined and included in the Basic Assessment part of the worksheet. However it is known that in this example the tunnel used reinforced concrete.

Using the More Detailed Assessment box, the tunnel concrete can be included in the reinforced concrete input box. The concrete for the dam can then be either left in the Basic Assessment box, or it can be included in the More Detailed assessment box its type is know. G-res will add all of the inputs no matter which section they are included in.

Basic Assessment

These are the basic materials likely to make up a significant part of the construction phase GHG emissions.

Earth and Rockfill	Material excavated and/or used for construction		m^3		km moved	0
Concrete	All concrete brought to site for the dam, tunnels, foundations	80000	m^3	50	km delivery distance	28685800
Steel	All steel brougth to site for reinforcement, pipelines, mechanical and electrical equipments		tonne		km delivery distance	0

More Detailed Assessment

This provides a more detailed list of typical materials used. Use these values if you have more detailed information about the types of material used on the scheme.

Earthworks	Soft Excavation		m^3		km moved	0
	Rock Excavation		m^3		km moved	0
	Clearance and Removals		ha			0
Fill	Granular Fill		m^3		km delivery distance	0
	Rock Armour		m^3		km delivery distance	0
	Zoned Rockfill		m^3		km delivery distance	0
	Rock bolts		number		km delivery distance	0
Concrete Works	Formwork		m^2			0
	Facing Concrete		m^3		km delivery distance	0
	Mass Concrete		m^3		km delivery distance	0
	Reinforced Concrete	50000	m^3	100	km delivery distance	22863750
	Shotcrete		m^2		km delivery distance	0

Input example 3: From a bill of materials

The bill of materials is likely to be a good source of information for the amounts of materials required. An example extract might look like this example:

Item No.	Item	No off	Unit	Quantity
3	**Concrete work**			
3.1	Concrete in crane beams	1	m^3	3,200
3.2	First stage concrete in power house	1	m^3	6,000
3.3	Second stage concrete in power house	1	m^3	38,700.0
3.4	Concrete in transformer hall	1	m^3	49,000
3.5	Concrete in galleries	1	m^3	1,500
3.6	Concrete in tailrace	1	m^3	22,000
3.7	Concrete in power house Control building	1	m^3	1,160
3.8	Precast concrete	1	m^3	1,700
3.9	Reinforcement steel bars, grade 60	1	Tonne	16,500

The user can use this information to populate the construction worksheet. For example, in the above the concrete and the reinforcement are separated. The concrete quantities in row 3.1 to 3.8 can be added together (123,260m³). The reinforcement quantity is already stated. The user can then input these values into G-res:

Concrete Works	Formwork		m^2			0
	Facing Concrete		m^3		km delivery distance	0
	Mass Concrete	123260	m^3	100	km delivery distance	33511313
	Reinforced Concrete		m^3		km delivery distance	0
	Shotcrete		m^2		km delivery distance	0
	Reinforcement	16500	tonne	200	km delivery distance	46900590