Database documentation: ctd (Fisheries Oceanography)

K. A. Mackay & W. J. Taylor

NIWA Fisheries Data Management
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Revision History

Version	Change	Date	Person responsible
1.0	Initial version as Marine Research database documentation 4: ctd (Fisheries Oceanography). *MAF Fisheries Internal Report No. 202.*	1993	Warrick Taylor
1.1	Conform to database standards in Ng 1992		K Mackay
1.2	?	21 Dec 2002	K Mackay
2.0	Postgres version	May 2016	D Fisher, F Wei

This revision history page was only added in May 2016 so may not include all the intermediate revision versions between version 1.0 and 2.0.

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1 Introduction to the Database Document series

The National Institute of Water and Atmospheric Research (NIWA) currently carries out the role of Data Manager and Custodian for the fisheries research data owned by the Ministry for Primary Industries (MPI) formerly the Ministry of Fisheries.

This MPI data set, incorporates historic research data, data collected by MAF Fisheries prior to the split in 1995 of Policy to the Ministry of Fisheries and research to NIWA, and data collected by NIWA and other agencies for the Ministry of Fisheries and subsequently for MPI.

This document is a brief introduction to the fisheries oceanography database **ctd**, and is part of the database documentation series produced by NIWA. It supersedes the previous documentation by Taylor (1993) on this database.

All documents in this series include an introduction to the database design, a description of the main data structures accompanied by an Entity Relationship Diagram (ERD), and a listing of all the main tables. The ERD graphically shows how all the tables link together and their relationship with other databases.

This document is intended as a guide for users and administrators of the **ctd** database.
This database has been implemented as a schema within the Postgres database called **fish**.

2 Fisheries Oceanography Database

2.1 Data sources

The **ctd** (fisheries oceanography) database contains some physical oceanography data collected during trips conducted by the Marine Research Group of the Ministry of Agriculture and Fisheries, and later NIWA. Much of the data collected were obtained using a conductivity, temperature, and depth (CTD) probe, hence the name of the database. The data on the **ctd** database were collected during trips conducted between 1982 and 1993, and from 2002 onwards. It may be necessary to alter the structure of the database later to allow for the storage of data from mechanical bathythermographs (MBT) and expendable bathythermographs (XBTs).

The database has been set up in accordance with Marine Research Computing database standards (Ng 1992).

2.2 Uses of the ctd Database

Physical oceanographic features such as thermoclines and upwellings affect the distribution and availability of fish. Data from the **ctd** database can be used to locate and study the nature of water masses, currents and temperature fronts. These data can also be used to describe the physical environment where fish are found.

The **ctd** database is designed to be used in conjunction with other data collected during research trips, such as catch rates, catch composition, etc, to assist in the interpretation of trends in species abundance. Since these data also span a range of seasons and years in many areas of New Zealand they can also assist in trip planning.

2.3 Trip, cruise, or voyage?

Over the years, trawl surveys have been labelled many things. In the last few years research surveys have been called “trips”, “cruises” or “voyages”, but all represent the same thing.

As a consequence, while the trawl database labels all trawl surveys and associated tables with the word “trip”, the words “cruise” or “voyage” can just as easily be substituted, and similarly for **ctd**.

3 Data Structures

3.1 Table relationships

This database contains several tables. The ERD for **ctd** (Figure 1) shows the logical structure[1] of the database and it’s entities (each entity is implemented as a database *table)* and relationships between these tables and tables in other databases. This schema is valid regardless of the database system chosen, and it can remain correct even if the Database Management System (DBMS) is changed. Each table represents an object, event, or concept in the real world that has been selected to be represented in the database. Each *attribute* of a table is a defining property or quality of the table. All of the table’s attributes are shown in the ERD. The underlined attributes represent the table’s primary key[2].

Note that Figure 1 shows the main tables only. Note that most tables contain foreign keys[3]. These foreign keys define the relationships between the tables in **ctd**.

The **ctd** database is implemented as a relational database; i.e., each table is a special case of the mathematical construct known as a *relation* and hence elementary relation theory is used to deal with the data within tables and the relationships between them. There are three types of relationships possible between tables, but only one exists in **ctd**: one-to-many[4]. These relationships can be seen in ERDs by connecting a single line (indicating ‘many’) from the child table; e.g., *t_bottle_casts*, to the parent table; e.g., *t_station,* with an arrowhead (indicating ‘one’) pointing to the parent.

Every relationship has a mandatory or optional aspect to it. If a relationship is mandatory, then it has to occur at least once, while an optional relationship might not occur at all. For example, in Figure 1, consider that relationship between the table *t_station* and it’s child table *t_bottle_casts.* The symbol ‘o’ by the child *t_bottle_casts* means that a station can have zero or many bottle cast records, while the bar by the parent *t_station* means that for every bottle cast record there must be a matching station record.

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[1] Also known as a database *schema.*
[2] A primary key is an attribute or a combination of attributes that contains an unique value to identify that record.
[3] A foreign key is an attribute or a combination of attributes that is a primary key in another table.
[4] A one-to-many relationship is where one record (the *parent*) in a table relates to one or many records (the *child*) in another table; e.g., one trip in *t_trip* can have many stations in *t_station* but one station can only come from one trip.

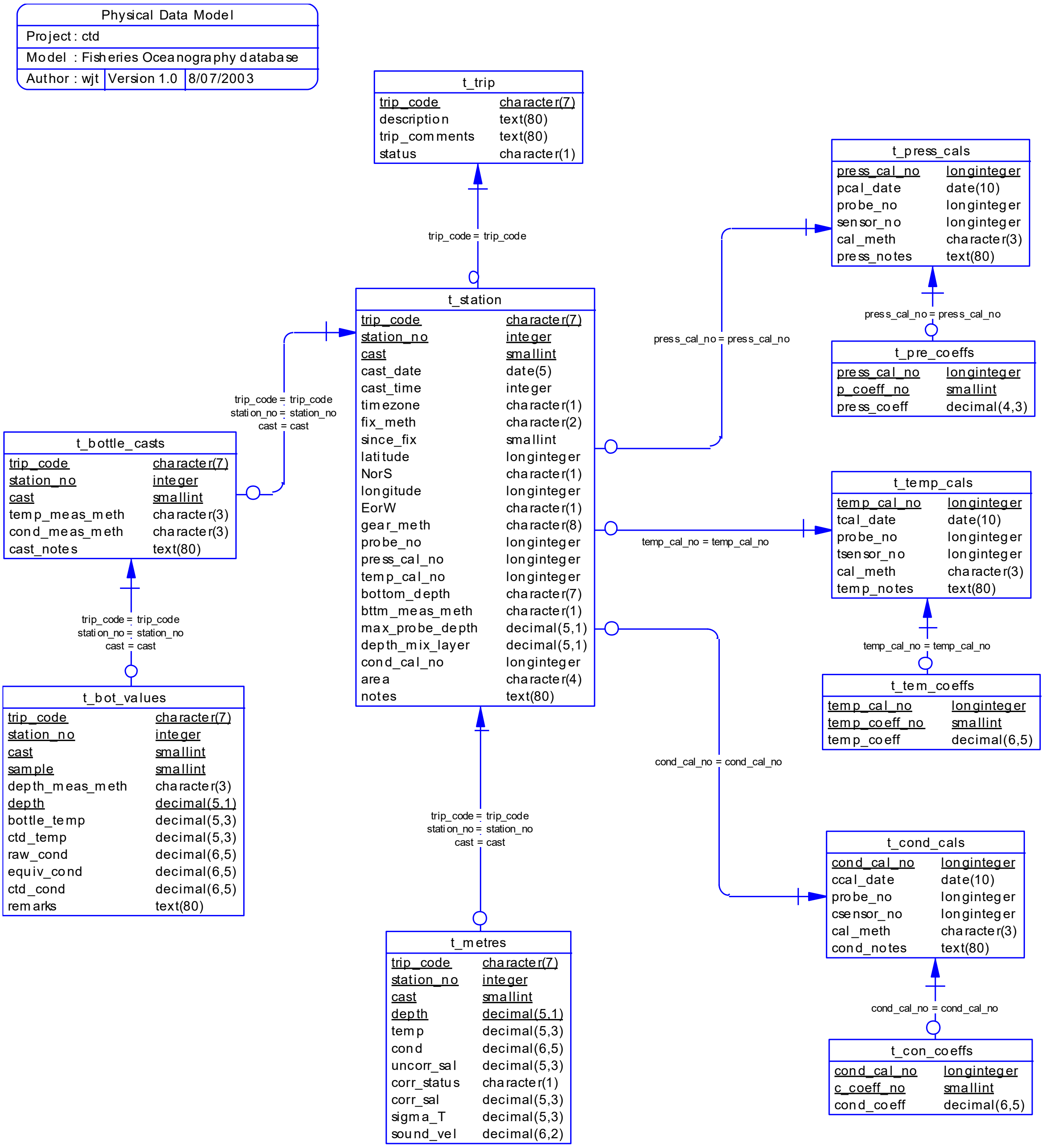

Table 1: Entity Relationship Diagram (ERD) for the ctd database.

These links are enforced by foreign key constraints[5]. These constraints do not allow *orphans* to exist in any table; i.e., where a child record exists without a related parent record. This may happen when: a parent record is deleted; the parent record is altered so the relationship is lost; or a child record is entered without a parent record

These constraints are shown in the table listings by the following format:

Foreign-key constraints:

"foreign key name" FOREIGN KEY (attribute[,attribute]) REFERENCES
parent table (attribute[, attribute])

Note that the typographical convention for the above format is that square brackets [] may contain more than one item or none at all. Items stacked between vertical lines | | are options of which one must be chosen.

For example, consider the following constraint found in the table *t_station*:

Foreign-key constraints:
"fk_t_station_t_trip" FOREIGN KEY (trip_code) REFERENCES t_trip(trip_code)

This means that the value of the attribute *trip_code* in the current record must already exist in the parent table *t_trip* or the record will be rejected and an error message will be displayed:

For tables residing in external databases, the parent table name will be prefixed by the name of the database.

Section 5 lists all the **ctd** tables as implemented by the Postgres RDBMS. As can be seen in the listing of the tables, most tables have a primary key. Primary keys are generally listed using the format:

Indices: index_name PRIMARY KEY, btree (*attribute* [, *attributes*])

where attribute(s) make up the primary key and the index name is the primary key name. These prevent records with null or duplicate key values from being inserted into the tables; e.g., a record with an existing trip code.

The database listing (Section 5) show that the tables also have indices on many attributes. That is, attributes that are most likely to be used as a searching key have like values linked together to speed up searches. These indices are listed using the following format:

Indices: index_name btree (*attribute*)

Note that indices may be simple, pointing to one attribute or composite pointing to more than one attribute.

[5] Also known as referential constraints or integrity checks.

3.2 Database design

Physical oceanography data are collected from casts[6] conducted at stations during a trip.

The table *t_trip* (Table 1) lists trips during which oceanographic data were collected, with a brief description and the processing status for each voyage. The processing status indicates whether all relevant data that can be recovered from a voyage have been loaded into the database.

There is generally only one cast at each station, but occasionally, such as when there are comparisons between instruments or where there are gear problems, there can be more than one. For each cast data such as station position, date, time, gear methods used, bottom depth, maximum probe depth and mixed layer depth are recorded. These data are contained in table *t_station* (Table 2). Records exist on *t_station* for almost every trip in *t_trip*. However, there are trips from which the data could not be recovered so there are no records on *t_station* for these.

The type, amount and accuracy of data collected depend on the gear used in a cast. Vertical profiles of temperature can be obtained from each cast. Mechanical bathythermographs (MBTs) and expendable bathythermographs (XBTs) give continuous temperature profiles. From casts where a CTD probe is used or where water samples are collected, vertical profiles of salinity as well a temperature can be obtained.

The gear methods used in a cast are held in *gear_meth* on *t_station*. This attribute is defined as a string of up to three two-digit code numbers, each code number being equal to and having the same meaning as a value of *code* in table *meth_codes*, the method codes table in the **rdb** database. This allows for situations where different gear methods were used during one cast. However, *gear_meth* cannot be a foreign key to *meth_codes* because it is defined as a string and may contain more than one code. This is a departure from third normal form. It would be possible to create a table with one record for each cast and gear method, but there would be difficulty in the selection of data where gear methods were specified and more than one method was used in a cast.

If a method of position fixing is known for a station the attribute *fix_method* must be a valid code equal to a value of *fix_method_code* in the table *t_fix_method_codes* on the **rdb** database. Similarly, if an area exists on a record on *t_station,* then it must be a valid area code as listed in the table *area_codes* on the **rdb** database.

CTD probes provide effectively continuous temperature and conductivity data throughout a cast. Summarised temperature, conductivity, salinity, specific gravity anomaly (σ_t) and speed of sound data at 1-metre depth intervals are on table *t_metres* (Table 3). This table is linked to *t_station* and has a primary key of *trip_code*, *station_no*, *cast*, and *depth*. It is a large table, with over 1 million records. In many cases it is sufficient to obtain data from standard depths (ie. 10, 20, 30, 50, 75, 100, 125, 150, 200, 250, 300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, 1500, 1750 and 2000 metres). To obtain these data more quickly a view, *v_std_depths* (Section 5.12), has been created on the table *t_metres* that contains the same data as *t_metres* but only at the standard depths listed above.

Discrete temperature and salinity data can be obtained by bottle hydrocasts. These casts are listed in *t_bottle_casts* (Table 4), which is linked to the table *t_station* and has a primary key of *trip_code*, *station_no*, and *cast*. Temperature data are collected using reversing thermometers. The mercury

[6] A cast is an event where oceanographic instruments are deployed to obtain measurements at depth.

column of a reversing thermometer is broken by suddenly flipping the thermometer when it has reached the desired depth, thereby recording temperature at that depth. On many casts a CTD probe was also deployed so the more accurate temperature measurements would have come from the CTD. The more accurate method used to measure temperature in each bottle cast is held in *t_bottle_casts*. The accuracy of the measurement of the salinity (or conductivity) of water samples depends on the salinometer used, so this information is also contained in the table.

Temperature and conductivity values in bottle casts and the method for measuring depth at which each sample was taken are listed in *t_bot_values* (Table 5). This table has a primary key of *trip_code*, *station_no*, *cast*, *depth* and *sample*, and is linked to the table *t_bottle_casts*. The accuracy of measurement of depth depends on the method by which depth was determined. The method of measuring depth may change during a cast so each record on *t_bot_values* has a code for depth measurement method. These methods are discussed in Appendix A. If a CTD probe was used with bottles, then CTD temperature and conductivity values corresponding to the depths at which water samples were taken are also listed on this table as are the conductivity values of the water samples, back-calculated to the pressures and temperatures at which the samples were obtained.

For trips where casts used a CTD probe in association with bottle sampling, CTD conductivity can be calibrated against conductivity of the water samples, using values from *t_bot_values*. These calibrations may change between stations because occasionally the conductivity sensor response may change suddenly. For this reason *t_station* has a foreign key, *cond_cal_no*, to table *t_cond_cals* (Table 6). The table *t_cond_cals* lists the date and method of each calibration of each conductivity sensor and is linked to *t_con_coeffs* (Table 7), which shows the conductivity correction coefficients derived from each calibration.

Pressure and temperature sensors are periodically calibrated in a laboratory. The correction coefficients from these calibrations are applied to the pressure and temperature as measured by the CTD probe when the data are being initially processed.

If a CTD probe was used in the cast, pressure and temperature calibration numbers (*press_cal_no* and *temp_cal_no*) will be listed. These are foreign keys to *t_press_cals* (Table 8) and *t_temp_cals* (Table 9) respectively. These tables provide information on calibration date and method and provide links to the tables *t_pre_coeffs* (Table 10) and *t_tem_coeffs* (Table 11), which list the pressure and temperature correction coefficients respectively. These coefficients are used to correct raw CTD pressure and temperature data when they are being summarised.

4 Table Summaries

The **ctd** database has 11 tables and one view. The tables are briefly described below:

1. **t_trip :** Trips where physical oceanography data were collected.
2. **t_station :** Information on each station and cast in each voyage.
3. **t_metres :** Temperature, conductivity, salinity, specific gravity anomaly and speed of sound information for each 1 metre of depth in a cast producing nearly continuous data (downcast only). There is a view on this table, v_std_depths.
4. **t_bottle_casts :** Casts using water sampling bottles and measurement methods used.
5. **t_bot_values :** Temperature and conductivity values from each sample in a bottle cast and, where applicable, CTD values from the same cast at the same depth.
6. **t_cond_cals :** Regressions (calibrations) of conductivity of water samples against conductivity as measured by CTD conductivity sensors.
7. **t_con_coeffs :** Conductivity correction coefficients from conductivity calibrations.
8. **t_press_cals :** Calibrations of CTD pressure sensors.
9. **t_temp_cals :** Calibrations of CTD temperature sensors.
10. **t_pre_coeffs :** Pressure correction coefficients from pressure calibrations.
11. **t_tem_coeffs :** Temperature correction coefficients from temperature calibrations.
12. **v_std_depths :** Contains data from *t_metres* at 10, 20, 30, 50, 75, 100, 125, 150, 200, 250, 300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, 1500, 1750 and 2000 metres.

5 ctd Tables

The following are listings of the tables in the **ctd** database, including attribute names, data types (and any range restrictions), and comments.

5.1 Table 1: t_trip

```
Comment: Gives a brief description of each trip where temperature and/or
salinity profiles were obtained. The description includes species being
targeted (if any) and area. The table also contains comments on data and an
indication of whether data have been loaded onto the database.
```

Column	Type	Null?	Description
trip_code	character varying(7)	No	Trip code - 3-character vessel name, 2-digit year and 2-digit trip number.
description	text		Brief description of purpose of trip and area or areas surveyed.
trip_comments	text		Notes on processing of trip data and/or reliability of data, including missing data and methods of calibration.
status	character(1)		Indicates whether loading of physical oceanography data (i.e., CTD or other data related to temperature and salinity casts) for this trip has been completed: y = all data for this voyage that can be recovered at time of processing have been loaded onto the database; n = loading of data has not been completed for this voyage.

```
Indexes:
   "pk_t_trip" PRIMARY KEY, btree (trip_code)
Check constraints:
   "status_check" CHECK (status::text = 'y'::text
    OR status::text = 'n'::text)
   "t_trip_trip_code_check" CHECK
    (trip_code::text ~ '[a-z0-9][a-z0-9][a-z0-9][0-9][0-9][0-9][0-9]'::text)
Referenced by:
   TABLE "ctd.t_station" CONSTRAINT "fk_t_station_t_trip" FOREIGN KEY
   (trip_code)   REFERENCES ctd.t_trip(trip_code)
```

5.2 Table 2: t_station

Comment: Identifying and descriptive features of each station.

Column	Type	Null?	Description
trip_code	character varying(7)	No	Trip code - 3-character vessel name, 2-digit year and 2-digit trip number.
station_no	smallint	No	Sequential number for each station in the voyage.
cast_no	smallint	No	Number of the cast at the station. There is usually only one cast per station, but occasionally there are more due to trials of gear, comparisons or gear malfunctions.
cast_date	date		Date of cast.
cast_time	smallint		Time of cast (24 hour format). This is usually the start time of the cast.
timezone	character varying(1)		1 character code for the timezone used for the cast time: D = NZDT, S = NZST, Z = Zulu (GMT).
fix_meth	character varying(2)		Method of fixing position. For method codes refer to rdb.t_fix_meth_codes.
since_fix	smallint		Time between the last position fix made and the time the cast was performed, in minutes. This attribute is often null as the time since the last fix was often not noted, or the advent of GPS with continuous navigation fixes has made it redundant.
latitude	integer		Latitude of the cast (DDMMmm format) where the last 4 digits are minutes and hundredths of minutes. E.g., 453480 is 45 degrees 34.80 minutes.
nors	character varying(1)		Hemisphere of latitude: N = north, S = south.
longitude	integer		Longitude of the cast (DDDMMmm format) where the last 4 digits are minutes and hundredths of minutes. E.g., 1743480 is 174 degrees 34.80 minutes.

eorw	character varying(1)	Hemisphere of longitude: E = east, W = west.
gear_meth	character varying(8)	Type of measurements made. This attribute can contain up to 3 method codes separated by commas. The codes are defined below: 80 = Nansen bottle hydrocast, 82 = CTD only, 83 = rosette only, 84 = CTD and rosette, 85 = MBT, 86 = XBT, 88 = MOCNESS CTD.
probe_no	integer	Digits of serial number of CTD probe.
press_cal_no	integer	Identification number of pressure sensor calibration used for the CTD probe in the cast.
temp_cal_no	integer	Identification number of temperature sensor calibration used for the CTD probe in the cast.
bottom_depth	character varying(7)	Bottom depth in metres.
bttm_meas_meth	character varying(7)	1-character code for the method used to determine the bottom depth: C = read off a chart (often a rough estimate), S = echo sounder (often accurate to 1 metre).
max_probe_depth	numeric(5,1)	Deepest depth reached in cast rounded down to the nearest metre. This is usually recorded only for CTD probes.
depth_mix_layer	numeric(5,1)	Depth of mixed layer, defined as the depth which the rate at which temperature decreases with depth equals or exceeds 0.5 degrees Celsius in 10 m. Generally, if this depth is less than 10 m then it is considered that no mixed layer exists and the attribute is null. However, there are exceptions to this, e.g. bays, sounds, etc.
cond_cal_no	integer	Identification number of conductivity correction used for cast.

area	character varying(4)	Area in which cast took place. This must be a valid 4 character area code as listed in the rdb.area_codes table. Areas are not well defined and for many stations this attribute is null.
notes	text	Notes on data, methods or conditions at the station.
dlat	numeric(7,5)	Latitude of vessel in decimal degree.
dlon	numeric(8,5)	Longitude of vessel in decimal degree.
position	geometry	Position of vessel as gis point type.

```
Indexes:
   "pk_t_station" PRIMARY KEY, btree (trip_code, station_no, cast_no)
Check constraints:
   "enforce_dims_position" CHECK (public.ndims("position") = 2)
   "enforce_geotype_position" CHECK (geometrytype("position") =
    'POINT'::text OR "position" IS NULL)
   "enforce_srid_position" CHECK (public.srid("position") = 4326)
   "t_station_bttm_meas_meth_check" CHECK (bttm_meas_meth::text ~
    '[CS]'::text)
   "t_station_cast_time_check" CHECK (cast_time IS NULL OR cast_time >= 0
    AND cast_time <= 2359)
   "t_station_eorw_check" CHECK (eorw::text ~ '[EW]'::text)
   "t_station_latitude_check" CHECK (latitude IS NULL OR latitude::text ~
    '[2-7][0-9][0-5][0-9][0-9][0-9]'::text)
   "t_station_longitude_check" CHECK (longitude IS NULL OR longitude::text ~
    '1[4-8][0-9][0-5][0-9][0-9][0-9]'::text)
   "t_station_nors_check" CHECK (nors::text ~ '[NS]'::text)

Foreign-key constraints:
   "fk_t_station_area_codes" FOREIGN KEY (area)
    REFERENCES rdb.area_codes(code)
   "fk_t_station_t_cond_cals" FOREIGN KEY (cond_cal_no)
    REFERENCES ctd.t_cond_cals(cond_cal_no)
   "fk_t_station_t_fix_meth_codes" FOREIGN KEY (fix_meth)
    REFERENCES rdb.t_fix_meth_codes(fix_meth_code)
   "fk_t_station_t_press_cals" FOREIGN KEY (press_cal_no)
    REFERENCES ctd.t_press_cals(press_cal_no)
   "fk_t_station_t_temp_cals" FOREIGN KEY (temp_cal_no)
    REFERENCES ctd.t_temp_cals(temp_cal_no)
   "fk_t_station_t_trip" FOREIGN KEY (trip_code)
    REFERENCES ctd.t_trip(trip_code)
Referenced by:
   TABLE "ctd.t_bottle_casts" CONSTRAINT "fk_t_bottle_casts_t_station"
    FOREIGN KEY (trip_code, station_no, cast_no)
   REFERENCES ctd.t_station(trip_code, station_no, cast_no)
```

5.3 Table 3: t_metres

Comment: Table of temperature, conductivity, salinity and sigmaT data in whole metre slices. Data is from downcast only.

Column	Type	Null?	Description
trip_code	character varying(7)		Trip code - 3-character vessel name, 2-digit year and 2-digit trip number.
station_no	smallint	No	Sequential number for each station in the trip.
cast_no	smallint		Number of the cast at the station. There is usually only one cast per station, but occasionally there are more due to trials of gear, comparisons or gear malfunctions.
depth	numeric(5,1)	No	Depth in metres.
temp	numeric(5,3)		Temperature in degrees Celsius.
cond	numeric(6,5)		Conductivity ratio = conductivity of water in metre slice as measured by conductivity sensor : conductivity of standard seawater at 0 m at 15 degrees Celsius.
uncorr_sal	numeric(5,3)		Salinity according to International Practical Salinity Scale 78 (IPSS-78) without correction from calibration being applied.
corr_status	character varying(1)	No	Status of correction of salinity data for cast. C = salinity corrected. N = salinity not corrected; i.e., calibration not possible or calibration not performed. Y = calibration possible but correction not applied as yet.
corr_sal	numeric(5,3)		Salinity according to International Practical Salinity Scale, after correction found by calibration has been applied. Except where otherwise stated, calibration is performed by back-calculating conductivities of water samples collected in bottles to conductivities at the pressures and temperatures when the samples were collected, and comparing these conductivities

		with in situ conductivities as measured by the CTD.
sigma_t	numeric(5,3)	Specific gravity anomaly. If both corrected and uncorrected salinities are available sigmaT is calculated using corrected salinity; otherwise uncorrected salinity is used to calculate sigmaT.
sound_vel	numeric(6,2)	Speed of sound through water (m/s).

```
Indexes:
   "nx_t_metres_trip_code" btree (trip_code)
Check constraints:
   "t_metres_temp_check" CHECK (temp IS NULL OR temp >= (-2.000) AND temp <=
                                            30.000)
```

5.4 Table 4: t_bottle_casts

Comment: Table listing rosette or Nansen bottle casts. The table gives methods used for measuring depth, temperature and salinity as well as notes on accuracy of data or variations in measuring depth.

Column	Type	Null?	Description
trip_code	character varying(7)	No	Voyage code - 3-character vessel name, 2-digit year and 2-digit trip number.
station_no	smallint	No	Sequential number for each station in the voyage.
cast_no	smallint	No	Number of the cast at the station. There is usually only one cast per station, but occasionally there are more due to trials of gear, comparisons or gear malfunctions.
temp_meas_meth	character varying(3)		Method used to measure water temperatures during the cast. This attribute gives the more accurate method used if both CTD and reversing thermometers were used. Codes are: CTD = CTD TEM = reversing thermometers.
cond_meas_meth	character varying(3)		Salinometer used to determine salinity of seawater samples. Codes are: FRC = Autolab salinometer NOI = NZOI/MRC Guildline Autosal 8400 salinometer.
cast_notes	text		Remarks on cast. These often include an indication of variation in methods used to measure depth during the cast, such as the use of protected and unprotected thermometers at given depths.

```
Indexes:
   "pk_t_bottle_casts" PRIMARY KEY, btree
    (trip_code, station_no, cast_no)

Foreign-key constraints:
   "fk_t_bottle_casts_t_station" FOREIGN KEY (trip_code, station_no,
    cast_no) REFERENCES ctd.t_station(trip_code, station_no, cast_no)
Referenced by:
   TABLE "ctd.t_bot_values" CONSTRAINT "fk_t_bot_values_t_bottle_casts"
    FOREIGN KEY (trip_code, station_no, cast_no)
    REFERENCES ctd.t_bottle_casts(trip_code, station_no, cast_no)
```

5.5 Table 5: t_bot_values

Comment: Table containing depth, temperature and conductivity data from Nansen bottle and rosette casts. Corresponding data from the CTD probe are also included where the CTD probe was used at the same position and time. These data can be used to calibrate CTD conductivity against conductivity of samples collected in sample bottles.

Column	Type	Null?	Description
trip_code	character varying(7)	No	Voyage code - 3-character vessel name, 2-digit year and 2-digit trip number.
station_no	smallint	No	Sequential number for each station in the voyage.
cast_no	smallint	No	Number of the cast at the station. There is usually only one cast per station, but occasionally there are more due to trials of gear, comparisons or gear malfunctions.
sample	smallint	No	Number of sample at the give depth for a cast. There is usually only one sample for each depth in a cast, but occasionally more than one bottle may be tripped to collect samples.
depth_meas_meth	character varying(3)		Method of determining depth at which sample was taken and/or thermometers were reversed. Codes are: CTD = CTD probe (accurate to about 0.5 m over 1000 m, but greater accuracy at shallower depths). CWA = cosine of wire angle (accuracy in the order of metres). MBC = metre block counter reading (not as accurate as cosine of wire angle). PUT = determined from difference between readings of protected and unprotected thermometers (accuracy in the order of metres if thermometer readings are accurate).
depth	numeric(5,1)	No	Depth at which water samples were taken and/or thermometers tripped. Accuracy of depth is dependent on the measurement method used.
bottle_temp	numeric(5,3)		Temperature as measured by protected reversing thermometer

		after thermometer corrections (for index and expansion of mercury and glass) have been applied. Accuracy is at best + or - 0.01 degrees Celsius, but is often less.
ctd_temp	numeric(5,3)	Temperature as measured by CTD at depth given. This is usually done by interpolating data that are averages of temperature over depths of about 1 metre. Accuracy of the CTD temperature is about + or - 0.03 degrees Celsius.
raw_cond	numeric(6,5)	Conductivity of hydrocast or rosette bottle sample water as measured by the salinometer (generally at 15 degrees Celsius near or at sea level).
equiv_cond	numeric(6,5)	Conductivity of bottle sample back-calculated to the in situ pressure and temperature where the sample was collected. Some error may be introduced during back-calculation.
ctd_cond	numeric(6,5)	Conductivity ratio as measured by CTD probe.
remarks	text	Notes on any errors that may occur (eg. loose tops on salinity sample bottles), or on any change in method of determining values (eg. finding raw conductivity by back-calculating salinity).

```
Indexes:
   "pk_t_bot_values" PRIMARY KEY, btree
    (trip_code, station_no, cast_no, depth, sample)
Check constraints:
   "t_bot_values_ctd_cond_check" CHECK
    (ctd_cond IS NULL OR ctd_cond >= 0.60000 AND ctd_cond <= 1.20000)
   "t_bot_values_raw_cond_check" CHECK
    (raw_cond IS NULL OR raw_cond >= 0.80000 AND raw_cond <= 1.20000)

Foreign-key constraints:
   "fk_t_bot_values_t_bottle_casts" FOREIGN KEY (trip_code, station_no,
   cast_no) REFERENCES ctd.t_bottle_casts(trip_code, station_no, cast_no)
```

5.6 Table 6: t_cond_cals

Comment: Information on each calibration of CTD conductivity against conductivity of rosette or hydrocast samples. These calibrations are made so that the conductivity measured by the CTD conductivity sensor can be corrected. Corrected conductivity is then used to calculate corrected salinity.

Column	Type	Null?	Description
cond_cal_no	integer	No	Identification number of conductivity calibration.
ccal_date	date	No	Date on which conductivity correction coefficients were determined. NB. This is neither the date of the voyage nor the date that the conductivity of water samples was measured.
probe_no	integer	No	Serial number of probe to which the calibration relates.
csensor_no	integer	No	Serial number of conductivity sensor to which calibration relates.
cal_meth	character varying(3)		Which salinometer - NOI = NZOI/FRC Guildline Autosal 8400. FRC = Autolab salinometer. SBD = Sea-Bird SBE37.
cond_notes	text		Remarks about conductivity calibration method, data or results.

```
Indexes:
   "pk_t_cond_cals" PRIMARY KEY, btree (cond_cal_no)
Referenced by:
   TABLE "ctd.t_con_coeffs" CONSTRAINT "fk_t_con_coeffs_t_cond_cals"
   FOREIGN KEY (cond_cal_no) REFERENCES ctd.t_cond_cals(cond_cal_no)
   TABLE "ctd.t_station" CONSTRAINT "fk_t_station_t_cond_cals"
   FOREIGN KEY (cond_cal_no) REFERENCES ctd.t_cond_cals(cond_cal_no)
```

5.7 Table 7: t_con_coeffs

Comment: Coefficients used to correct the conductivity as measured by the conductivity sensor are listed in this table. Corrected conductivity is found by using a polynomial of the form: Cc = c0 + c1Cr + c2Cr ** 2 + ... + cnCr ** n . Where: Cc is corrected conductivity, Cr is raw conductivity, and c0, c1, c2, etc, are the correction coefficients listed in this table.

Column	Type	Null?	Description
cond_cal_no	integer	No	Identification number of conductivity calibration.
c_coeff_no	smallint	No	Which coefficient in correction equation. E.g., 0 denotes that the coefficient is the constant term.
cond_coeff	numeric(6,5)	No	Value of conductivity correction coefficient.

```
Indexes:
   "pk_t_con_coeffs" PRIMARY KEY, btree (cond_cal_no, c_coeff_no)

Foreign-key constraints:
   "fk_t_con_coeffs_t_cond_cals" FOREIGN KEY (cond_cal_no)
    REFERENCES ctd.t_cond_cals(cond_cal_no)
```

5.8 Table 8: t_press_cals

Comment: Information about each pressure sensor calibration.

Column	Type	Null?	Description
press_cal_no	integer	No	Identification number of pressure sensor calibration.
pcal_date	date	No	Date of pressure calibration.
probe_no	integer	No	Serial number of probe to which the calibration relates.
sensor_no	integer	No	Serial number of pressure sensor that was calibrated.
cal_meth	character varying(3)	No	Site or organisation where pressure sensor was calibrated. Codes are: MAN = manufacturer PEL = former Physics and Engineering Laboratory. (now Industrial Research Ltd, Gracefield). NOI = NZ Oceanographic Institute.
press_notes	text		Remarks about pressure calibration method, data or results.

```
Indexes:
   "pk_t_press_cals" PRIMARY KEY, btree (press_cal_no)
Referenced by:
   TABLE "ctd.t_pre_coeffs" CONSTRAINT "fk_t_pre_coeffs_t_press_cals"
    FOREIGN KEY (press_cal_no) REFERENCES ctd.t_press_cals(press_cal_no)
   TABLE "ctd.t_station" CONSTRAINT "fk_t_station_t_press_cals"
    FOREIGN KEY (press_cal_no) REFERENCES ctd.t_press_cals(press_cal_no)
```

5.9 Table 9: t_temp_cals

Comment: Information on each temperature sensor calibration. Calibrations of probe 45656 up to calibration number 1006 and those of probe 49088 up to calibration number 5 were performed according to International Practical Temperature Scale 68 (IPTS-68). Later calibrations were performed according to International Temperature Scale 90 (ITS-90). To calculate salinity according to the International Salinity Scale (ITSS-78) using temperature measured according to ITS-90, it is necessary to convert these temperatures to IPTS-68 temperatures using the formula: T68 = 1.00024*T90.

Column	Type	Null?	Description
temp_cal_no	integer	No	Identification number of temperature sensor calibration.
tcal_date	date	No	Date of temperature sensor calibration.
probe_no	integer	No	Serial number of probe to which the calibration relates.
tsensor_no	integer	No	Serial number of temperature sensor that was calibrated.
cal_meth	character varying(3)	No	Site or organisation where temperature sensor was calibrated. Codes are: MAN = manufacturer. PEL = former Physics and Engineering Laboratory (now Industrial Research Ltd, Gracefield). NOI = NZ Oceanographic Institute.
temp_notes	text		Remarks on temperature calibration method, data, or result.

```
Indexes:
   "pk_t_temp_cals" PRIMARY KEY, btree (temp_cal_no)
Referenced by:
   TABLE "ctd.t_station" CONSTRAINT "fk_t_station_t_temp_cals"
    FOREIGN KEY (temp_cal_no) REFERENCES ctd.t_temp_cals(temp_cal_no)
   TABLE "ctd.t_tem_coeffs" CONSTRAINT "fk_t_tem_coeffs_t_temp_cals"
    FOREIGN KEY (temp_cal_no) REFERENCES ctd.t_temp_cals(temp_cal_no)
```

5.10 Table 10: t_pre_coeffs

Comment: Pressure corrections used in summarising raw CTD data are found by using a polynomial whose coefficients are listed in this table. The polynomial is of the form Pc = p0 + p1Pr + p2Pr**2 +... + pnPr ** n where Pc is corrected pressure, Pr is raw pressure and p0, p1, p2, etc, are the correction coefficients. NB. Depth data in the database that were obtained by CTD observations were calculated using corrected pressure.

Column	Type	Null?	Description
press_cal_no	integer	No	Identification number of pressure sensor calibration.
p_coeff_no	smallint	No	Which coefficient in correction formula. Eg. 0 denotes that the coefficient is the constant term.
press_coeff	real		Value of coefficient.

```
Indexes:
   "pk_t_pre_coeffs" PRIMARY KEY, btree (press_cal_no, p_coeff_no)

Foreign-key constraints:
   "fk_t_pre_coeffs_t_press_cals" FOREIGN KEY (press_cal_no)
    REFERENCES ctd.t_press_cals(press_cal_no)
```

5.10 Table 10: t_tem_coeffs

Comment: Temperature correction used in summarising raw CTD data are found by using a polynomial whose coefficients are listed in this table. The polynomial is of the form Tc = t0 + t1Tr + t2Tr**2 +.. + tnTr**n where: Tc is corrected temperature, Tr is raw temperature, and t0, t1, t2, etc, are the correction coefficients. NB. Temperature data in the database that were obtained by CTD probes have already had the corrections applied to them.

Column	Type	Null?	Description
temp_cal_no	integer	No	Identification number of temperature sensor calibration.
temp_coeff_no	smallint	No	Which coefficient in correction equation. E.g., 0 denotes that the coefficient is a constant.
temp_coeff	real		Value of temperature correction coefficient.

Indexes:
"pk_t_tem_coeffs" PRIMARY KEY, btree (temp_cal_no, temp_coeff_no)

Foreign-key constraints:
"fk_t_tem_coeffs_t_temp_cals" FOREIGN KEY (temp_cal_no) REFERENCES ctd.t_temp_cals(temp_cal_no)

5.12 View 1: v_std_depths

```
Comment: Contains data from t_metres at 10, 20, 30, 50, 75, 100, 125, 150,
         200, 250, 300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1200,
         1300, 1400, 1500, 1750 and 2000 metres.

Column          Type                    Null?

trip_code       character varying(7)

station_no      smallint

cast            smallint

depth           numeric(5,1)

temp            numeric(5,3)

cond            numeric(6,5)

uncorr_sal      numeric(5,3)

corr_status     character varying(1)

corr_sal        numeric(5,3)

sigma_t         numeric(5,3)

sound_vel       numeric(6,2)

View definition:
SELECT t_metres.trip_code, t_metres.station_no, t_metres.cast_no AS "cast",
t_metres.depth, t_metres.temp, t_metres.cond, t_metres.uncorr_sal,
t_metres.corr_status, t_metres.corr_sal, t_metres.sigma_t,
t_metres.sound_vel
  FROM ctd.t_metres
 WHERE t_metres.depth = 10::numeric OR t_metres.depth = 20::numeric OR
t_metres.depth = 30::numeric OR t_metres.depth = 50::numeric OR
t_metres.depth = 75::numeric OR t_metres.depth = 100::numeric OR
t_metres.depth = 125::numeric OR t_metres.depth = 150::numeric OR
t_metres.depth = 200::numeric OR t_metres.depth = 250::numeric OR
t_metres.depth = 300::numeric OR t_metres.depth = 400::numeric OR
t_metres.depth = 500::numeric OR t_metres.depth = 600::numeric OR
t_metres.depth = 700::numeric OR t_metres.depth = 800::numeric OR
t_metres.depth = 900::numeric OR t_metres.depth = 1000::numeric OR
t_metres.depth = 1100::numeric OR t_metres.depth = 1200::numeric OR
t_metres.depth = 1300::numeric OR t_metres.depth = 1400::numeric OR
t_metres.depth = 1500::numeric OR t_metres.depth = 1750::numeric OR
t_metres.depth = 2000::numeric;
```

6 References

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5. Stanton, B.R. and Singleton, R.J. 1973: Routine Physical Oceanographic Data Reduction Using a Programmable Desk Calculator. *NZOI Misc Pub 73 1980.* 4 p.

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Appendix

A Derivation of Physical Quantities

A.1 Depth Using Cosine of Wire Angle

Depths in this database, which have been ascertained using cosine of wire angle (CWA), are determined by multiplying the length of cable payed out by the cosine of the wire angle, and adding 0.5. If the wire angle is less than 5° the depth can be taken as the length of wire payed out. Where therometric measurements were made on the same cast the depth can be determined more accurately by finding the ratio of the depth found by reversing thermometers to the depth found by cosine of wire angle, and multiplying by the latter depth. This method has not been used to find depth data for the database.

A.2 Depth and Temperature Using Reversing Thermometers

A.2.1 Temperature

For both protected and unprotected thermometers corrections must be applied to the reading of the main thermometer to allow for index error, which results from any incorrect etchings on the scale and any variations in capillary width.

Corrections are then applied for to allow for thermal expansion of the thermometers after they have been reversed. The corrections for protected thermometers are given by:

$$C_p = \frac{(V_o + T')(T' - t)}{K - (V_o + T') - (T' - t)}$$

and for unprotected thermometers:

$$C_u = \frac{(V_o + T')(T_w - t)}{K - (T_w - t)}$$

where:

V_o	=	volume of mercury (in below 0° C) when thermometer is reversed
K	=	reciprocal of coefficient of thermal expansion of the thermometer glass
T'	=	main thermometer reading after index correction has been applied
t	=	auxiliary thermometer reading after index correction has been applied
T_w	=	corrected protected thermometer reading; i.e. water temperature at depth of reversal (Stanton and Singleton 1980).

A.2.2 Depth

The protected thermometer reads the actual temperature of the water whereas the hydrostatic pressure of the water affects the reading of the unprotected thermometer. Once the corrected protected thermometer reading T_p and the unprotected thermometer reading T_u are known, the depth of reversal (D) can be calculated from:

$$D = \frac{T_u - T_w}{\rho_m Q}$$

where:

ρ_m	=	mean density of water column above depth of reversal.
Q	=	pressure coefficient of individual unprotected thermometer, i.e. the rate of increase in apparent temperature with pressure.

However ρ_m varies with depth and location. Using a constant value for ρ_m at 1000 m of 1.0294 kg.m^{-3} a more accurate value of D can be found using the formula:

$$D = D' + \Delta D$$

where:

$$D' = \frac{T_u - T_p}{1.0294\,Q}$$

and ΔD = correction due to change in ρ_m with depth from its value at 1000 m.

According to Stanton and Singleton (1980), ΔD can be approximated by the quadratic expression:

$$\Delta D = 2.6\left(1 - \frac{D'}{1000}\right)\frac{D'}{1000}$$

A.3 Depth and Temperature Data from Bathythermographs

A mechanical bathythermograph has pressure and temperature sensors that activate a pen that makes a trace on a gold or smoked glass slide. Depth and pressure can be read off the slide with the aid of a scale produced for the specific instrument being used.

The temperatures from an expendable bathythermograph are obtained by reading from a chart or from digital data depending on the system used. Depth is obtained by taking an assumed rate of descent.

A.4 Physical Quantities Derived from the CTD Probe

A.4.1 Initial Processing of Data

Pressure, temperature and conductivity ratio data are sampled by the CTD control unit every 40 milliseconds. Data in a slice of about 1 dbar are averaged. Any data value that deviates from the preceding and succeeding data values by a given amount is not included in the average. The deviations allowed for each quantity are:

pressure	± 0.2 dbar
temperature	± 0.005 ºC
conductivity ratio	± 0.004

The formulae below can also be used for calculating salinity and σ_t for bottle samples whose conductivity has been measured by a laboratory salinometer where the temperature is usually 15 ºC.

A.4.2 Depth

Depth (*D*) is calculated from pressure (*P*) and latitude expressed in radians (*radlat*) using Saunders' Method (Saunders 1981):

$$D = ((1.0 - c1) - c2P)P + \frac{dh}{9.8}$$

where:

$c1 = (5.92 + 5.25(\sin^2(radlat))1000$
$c2 = 2.21E - 6$
dh = dynamic height anomaly (at present set to 0).

(From source code written by Michael Moore, NZOI, 20 August 1986.)
This method differs from the standard UNESCO formula by less than 1 m over 7000 m.

A.4.3 Calculation of the Conductivity Ratio

Historically, CTD probes have reported conductivity as a ratio to a standard seawater sample and this is reflected in the database schema. Later CTD probes, such as the Sea Bird S-37, report the conductivity in units of either mmho/cm or (S/m). In order to load these later readings into the database, the conductivity readings must be converted to the conductivity ratio. The value for conductivity for standard seawater at 35 ppt, 15 degrees C, and 0 pressure [C(35,15,0)] was not agreed upon in the IEEE reports--Culkin & Smith used 42.914 mmho/cm (p 23), while Poisson used 42.933 mmho/cm (p 47). It really does not matter which value is used, provided that the same value is used during data reduction that was used to compute instrument calibration coefficients. The CTD database ratios are computed using C(35,15,0) = 4.2914 S/m. **If you are working in conductivity units of Siemens/meter (S/m), multiply your conductivity values by 10 before using the PSS 1978 equations**.

A.4.4 Salinity

Salinity (S) is calculated from pressure (P), temperature (T) and conductivity (R) using the following method.

Let C = conductivity and $R = \frac{C(S,T,P)}{C(35,15,0)} = r_t(T)R_t(S,t)R_p(R,T,P)$

Now:

$$r_t(T) = \frac{C(35,t,0)}{c(35,15,0)} = \sum_{n=0}^{4} C_n T^n$$

where:

$C_0 = 0.06766097$ $\quad C_3 = -6.9698E\text{-}7$
$C_1 = 2.00564E\text{-}2$ $\quad C_4 = 1.0031E\text{-}9$
$C_5 = 1.104252E\text{-}4$

And:

$$R_p = 1 + \frac{e_1 P + e_2 P^2 + e_3 P^3}{1 + d_1 T + d_2 T^2 + (d_3 + d_4 T)R}$$

where:

$e_1 = 2.070E\text{-}5$ $\quad d_1 = 3.426E\text{-}2$
$e_2 = -6.370E\text{-}10$ $\quad d_2 = 4.464E\text{-}4$
$e = 3.989E\text{-}15$ $\quad d_3 = 4.215E\text{-}1$
$d_4 = -3.107E\text{-}3$

so given R, T and P, R_t can now be calculated using:

$$R_t = \frac{R}{R_p r_t}$$

Salinity can then be calculated using the formula:

$$S = \sum_{n=0}^{5} [a_n + \frac{\Delta T}{1 + k\Delta T}] R_t^{n2}$$

(Joint Panel on Oceanographic Tables and Standards 1991).

A.4.5 Derivation of Specific Gravity Anomaly σ_t

The specific gravity anomaly σ_t is defined as the difference between the density of the water sample at atmospheric pressure $\rho_{S,T}$ in g.cm^{-3} multiplied by 1000.
i.e., from McLellan (1968):

$$\sigma_t = [(\rho_{S,T}) - 1]1000$$

or

$$\sigma_t = (\frac{\rho}{\rho_m} - 1)1000$$

where ρ_m = the maximum density or pure water, which was accepted by 1 g.cm^{-3}. However, the Equation of State of Seawater (EOS-80) defines a density anomaly (γ) as:

$$\gamma = \rho - 1000$$

and the accepted value of density of standard mean ocean water (SMOW) is ρ = 999.975 kg.m^{-3} so:

$$\gamma = 0.999975\,\sigma_t - 0.025$$

(from Joint Panel on Oceanographic Tables and Standards 1991).

σ_t is still an acceptable measure of density anomaly and is calculated using the formula:

$$\sigma_t = \rho(S, t, 0)$$

where:

$$\rho = A + BS + CS^{3/2} + DS^2$$

The coefficients *A*, *B*, *C* and *D* are polynomials in temperature (*T*) and are listed in Table 1:

	A	*B*	*C*	*D*
T^0	999.8425944	8.24493E-1	-5.72466E-3	+ 4.8314E-4
T^1	6.793952E-2	4.0899E-3	1.0227E-4	
T^2	-9.095290E-3	7.6438E-5	-1.6546E-6	
T^3	1.001685E-4	-8.2467E-7	+5.3875E-9	
T^4	-1.120083E-6			
T^5	6.536332E-9			

Table 2: Temperature Coefficient s for the calculation of σ_t

B Data Accuracy

Accuracy of data on the database varies greatly and depends on the measurement methods used. Table 2 shows the accuracy of measurement of depth, temperature and salinity using different gear methods. The gear methods are listed down the side of the table and the physical quantities are listed along the top. Some quantities may be measured using different techniques for the same gear type (e.g. in a messenger bottle cast depth may be measured in three different ways). The body of the table contains accuracy of measurement and any variations in accuracy due to the measurement techniques used.

Note that according to Intergovernmental Oceanographic Commission Standards salinity is defined against a single reference point (S = 35), which has the same electrical conductivity as a reference potassium chloride solution with a temperature of 15 °C at atmospheric pressure, and is no longer measured in parts per thousand (from Joint Panel on Oceanographic Tables and Standards 1991).

Method	**Physical Quantity**		
	Depth	**Temperature (°C)**	**Salinity**
Bottle Casts	• Metre block counter (MBC) ± 10% (10m or more at depth[a]. • Cosine of wire angle ± 5% (10m or more at depth)[b]. • Protected and unprotected thermometers (PUT) ± 5m down to 1000m, 5% at depths >1000m[c].	• Usually ± 0.02°C, can be as good as ± 0.01°C	• Autolab salinometer ± 0.010[d] • Guildline Autosal 8400 salinometer ± 0.002[e]
CTD Probe	± 0.15% (<2m at 2000m)[e]	± 0.005°C[e]	± 0.005 after calibration against water samples[e], ± 0.005 otherwise[f]
MOCNESS CTD	± 5m[e]	± 0.1[e]	Not yet tested.
MBT[g]	± 1%	± 0.5	
XBT[e] ***Mechanical recording*** ***Electronic recording***	 ± 2% (a few metres) ± 2% (a few metres)	 ± 0.2 ± 0.1	

Table 3: Accuracy of depth, temperature, and salinity data acquired using various methods.

[a] Estimate only. If the wire angle is less than 5° the length of wire can be used as a measure of depth.
[b] Estimate based on deviation from correct depth at maximum wire angle of 20°, taking no account of variations in subsurface currents.
[c] 0.01°C given in Sverdrup *et al* (1942) but thermometer performance may change with time.
[d] Anthony Cole, NIWA, *pers. comm*.
[e] Manufacturer's Manual
[f] This is the largest difference between CTD and rosette salinities that has been found from calibration against bottle samples at Greta Point.
[g] From a set of locally-produced instructions on calibrating the MBT.