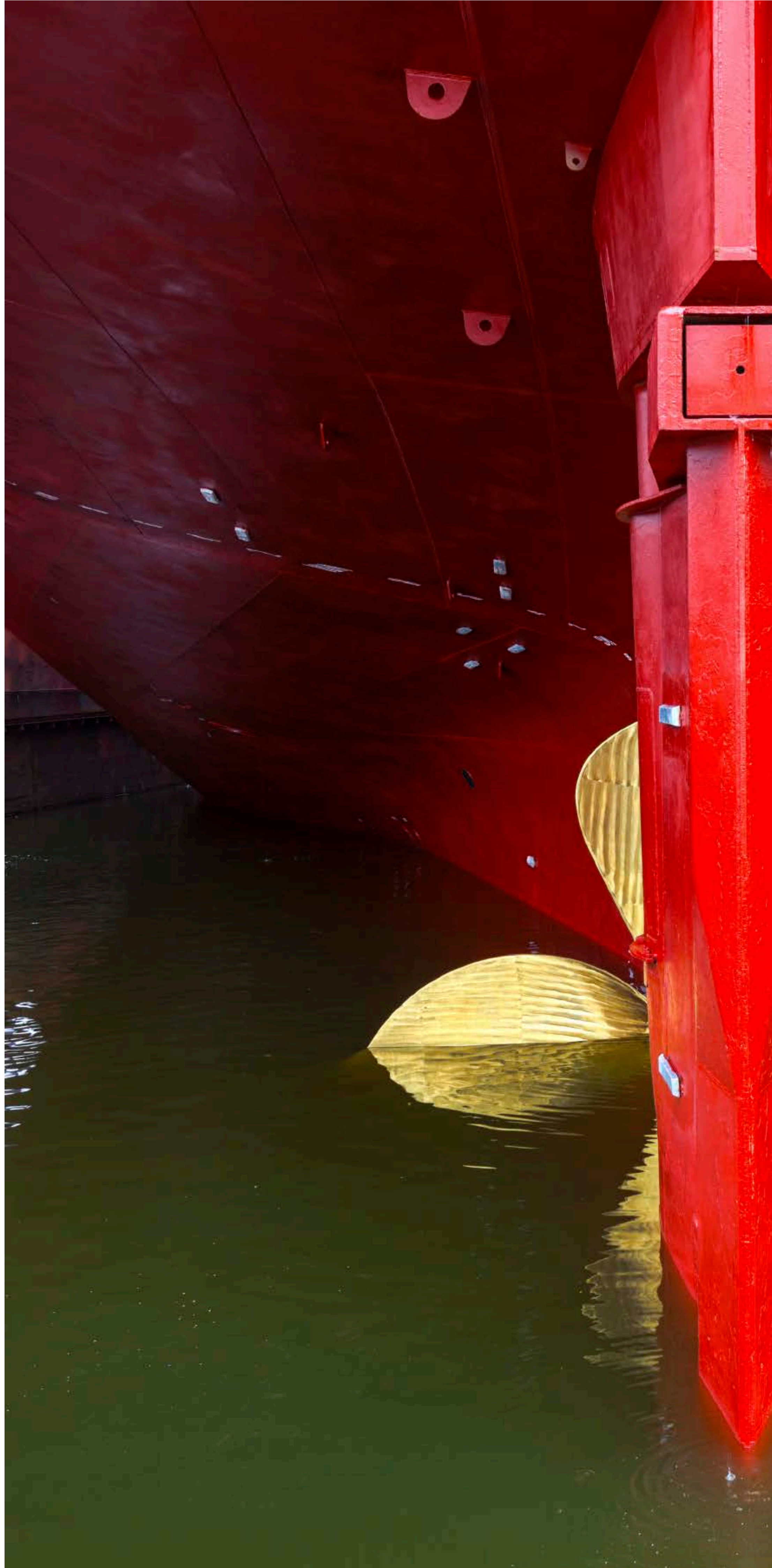
Marine Management Organisation

Technical Annex: Modelled Mapping of Continuous Underwater Noise Generated by Activities

August 2015



Technical Annex: Modelled Mapping of Continuous Underwater Noise Generated by Activities

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Contents

Figures

Tables

1. Introduction

This technical annex has been prepared by ABP Marine Environmental Research Ltd (ABPmer) on behalf of the Marine Management Organisation (MMO). It presents technical information that has supported the development of a Geographic Information System (GIS) tool that can produce indicative data for mapping the distribution of continuous anthropogenic underwater noise generated by activities in the south marine plan areas.

1.1 Technical annex structure

This technical annex has been structured as follows:

Section 1	Introduction – presents the overall aim of the project and technical annex structure
Section 2	Collation of Noise Sources and Hearing Thresholds – presents the data that have been collated and have informed the development of the GIS tool
Section 3	Logical Data Process Model - describes the detail of the noise propagation ArcGIS Toolbox including all tools, inputs to the model and outputs generated
Section 4	ArcGIS geodatabase schemas – presents the schemas for the four geodatabases which accompany the tool and the feature classes which are used within the tool or are created by the tool.

2. Collation of Noise Sources and Hearing Thresholds

A literature review was undertaken to identify and categorise the range of natural ambient and anthropogenic continuous noise sources that are relevant to the south marine plan areas. The literature review has drawn on ABPmer's existing in-house library of underwater noise references together with searches using scientific databases and internet search tools such as 'Google Scholar'. The outputs of the literature review have helped to identify significant anthropogenic continuous noise sources in the UK marine area that could be taken into account in a continuous underwater noise mapping GIS tool.

2.1 Anthropogenic continuous noise sources

A range of anthropogenic continuous noise sources have been collated as part of the literature review and are presented in Table 1. Information on the noise generated by operational offshore wind farms structures and oil and gas installations has also been collated, while noting that these do not currently occur in the south marine plan areas at present. The full range of noise sources of anthropogenic activities and sub-activities (in brackets) that have been collated are as follows:

- dredging (backhoe dredger, clamshell dredger, cutter suction dredger, suction dredger, trailer suction hopper dredger)
- drilling exploration (drilling production, jack-up, semi-submersible)
- fishing (trawler trawling)
- military (low-frequency sonar, mid-frequency sonar)
- offshore wind (operational turbine)
- oil and gas (operational platform and support vessel)
- recreation (inflatable boat with outboard motor, jet ski, speed boat)
- shipping (boat, bulk cargo/carrier, container, fishing boat/trawler, oceanographic vessel, offshore oil production vessel, passenger, ship, supertanker, tanker/freighter, tug and barge, vehicle carrier, work boat).

Table 1: Anthropogenic continuous noise sources that have been collated from available literature.

Activity	Sub-activity	Source level		Frequency (Hz)		Vessel length (m)	Vessel speed (knots)	Engine (type/ size)	Other Information	Confidence (H/M/L)
		Value	Units (metric)	Range	Peak					
Dredging	Backhoe dredger	163	dB re 1µPa^{2}m^2	20-20,000	35-45	-	-	-	Excavation of material	M
Dredging	Backhoe dredger	179	dB re 1µPa^{2}m^2	3-20,000	315	-	-	-	Removing fractured rock	M
Dredging	Backhoe dredger	168-186	dB re 1µPa m (RMS)	30 ->20,000	100-500	-	-	-	Omni-directional Continuous	M
Dredging	Clamshell dredger	150-162	dB re 1µPa m (SPL)	10-1,000	-	-	-	-		H
Dredging	Cutter Suction Dredger	175	dB re 1µPa^{2}m^2	-	<2,500	-	-	-	Fracturing rock.	L
Dredging	Cutter Suction Dredger	160-180	dB re 1µPa m (SPL)	10-1000	-	-	-	-		M
Dredging	Cutter Suction Dredger	172-185	dB re 1µPa m (RMS)	30->20,000	100-500	-	-	-	Continuous Omni-directional	M
Dredging	Suction dredger	160	dB re 1µPa m	-	380	-	-	-		H
Dredging	Trailer Suction Hopper Dredger	187	dB re 1µPa^{2}m^2	30-63,000	40-500	-	-	-	Sand extraction	M
Dredging	Trailer Suction Hopper Dredger	150-170	dB re 1µPa m (SPL)	-	-	-	-	-	UKD Bluefin	L
Dredging	Trailer Suction Hopper Dredger	184-188	dB re 1µPa^{2}m^2	-	100-500	-	-	-	Sand extraction	M
Dredging	Trailer Suction Hopper Dredger	186-188	dB re 1µPa m (RMS)	30->20,000	100-500	-	-	-	Continuous Omni-directional	M
Drilling Exploration	Drilling production	163	dB re 1µPa m	-	250	-	-	-		H
Drilling Exploration	Jack-up	59	dB re 1µPa m	45-7,070	16	-	-	-	Sedco J jack-up rig	M
Drilling Exploration	Jack-up	85-127	dB re 1µPa m	5-1,200	-	-	-	-		H
Drilling Exploration	Semi-submersible	167-171	dB re 1µPa m	16-200	-	-	-	-		H
Fishing	Trawler trawling	147	dB re 1µPa m	40-1,000	100	-	5	-		M
Military	Low-frequency sonar	215	dB re 1µPa m (0-pk)	100-500	-	-	-	-	Duration (600-1,000ms) Horizontally focussed	M

Activity	Sub-activity	Source level		Frequency (Hz)		Vessel length (m)	Vessel speed (knots)	Engine (type/ size)	Other Information	Confidence (H/M/L)
		Value	Units (metric)	Range	Peak					
Military	Low-frequency sonar	235	dB re 1µPa m (0-pk)	100-500	-	-	-	-	Duration (6s-100s) Horizontally focussed	H
Military	Low-frequency sonar	240	dB re 1µPa m (0-pk)	100-500	-	-	-	-	Duration (6s-100s) Horizontally focussed	M
Military	Mid- frequency sonar	235	dB re 1µPa m	2,000-8,000	-	-	-	-	Duration (2s) Horizontally focussed	H
Military	Mid- frequency sonar	223-235	dB re 1µPa m (0-pk)	2,800-8,200	3,500	-	-	-	Duration (500-2,000ms) Horizontally focussed	M
Offshore wind	Operational turbine	142	dB re 1µPa m (RMS)	16-20,000	30-200	-	-	-	Continuous Omni-directional	M
Offshore wind	Operational turbine	151	dB re 1µPa m	-	-	-	-	-	Swedish Baltic Sea Wind speed 13ms^{-1}	L
Offshore wind	Operational turbine	151	dB re 1µPa m	60-300	-	-	-	-		H
Offshore wind	Operational turbine	153	dB re 1µPa m	-	16	-	-	-	Individual turbines of relatively low power (<1 MW).	M
Offshore wind	Operational turbine	73-99	dB re 1µPa m	30-1,600	400	-	-	-		M
Oil and gas	Operational platform and support vessel	196	dB re 1µPa m	10-100,000	100-300	-	-	-	Recorded at 5m depth Support vessel in close proximity to platform	M
Oil and gas	Operational platform and support vessel	226	dB re 1µPa m	10-100,000	100-300	-	-	-	Recorded at 10m depth Support vessel in close proximity to platform	M
Recreation	Boat	150	dB re 1µPa m	-	-	-	5	18hp outboard		L
Recreation	Boat	152	dB re 1µPa m	-	-	4	20	25hp outboard		L
Recreation	Boat	156	dB re 1µPa m	-	-	7	20	2 x 80hp outdrive		L
Recreation	Boat	156	dB re 1µPa m	-	-	8	10	260hp outdrive		L
Recreation	Boats	>175	dB re 1µPa	-	-	-	-	Large outboard	Small boats	L
Recreation	Inflatable	152	dB re 1µPa m	-	6,300	-	-			M

Activity	Sub-activity	Source level		Frequency (Hz)		Vessel length (m)	Vessel speed (knots)	Engine (type/ size)	Other Information	Confidence (H/M/L)
		Value	Units (metric)	Range	Peak					
Recreation	Inflatable	156	dB re 1µPa m	-	6,300	5	-		Zodiac	M
Recreation	Inflatable	105-130	dB re 1µPa m	800-20,000	-	-	-	6hp outboard		H
Recreation	Jet ski	75-125	dB re 1µPa m	800-20,000	-	-	-	650cc		H
Recreation	Jet ski	75-125	dB re 1µPa m	800-50,000	-	-	-	650cc		H
Recreation	Speedboat	156	dB re 1µPa m	-	630	7	-			M
Recreation	Speedboat	110-130	dB re 1µPa m	800-20,000	-	-	-	90hp outdrive		H
Recreation	Tour boat	150	dB re 1µPa m	-	-	20	10	-		L
Recreation	Whaler	153	dB re 1µPa m	-	-	4	20	20hp outboard	Boston whaler	L
Recreation	Zodiac	152	dB re 1µPa m	-	-	5	20	20hp outboard		L
Shipping	Boat	157	dB re 1µPa m (SPL)	10->10,000	60-500	18.6	9.1	-	Modelled source depth 1.25m	M
Shipping	Boat	160	dB re 1µPa m	1,000-5,000	-	-	20	-	Small boat, outboard engine	H
Shipping	Boat	164	dB re 1µPa m (SPL)	10->10,000	60-500	7.8	15.6	-	Modelled source depth 0.5m	M
Shipping	Boats and ships	160-180	dB re 1µPa m (RMS)	20->10,000	>1,000	-	-	-	Omni-directional Continuous Small and medium sized boats and ships	L
Shipping	Bulk cargo ship	178-192	dB re 1µPa m (SPL)	-	<500	-	-	-		H
Shipping	Bulk carrier	175	dB re 1µPa m	10-40,000	25	173	-	Direct drive low-speed diesel engine	Propeller rotation rate 68rpm	H
Shipping	Bulk carrier	185	dB re 1µPa m	10-40,000	25-200	173	-	Direct drive low-speed diesel engine	Propeller rotation rate 140rpm	H
Shipping	Bulk carriers	184-187	dB re 1µPa m	-	20-1,000	167-229	14	-		H

Activity	Sub-activity	Source level		Frequency (Hz)		Vessel length (m)	Vessel speed (knots)	Engine (type/ size)	Other Information	Confidence (H/M/L)
		Value	Units (metric)	Range	Peak					
Shipping	Car carrier	162	dB re 1µPa m	-		190	16	-		L
Shipping	Cargo vessel	192	dB re 1µPa m	40-100	-	173	16	-		H
Shipping	Chemical product tankers	177-185	dB re 1µPa m	-	20-1,000	148-182	10-16	-		H
Shipping	Container ship	169	dB re 1µPa m	-	-	210	19	-		L
Shipping	Container ship	171	dB re 1µPa m	1-120,000	-	300	-	-	Low speed Vessel CMA CGM Verlaine Clear and calm with minimal wind speeds	M
Shipping	Container ship	181	dB re 1µPa m	-	33	219	-	-		M
Shipping	Container ship	181	dB re 1µPa m	-	8	274	-	-		H
Shipping	Container ship	186	dB re 1µPa m	1-120,000	-	129	-	-	Low speed Vessel Vega Stockholm Calm with minimal wind speeds	M
Shipping	Container ship	198	dB re 1µPa m	-	23	274	-	-		M
Shipping	Container ship	169-173	dB re 1µPa m	1-120,000	-	335	-	-	Low speed Vessel Kyoto Express Very calm with minimal wind speeds	M
Shipping	Container ship	184-188	dB re 1µPa m	20-1,000	-	294-298	21	-		H
Shipping	Crew boat	156	dB re 1µPa m	-	-	16	-	-		L
Shipping	Crude oil tanker	179-182	dB re 1µPa m	-	20-1,000	229-243	14-16	-		H
Shipping	Cruise ship	168	dB re 1µPa m	-	-	-	19	-		L
Shipping	Dynamic positioning	177	dB re 1µPa m	-	-	-	-	-		L
Shipping	Dynamic positioning	121-197	dB re 1µPa m	50-3,200	-	-	-	-		L
Shipping	Dynamic positioning	162-180	dB re 1µPa m	-	-	-	-	-		L

Activity	Sub-activity	Source level		Frequency (Hz)		Vessel length (m)	Vessel speed (knots)	Engine (type/ size)	Other Information	Confidence (H/M/L)
		Value	Units (metric)	Range	Peak					
Shipping	Fishing boat	151	dB re 1µPa m	250-1,000	-	-	-	-		M
Shipping	Fishing boat	110-135	dB re 1µPa m	100-20,000	-	-	-	240hp outboard		H
Shipping	Fishing trawler	158	dB re 1µPa m	100-250	-	30	-	-		H
Shipping	Fishing trawler	158	dB re 1µPa m	-	-	-	10	-	In transit	L
Shipping	Freighter	172	dB re 1µPa m	-	41	135	-	-		M
Shipping	Icebreaker	174	dB re 1µPa m	-	-	-	10	-		L
Shipping	Large ferry	171	dB re 1µPa m	-	-	-	16	-		L
Shipping	Large merchant vessel	160-190	dB re 1µPa m	50-900	-	-	-	-		H
Shipping	Large vessel movements	180-190	dB re 1µPa m (RMS)	6->30,000	<200	-	-	-	Omni-directional Continuous	L
Shipping	Military vessel	190-203	dB re 1µPa m	-	-	-	-	-		L
Shipping	Oceanographic vessel	170-230	dB re 1µPa m	<100	-	-	-	-		H
Shipping	Offshore oil production vessels	174-183	dB re 1µPa m	20-2,500	-	209-340	-	-	Water depth 75-350m	H
Shipping	Oil tanker	203	dB re 1µPa m	-	-	>250	16	-		L
Shipping	Open hatch cargo ships	179-184	dB re 1µPa m	-	20-1,000	190-213	14	-		H
Shipping	Passenger	154-155	dB re 1µPa m	1-120,000	-	-	>10	-	Red Jet Ferry (jet hydrofoil ferry) Clear with a moderate south-westerly breeze and slight chop on the water.	M
Shipping	Product tankers	179-183	dB re 1µPa m	-	20-1,000	180-228	14-16	-		H
Shipping	Roll on/off	165	dB re 1µPa m	-	-	200	15	-		L
Shipping	Ship	176	dB re 1µPa m (SPL)	10->10,000	60-120	38.9	14.6	-	Modelled source depth 3m	M
Shipping	Ship	181	dB re 1µPa m (SPL)	10->10,000	60-100	77.8	13.6	-	Modelled source depth 6m	M
Shipping	Ship	191	dB re 1µPa m (SPL)	10->10,000	60-100	155.6	15	-	Modelled source depth 6m	M
Shipping	Ships	180-190	dB re 1µPa (RMS)	6->30,000	<200	-	-	-	Continuous Omni-directional	L

Activity	Sub-activity	Source level		Frequency (Hz)		Vessel length (m)	Vessel speed (knots)	Engine (type/ size)	Other Information	Confidence (H/M/L)
		Value	Units (metric)	Range	Peak					
Shipping	Small sea going vessels	170-180	dB re 1µPa m	-	-	-	-	-		L
Shipping	Smaller tanker or freighter	170	dB re 1µPa m	-	40-400	135	-	-		H
Shipping	Supertanker	185	dB re 1µPa m	-	7	337	-	-		M
Shipping	Supertanker	187	dB re 1µPa m	-	8	266	-	-		M
Shipping	Supertanker	190	dB re 1µPa m	-		340	20	-		M
Shipping	Supertanker	190	dB re 1µPa m	-	7	340	-	-		M
Shipping	Supertanker	198	dB re 1µPa m	-	-	-	-	-		L
Shipping	Supertanker	187-232	dB re 1µPa m	20-100	-	-	-	-		L
Shipping	Supertanker/Container ship	180-190	dB re 1µPa m (SPL)	<500	-	-	-	-		H
Shipping	Tanker	169	dB re 1µPa m	-	430	135	-	-		M
Shipping	Tanker	177	dB re 1µPa m	-		337	16	-		L
Shipping	Tanker	180	dB re 1µPa m	-	60	179	-	-		H
Shipping	Tug and barge	161	dB re 1µPa m	-	5,000	-	-	-	Loaded barge	M
Shipping	Tug and barge	162	dB re 1µPa m	-		-	10	-		L
Shipping	Tug and barge	164	dB re 1µPa m	-	1,000	-	-	-	Empty barge	M
Shipping	Tug and barge	166	dB re 1µPa m	-	37	20	-	-	Empty barge	M
Shipping	Tug and barge	170	dB re 1µPa m	-	1,000	-	-	-	Loaded barge	M
Shipping	Tug and barge	171	dB re 1µPa m	45-7,070	630	-	-	-		M
Shipping	Vehicle carriers	178-182	dB re 1µPa m	-	20-1,000	173-199	16-17	-		H
Shipping	Workboat	159	dB re 1µPa m	-	630	34	-	Twin diesel engine		M
Shipping	WWII Battleship	183	dB re 1µPa m	-	-	-	20	-		L

The acoustic properties (i.e. source level[1] and frequency range) of each anthropogenic activity and sub-activity category were collated from scientific literature and published field monitoring reports. The specific source level units that are quoted in the literature were also included in Table 1. The metric is also included in Table 1 where this is provided in the literature. The metric most suitable for continuous noise is considered to be Sound Pressure Level[2] (SPL) which may be written as dB re 1µPa m (NPL, 2014).

Ship source levels have generally been considered a simple function of ship length and speed (Erbe *et al.*, 2012; Erbe *et al*., 2014). There are a number of studies relating ship noise to speed, however, that did not find evidence for a positive relationship between speed and source levels (e.g. Wales and Heitmeyer, 2002; Heitmeyer *et al*., 2003 cited in Mckenna *et al.*, 2013). The lack of a relationship may be an artefact of combining multiple ship-types into a single regression analysis (Mckenna *et al*., 2012). In addition, propeller cavitation can be a dominant noise source of vessels travelling at moderate to high speeds (Leaper *et al.,* 2014). Under the shipping and recreation category, therefore, any information on vessel length, vessel speeds and engine size/type were collated in separate columns in the accompanying Technical Annex document, Table 1. Additional information that could potentially support the development of a noise mapping model was also noted (e.g. water depth, duration, directionality, sediment type, location, local weather conditions).

The associated data limitations and/or constraints are also provided in Table 1. These included whether the data source was peer-reviewed, whether there were any information gaps (e.g. no documented frequency information) or whether any information was potentially incorrect or inaccurate (e.g. if source level units were not properly documented). Any limitations and/or constraints associated with the data formed the basis of assigning a confidence level (high, medium or low) with classification criteria detailed in Table 2. Of the 107 sources of information collated, a total of 33 were considered to have a low confidence and were excluded from further consideration in the model. Exclusions were predominantly sources that lacked both frequency information and were not peer-reviewed.

Table 2: Criteria used to assign confidence level to data sources.

Confidence level	Criteria
High (H)	Measurement data that is from a peer-reviewed journal and/or published book.
Medium (M)	Measurement data that is not from a peer-reviewed journal and/or published book. Modelled data from a peer-reviewed journal and/or published book.
Low (L)	Measurement and/or modelled data that is not from a peer-reviewed journal and/or published book. No documented frequency information. Source level units are not properly documented. Original data source is not referenced.

[1] The source level is a measure of the acoustic output of a source, and may be considered as a characteristic property of the source itself, independent of the propagation path from source to receiver position.
[2] SPL (in dB) = $10 \log_{10} (P^2/P_0^2)$ where P is the root mean square sound pressure and P_0 is the reference pressure. The reference pressure in underwater acoustics is defined as 1 microPascal (µPa).

2.2 Natural ambient sound

A brief review of sources of natural noise has also been undertaken in parallel to the review of anthropogenic sources. The results of this review are presented in Table 3. The sources of natural noise that have been collated are as follows:

- ambient
- bottlenose dolphin (clicks, whistles)
- fish[3] (swimbladder noise)
- harbour porpoise (clicks)
- invertebrates (snapping shrimp[4])
- weather (lightning, rain, storm, wind).

[3] Fish species is not provided in the literature source (Battele, 2004).
[4] This is the only invertebrate that has been identified in the literature review.

Table 3: Natural noise sources that have been collated from available literature.

Source	Sub-type	Source level		Frequency (Hz)		Additional Information	Confidence (H/M/L)
		Value	Unis (metric)	Range	Peak		
Ambient	-	60	dB re 1µPa m	-	<100	Cook Inlet, Alaska	M
Ambient	-	100-140	dB re 1µPa	1,000-120,000	-	Hastings Shingle Bank	M
Ambient	-	101-141	dB re 1µPa (SPL)	1-120,000	-	Southampton Water Typical SPLs were 120-130dB re 1µPa	M
Ambient	-	92-105	dB re 1µPa (SPL)	-	-	Weymouth Bay Sea state 1 to 2 No vessels within 2,000m	M
Ambient	-	70-100	dB re 1µPa m	-	-	Offshore central California Sea state 3-5	L
Bottlenose dolphin	Clicks	226	dB re 1µPa m	-	40,000-140,000		M
Bottlenose dolphin	Clicks	218-228	dB re 1µPa m	-	110,000-130,000		H
Bottlenose dolphin	Clicks	226	dB re 1µPa m	40,000-140,000	-		M
Bottlenose dolphin	Whistles	125-173	dB re 1µPa m	4,000-20,000	3,500-14,500		H
Fish	Swimbladder noise	140	dB re 1µPa m	-	50-3,000		M
Harbour porpoise	Clicks	175	dB re 1µPa m	4,000-14,000	-		M
Harbour porpoise	Clicks	205	dB re 1µPa m (pk-pk)	110,000-160,000	130,000-140,000	Duration 100µs Directional Clicks	H
Harbour porpoise	Clicks	135-177	dB re 1µPa m	-	110,000-150,000		H
Harbour porpoise	Clicks	170	dB re 1µPa m	40,000-140,000	-		M
Invertebrates	Snapping shrimp	183-189	dB re 1µPa m (pk-pk)	2,000-200,000	2,000-5,000	Duration milliseconds Omnidirectional	H
Invertebrates	Snapping shrimp	200	dB re 1µPa m	1,000-100,000	7,000	Occur at rates up to 2-3 per second	M
Weather	Lightning strike on water surface	250	dB re 1µPa m	-	-		L
Weather	Rain	105	dB re 1µPa	100-6,300	10,000	Rainfall rate 10cm/hr	M
Weather	Rain	81	dB re 1µPa	100-6,300	10,000	Rainfall rate 0.25cm/hr	M

Source	Sub-type	Source level		Frequency (Hz)		Additional Information	Confidence (H/M/L)
		Value	Unis (metric)	Range	Peak		
Weather	Rain storm	80	dB re 1µPa m	-	-	Heavy rain shower Flat frequency spectrum	L
Weather	Wind	95	dB re 1µPa	100-6,300	1,000	Shallow open water Wind speed 34-40 knots	M
Weather	Wind	82	dB re 1µPa	100-6,300	1,000	Shallow open water Wind speed 7-10 knots	M
Weather	Wind	66	dB re 1µPa m	-	-	Force 3 wind over water	L

Pk-pk – Peak-to-peak

2.3 Hearing thresholds

To provide additional ecological context, the noise sources that overlap with the hearing sensitivity of marine fauna found in UK waters and may potentially result in a behavioural effect have been identified. This has involved collating hearing threshold data from published peer reviewed audiograms[5] of a range of marine species that occur in UK waters (Table 4). There are three separate studies that measured the hearing threshold of Atlantic cod and these are labelled as Atlantic cod 1, 2 and 3 in Table 4. Two separate studies for grey seal (grey seal 1 and 2 in Table 4) were also identified but these were well outside the frequency range of interest in this study (1/3 octave bands 63 and 125Hz (centre frequency) corresponding with the Marine Strategy Framework Directive (MSFD) indicator for ambient noise[6]).

Table 4: Hearing thresholds provided in published reports.

Species (common name)	Frequency (Hz)	Hearing Threshold (dB re 1µPa)
Atlantic cod 1	10	82.8
	20	63.4
	37.5	75.4
	75	68.9
	150	64.8
	300	75.4
	600	139
Atlantic cod 2	30	91
	40	90.4
	50	83.1
	60	79.8
	100	77.3
	160	75.3
	200	81.6
	300	81.2
	400	84.7
	450	110.2
Atlantic cod 3	17.6	94.8
	35.3	99.2
	70.7	100.4
	141	101.3
	283	95.4
	400	118.5
Dab	30	95
	40	93.8
	60	91.7
	80	89.8
	110	89
	160	95.9
	200	104.9
Haddock	30	98.4
	40	92.2
	50	94.9
	60	87.1
	110	80.4
	160	84.9
	200	80.3
	250	82.7
	310	80.7
	380	87.3
	470	103.7
Herring	30	79
	50	76
	100	75
	200	76
	400	77
	1,000	79
	2,000	96
	4,000	136
Pollack	40	87.4
	60	81
	110	83
	160	80.8
	310	86.5
	470	107.7
Atlantic salmon	32	107.5
	60	105
	110	97.5
	160	95.2
	250	106
	310	112.5
	380	131.5
Bottlenose dolphin	75	132
	100	131
	200	113
	300	104
	400	100
	500	98
	600	105
	700	91
	800	94

[5] An audiogram is a hearing curve that depicts the frequency dependent hearing sensitivity or hearing threshold of a species, which in fish and marine mammals usually exhibits a U-shaped form. The hearing threshold increases (i.e. hearing sensitivity reduces) for frequencies outside those optimal for those species.
[6] The MSFD provides a guide for the monitoring of ambient noise as covered by Indicator 11.2.1 on 'Continuous low frequency sound (ambient noise)'. This indicator is described in the Commission Decision as "*Trends in the ambient noise level within the 1/3 octave bands 63 and 125 Hz (centre frequency) (re 1µPa RMS; average noise level in these octave bands over a year) measured by observation stations and/or with the use of models if appropriate*" (Dekeling *et al*., 2014, p 5).

Species (common name)	Frequency (Hz)	Hearing Threshold (dB re 1µPa)
	900	98
	1,000	96
	2,000	72
	3,000	76
	4,000	80
	5,000	73
	6,000	68
	7,000	62
	8,000	66
	9,000	62
	10,000	60
	12,000	53
Grey seal 1	2,000	84
	5,000	80
	10,000	80
	20,000	62
	30,000	67
	40,000	80
	50,000	91
Grey seal 2	1,400	83
	4,000	84

Species (common name)	Frequency (Hz)	Hearing Threshold (dB re 1µPa)
	10,000	73
	20,000	65
	25,000	61
	30,000	70
	40,000	84
Common seal	75	101.9
	100	95.9
	200	83.8
	400	83.9
	800	79.8
	1,600	67.1
	6,400	62.8
Harbour porpoise	250	115
	500	92
	1,000	80
	2,000	72
	4,000	67
	8,000	59

3. Logical Data Process Tool

This section describes the detail of the noise propagation ArcGIS Toolbox including all tools, inputs to the tool and outputs generated. A diagrammatic representation of the ArcGIS "Noise Model Toolbox" is provided which clearly describes the steps and geoprocessing tools used in the tool in a logical manner.

3.1 Tool principles

The tool works on the principle that noise levels will vary depending on the distance from the source. Each cell in the grid will have a value in time associated with the activity which occurs within that grid cell; however neighbouring cells will then have noise propagated from the source cell at a lower noise level but with the same time value. To mimic this propagation of noise, multiple ring buffers have been generated from each cell centroid out to 4.642km. This corresponds to 55dB attenuation from source using the recommended practical spreading model:

$$TL = 15\ log_{10}(R)$$

This relates to noise propagating to 20 neighbouring cells. Due to computational constraints this was considered a reasonable limit to represent the propagation of noise using the practical spreading model in the GIS tool.

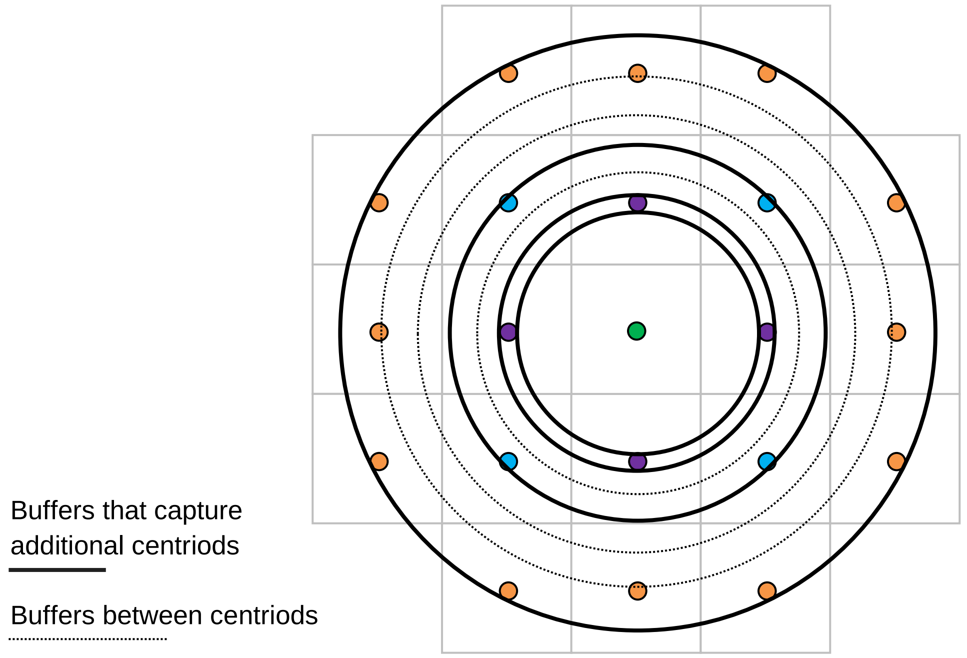
Table 5 shows example received levels (in dB re 1μPa m) for each buffer distance. The distance of propagation was calculated for each 1dB attenuation decrease from the source level. The buffers start at 50dB attenuation from source as this is where the buffer propagation is beyond 2km i.e. the distance needed to reach the centroids of the closest neighbouring cells to the source cell.

Table 5: The relationship of attenuation from source level (dB) to the received level at calculated buffer distances.

dB attenuation from source Total or Σ TL (dB)	Received Level	Buffer Propagation - "R" (metres) 10^(TL/N)	Buffer Distance (kilometres)
0 (Source Level)	**173**	**0**	**1.9**
50	**124**	**2154**	**2.15**
51	123	2511	2.51
52	**122**	**2929**	**2.93**
53	121	3414	3.41
54	120	3981	3.98
55	**119**	**4642**	**4.64**

Buffers have been generated at 1.9km (to encapsulate the source cell), 2.15km, 2.51km, 2.93km, 3.41km, 3.98km and 4.64km. However cell centroids of neighbouring cells only fall within the 2.15km, 2.93km and 4.64km buffers. Figure 1 displays the buffers and their relationships to neighbouring cells.

Figure 1: Visual representation of the buffers applied to the source cell and the neighbouring cell centroids which fall within the buffers.



The value in time and noise level will then be applied to the neighbouring cells based on the source cell buffer which the centroid of the neighbouring cell falls within and the time value of the source cell. As each cell will have values for both source levels and the propagated noise from neighbouring cells, the value in time is summed where there is multiple values of time for the same dB level.

3.2 Tool input data layers

Spatial data layers that provide information on both the location and intensity of relevant anthropogenic activities in the south marine plan areas have been identified and sourced. The following spatial data layers are used in the GIS tool to represent the spatiotemporal distribution of anthropogenic activities:

- Automatic Identification System (AIS) shipping data density grid
- Electronic Monitoring System (EMS) aggregate dredging data
- Vessel Monitoring System (VMS) fishing data.

Noise associated with shipping activities is derived from the AIS density grid, fishing activity noise is derived from VMS data and noise associated with aggregate dredging is derived from the EMS data. The base grid for the final outputs will be based on the AIS density vector grid of 2km x 2km, both the EMS and VMS data are converted to this grid resolution. Six ship type groups are used from the AIS density data, making a total of eight categories of noise sources;

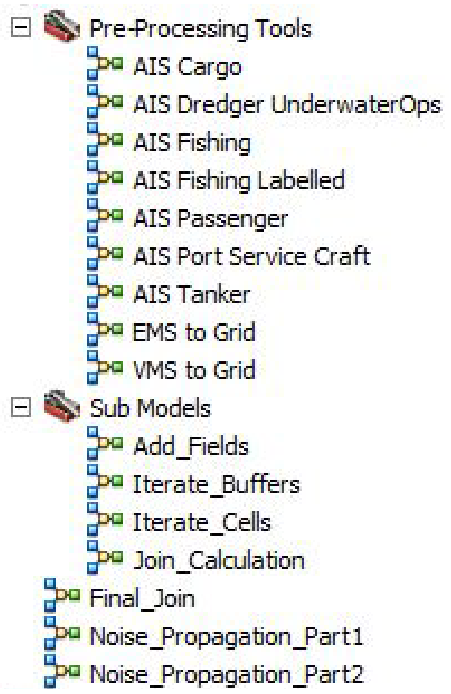
- Mobile Gear Fishing Activity (VMS data)
- Aggregate Dredging (EMS data)
- Cargo Ships (AIS data)
- Dredger and Underwater Operations (AIS data)
- Fishing Vessels in transit (AIS data)

- Passenger Vessels (AIS data)
- Port Service Craft (AIS data)
- Tankers (AIS data).

3.3 Toolbox overview

The toolbox contains two toolsets ('Pre-Processing Tools' & 'Sub Models') and two standalone tools ('Noise Propagation' and 'Final Join'). Figure 2 shows the expanded view of the toolbox.

Figure 2: Image of Noise Model Toolbox and the tools contained within the toolbox.



To accompany the toolbox four file geodatabases have been provided:

- NM Buffers
- NM Raw Datasets
- NM Tool Inputs
- NM Tool Outputs.

The 'Raw Datasets' geodatabase contains the un-processed datasets as have been provided from the data layer source, these data layers are the inputs to the pre-processing tools.
The 'Tool Inputs' geodatabase houses the outputs of the pre-processing tools which have been run on the 'Raw Datasets', these processed data layers are now the input layers for the 'Noise Propagation' tool.

The 'Tool Outputs' database houses the final outputs from the 'Noise Propagation' and 'Final Join' tools.

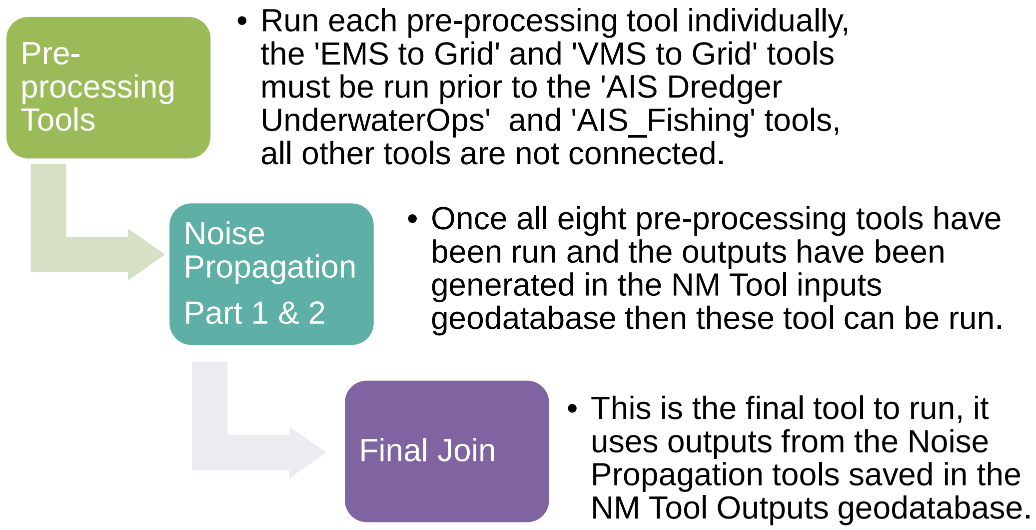
The 'Buffers' databases contain buffers for each cell in the south coast AIS grid; these buffers are used as selection criteria in the 'Noise Propagation' tool.

Three other feature classes have been provided in the tool inputs geodatabase;

- a template grid which is used by the 'Final Join' tool to create the final grid
- a look up table which provides the source and propagated noise levels which are used by the 'Noise Propagation' tool
- a look up table which lists the 3 dB re 1μPa m bands used to summarise the values in the Final Join grid output.

It is recommended that the tools are run in ESRI ArcCatalog to speed up the processing time and no GIS extensions are needed for the tools to run. Each tool should be run individually and the next tool should only be run once the previous tool is completed. Figure 3 shows the order in which the Noise Model toolbox tools should be run, some of the tools rely on outputs from the previous tool to be able to run. The Sub Models toolset contains tools which are used within the Noise Propagation and Final Join tools and although are essential to the toolbox they do not need to be run individually.

Figure 3: Diagram showing the order in which to run the Noise model toolbox tools.



Each of the eight categories of noise source has an associated pre-processing tool which generates the vector grid input for that noise category; this is subsequently used in the 'Noise Propagation' tools. An output noise grid for each category is generated from the 'Noise Propagation' tool; these eight grids are then combined into the final output grid via the 'Final Join' tool. The output data layer is represented as the sum of time (in hours) within one year for different noise levels based on a 3 dB re 1μPa m interval scale. Within all the toolbox tools the intermediate steps are saved in the Scratch Geodatabase and in-line variables are used to specify input and output locations to avoid the need to specify the same location multiple times.

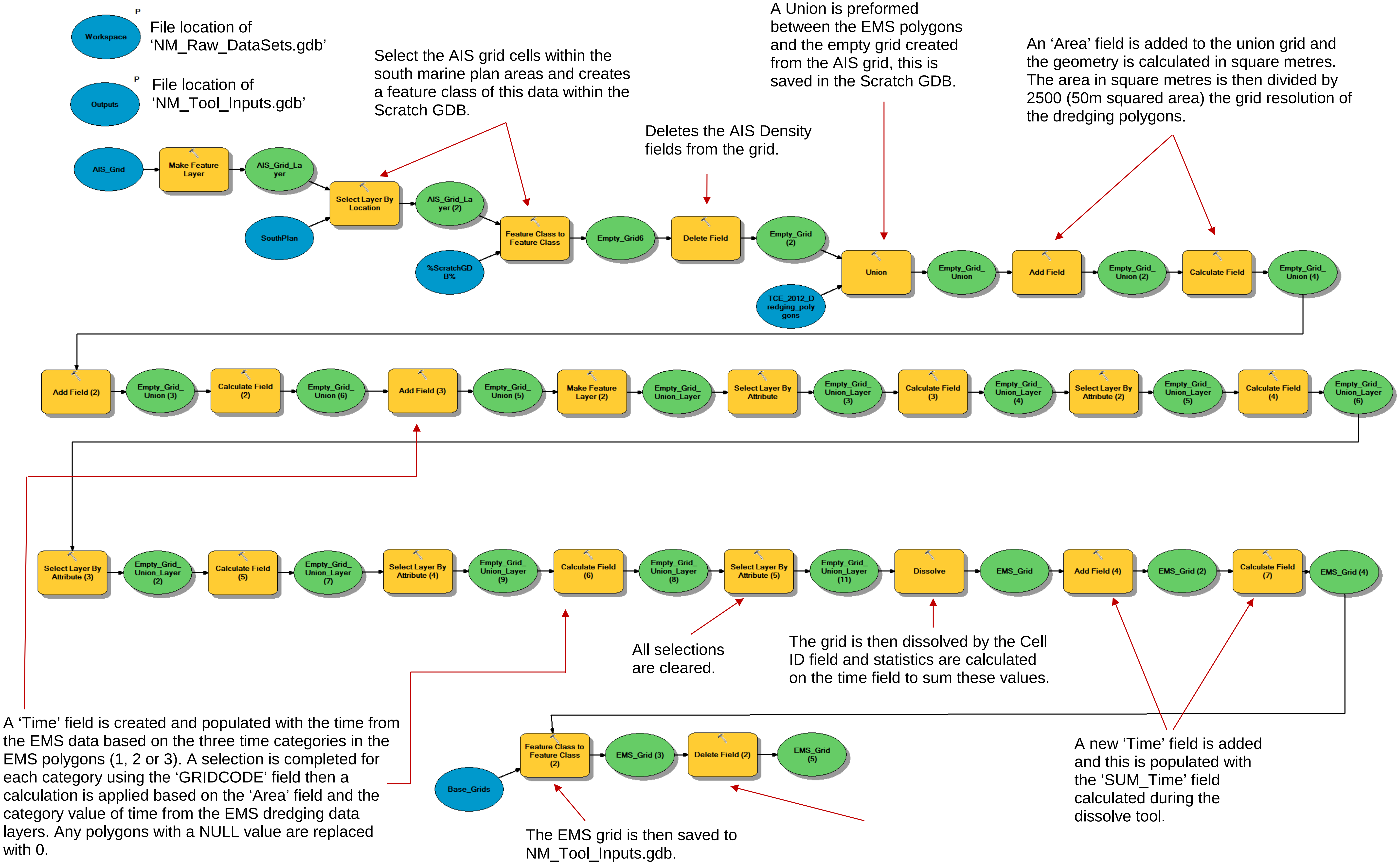
The suggested order to run the tools is listed below:

1. EMS to Grid
2. VMS to Grid
3. AIS Cargo
4. AIS Dredger UnderwaterOps
5. AIS Fishing
6. AIS Passenger
7. AIS Port Service Craft
8. AIS Tanker
9. Noise Propagation Part 1 - Applied to the first buffer geodatabase
10. Noise Propagation Part 2 - Applied to subsequent buffer geodatabase
11. Final Join

3.4 Pre-processing tools

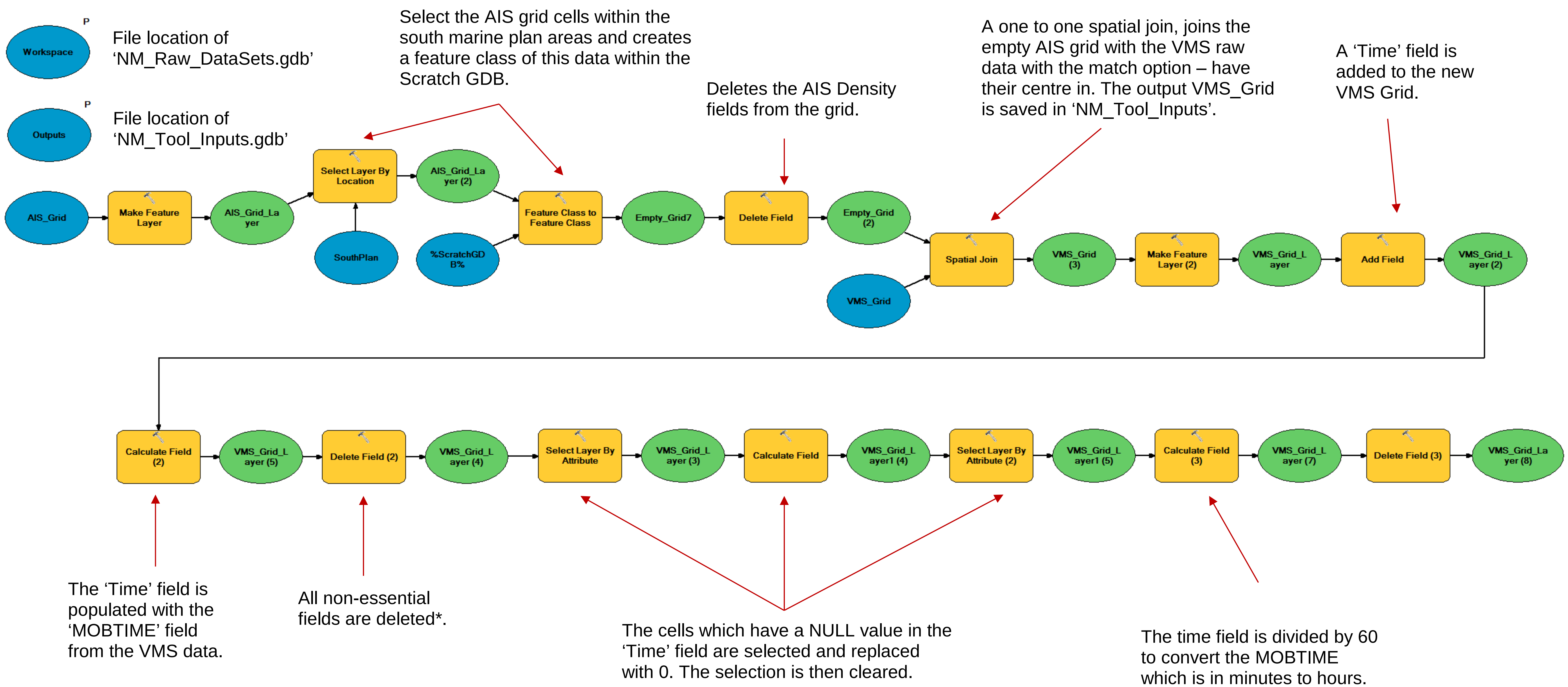
Each pre-processing tool is detailed in-turn below with an accompanying schematic diagram detailing the geoprocessing steps. The schematic diagrams show the input data sets (blue ovals), geoprocessing tools (yellow rectangles) and the outputs from each step (green ovals). Each process is linked via a connector arrow showing the direction of movement through the processing steps, any precondition connectors (where an un-related step has to be completed prior to another step starting) are represented as dotted lines.

3.4.1 Pre-processing tool – EMS to Grid



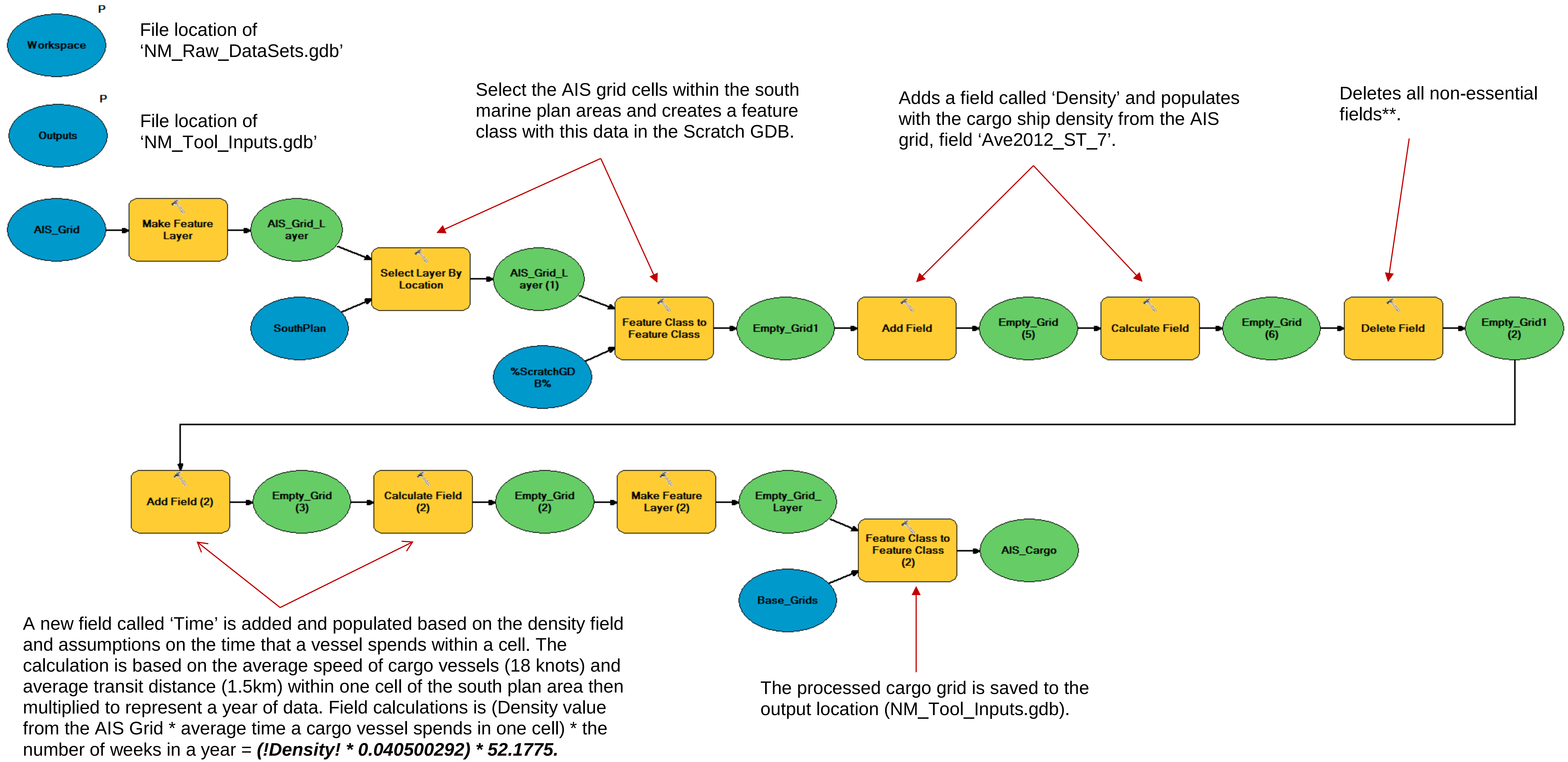
3.4.2 Pre-processing tool – VMS to Grid

The SUM Time field generated by the Dissolve tool is deleted.



* Essential fields include those integral to the database structure such as Object ID, Shape Area and Shape Length. Cell ID is also an essential field as it is used within the noise propagation and the final join tools.

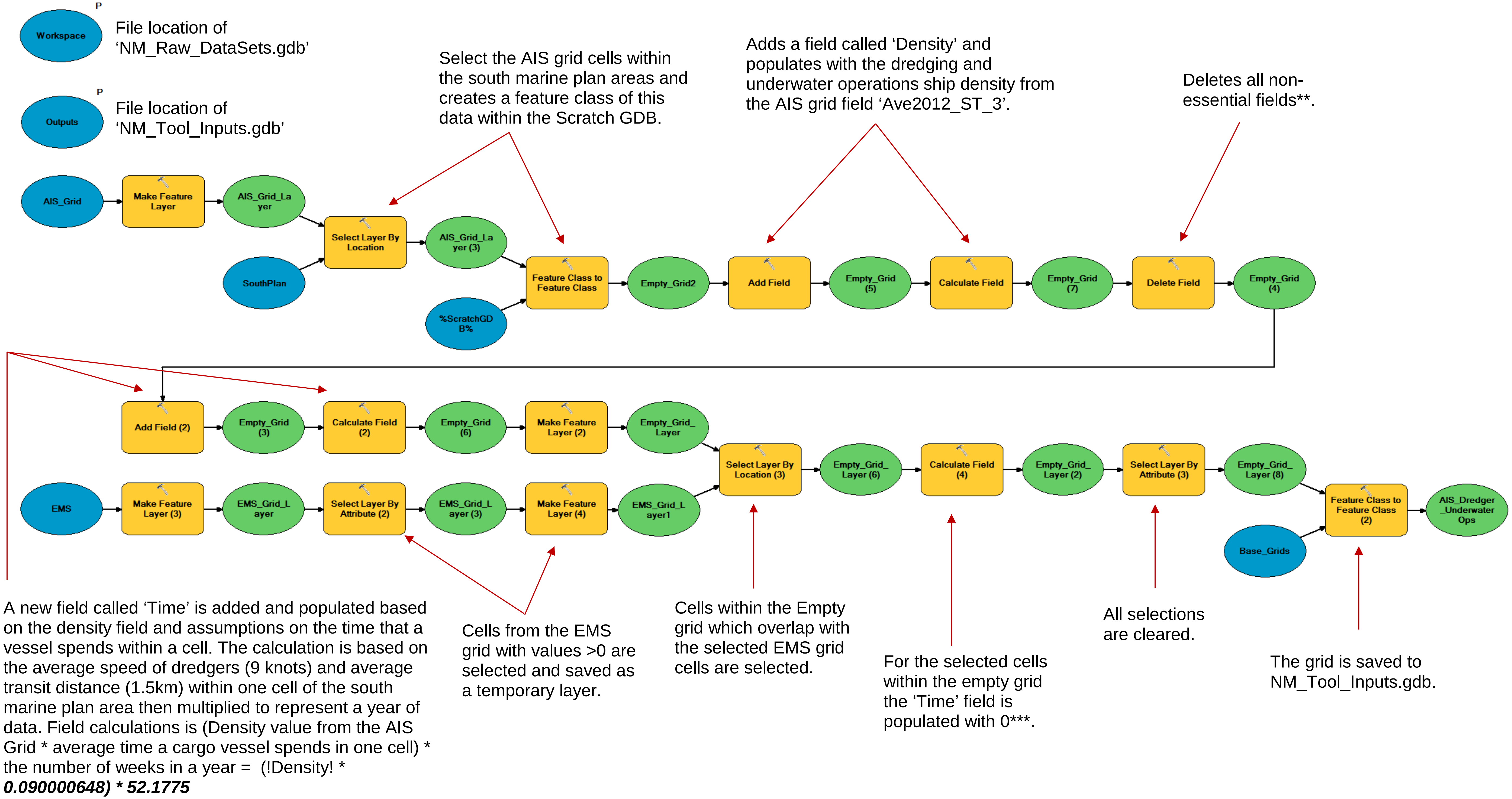
3.4.3 Pre-processing tool – AIS Cargo



** Essential fields include those integral to the database structure such as Object ID, Shape Area and Shape Length. Cell ID is also an essential field as it is used within the noise propagation and the final join tools.

3.4.4 Pre-processing tool – AIS Dredger UnderwaterOps

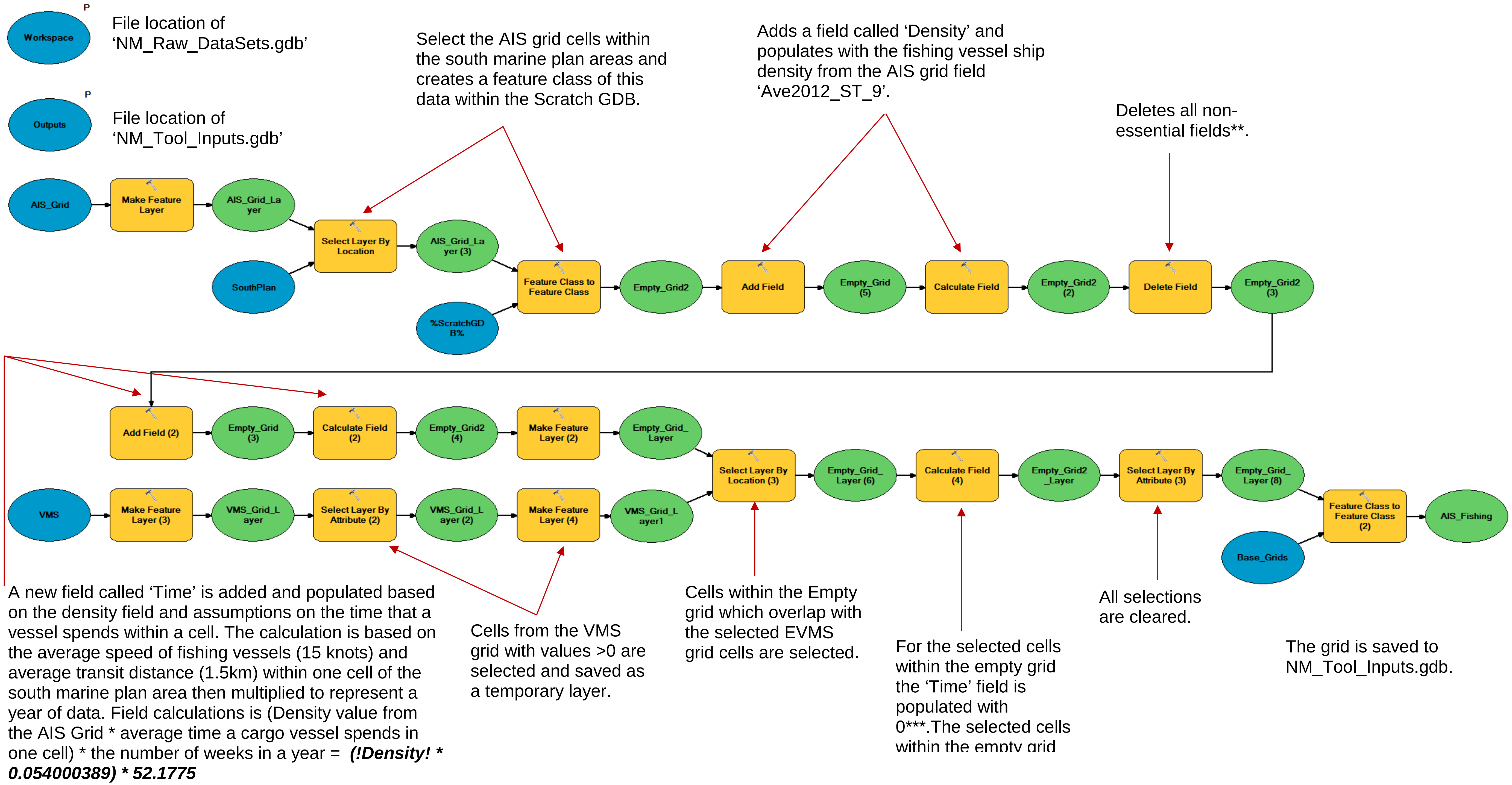
The EMS to Grid tool needs to be run before the AIS Dredger UnderwaterOps tool can be run as it uses the outputted EMS grid within the tool.



** Essential fields include those integral to the database structure such as Object ID, Shape Area and Shape Length. Cell ID is also an essential field as it is used within the noise propagation and the final join tools.

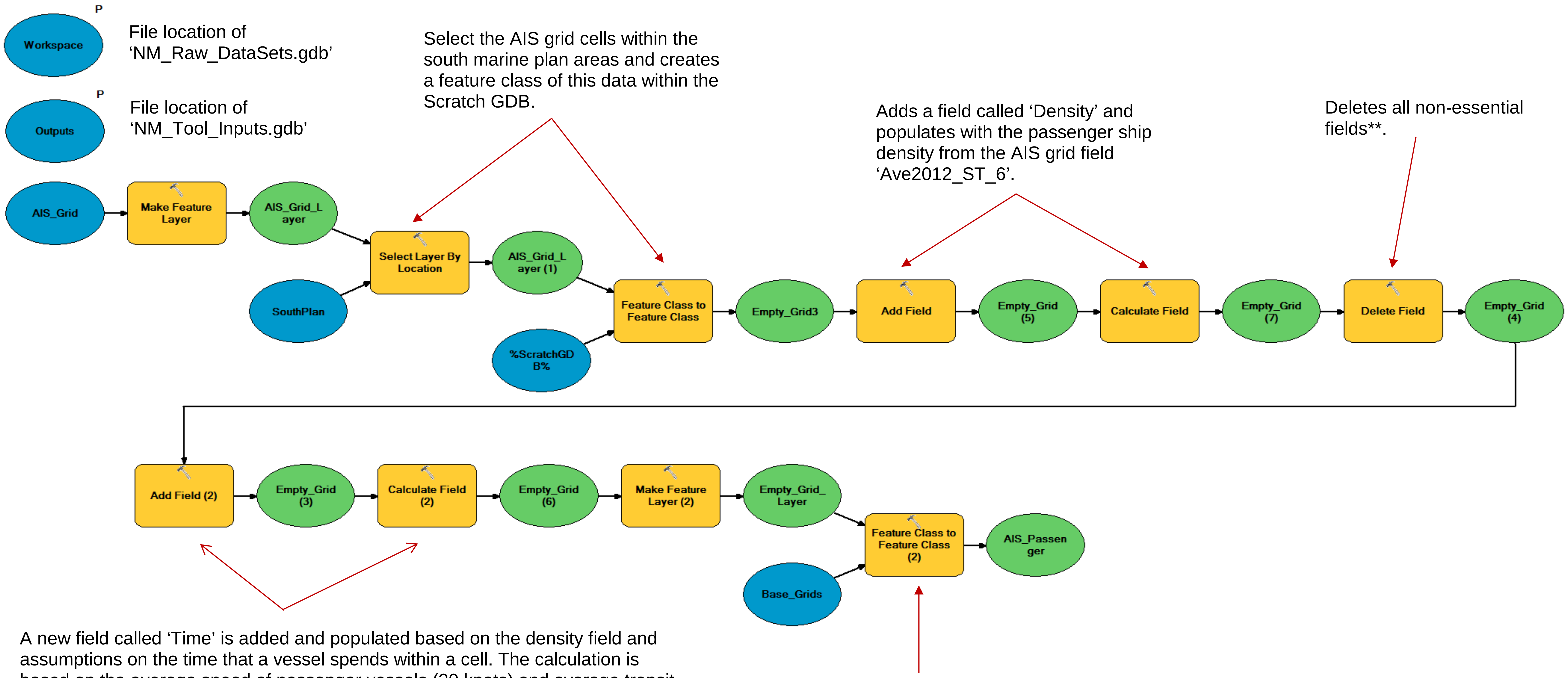
*** To avoid double counting of dredging activity time where EMS data exists, a 0 value is given to the 'Time' field for the AIS Dredger and Underwater Operations grid.

3.4.5 Pre-processing tool – AIS Fishing



** Essential fields include those integral to the database structure such as Object ID, Shape Area and Shape Length. Cell ID is also an essential field as it is used within the noise propagation and the final join tools.
*** To avoid double counting of dredging activity time where VMS data exists, a 0 value is given to the 'Time' field for the AIS Fishing grid.

3.4.6 Pre-processing tool – AIS Passenger

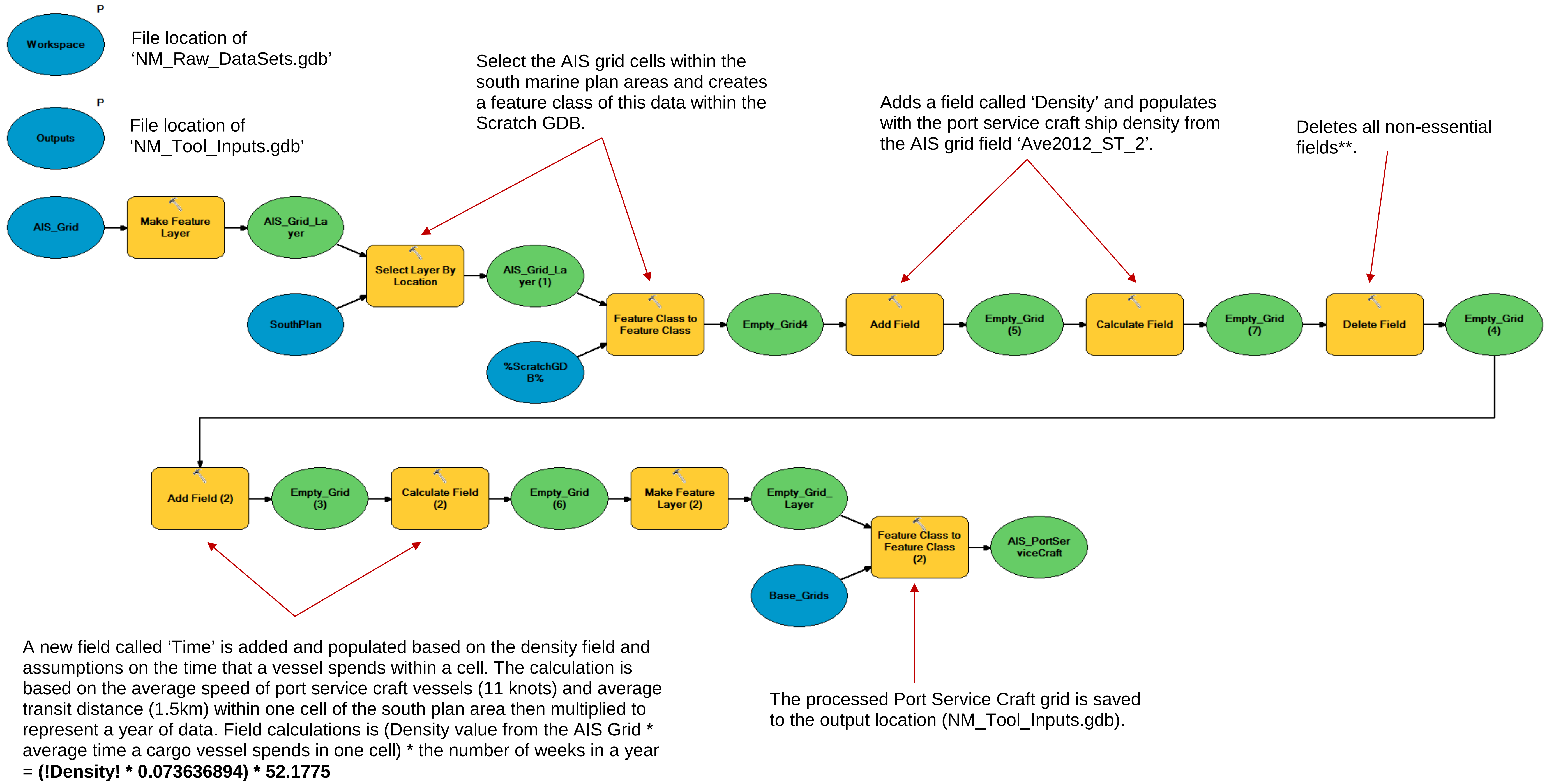


A new field called 'Time' is added and populated based on the density field and assumptions on the time that a vessel spends within a cell. The calculation is based on the average speed of passenger vessels (20 knots) and average transit distance (1.5km) within one cell of the south plan area then multiplied to represent a year of data. Field calculations is (Density value from the AIS Grid * average time a cargo vessel spends in one cell) * the number of weeks in a year = ***(!Density! * 0.040500292) * 52.1775***

The processed Passenger grid is saved to the output location (NM_Tool_Inputs.gdb).

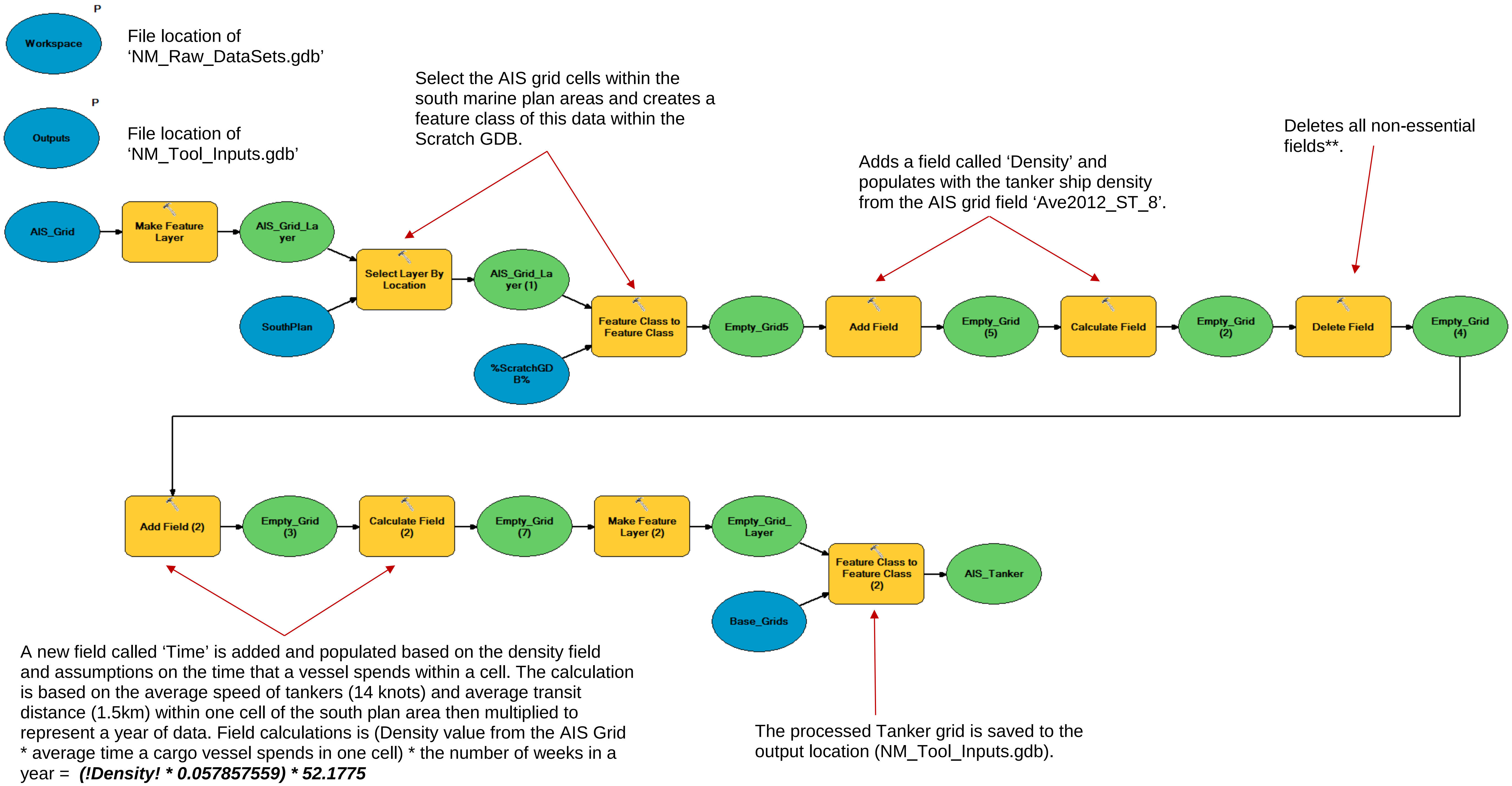
** Essential fields include those integral to the database structure such as Object ID, Shape Area and Shape Length. Cell ID is also an essential field as it is used within the noise propagation and the final join tools.

3.4.7 Pre-processing tool – AIS Port Service Craft



** Essential fields include those integral to the database structure such as Object ID, Shape Area and Shape Length. Cell ID is also an essential field as it is used within the noise propagation and the final join tools.

3.4.8 Pre-processing tool – AIS Tanker



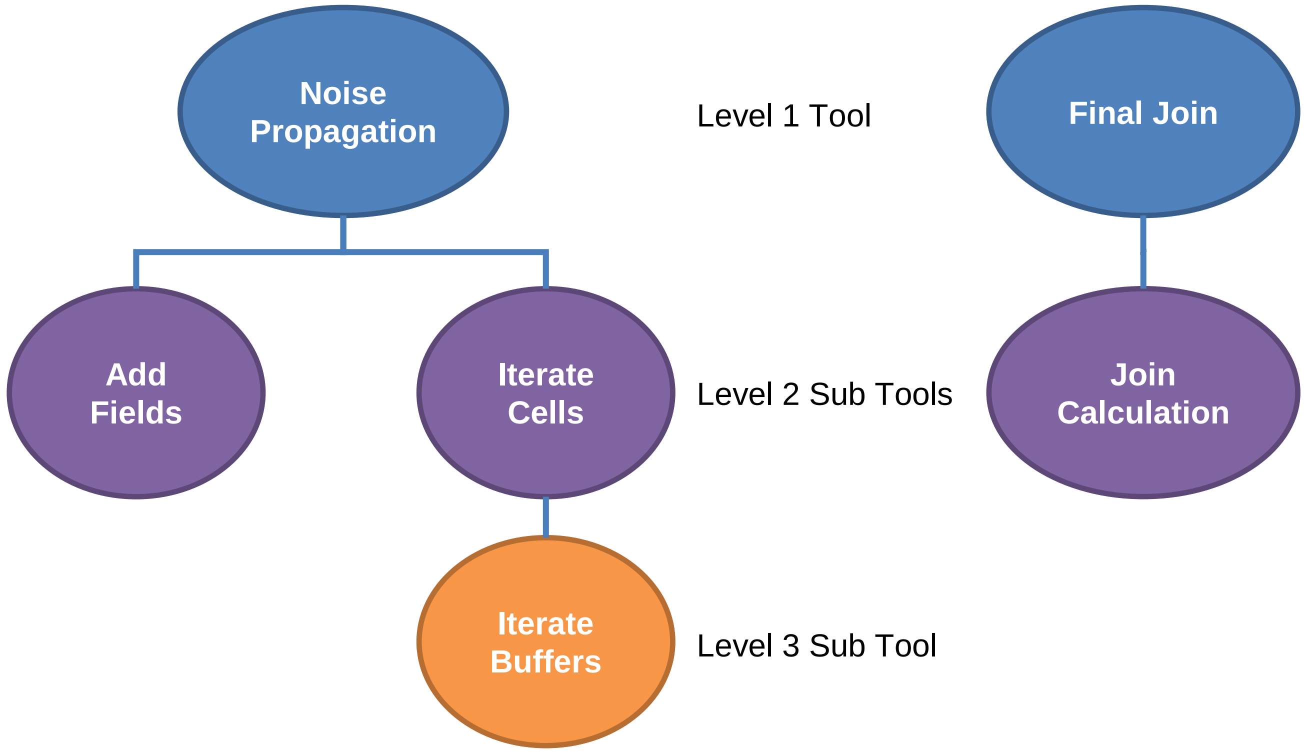
** Essential fields include those integral to the database structure such as Object ID, Shape Area and Shape Length. Cell ID is also an essential field as it is used within the noise propagation and the final join tools

3.5 Noise propagation tools

The noise propagation tool should be run after all the pre-processing tools have generated outputs and these have been saved within 'NM_Tool_Inputs.gdb'. The noise propagation tool will generate eight noise grids; one for each noise category, these will be saved in 'NM_Tool_Outputs.gdb'.

The tool incorporates three sub-tools within the model; 'Add Fields', 'Iterate Cells' and 'Iterate Buffers'. The sub models have been incorporated into the noise propagation tool to allow for multiple iterators within the model, the hierarchal relationship between these models is shown in Figure 4.

Figure 4: The hierarchal relationship between the Noise Propagation model and the sub models.



The Noise Propagation tool and each of the sub tools are described via schematic diagrams in the following figures. The output feature class is generated within the level 1 tool, both the level 2 and level 3 sub tools only add and calculate fields to this output feature class.

The Noise propagation tool requires a high level of computational power to run, if the tool fails to run on a machine due to computational constraints then there are steps which can be taken to break the data into smaller chunks to allow it to run.

Firstly each of the noise grids which have been saved within the NM Tool Inputs geodatabase "Base Grids" data set can be run individually. The simplest way to do this is save a copy of the entire database with a suffix of "_1", then delete all bar one of the noise base grids from the original geodatabase. This will run the tool on only the one noise grid which is left within the "Base Grids" dataset. Once this is finished you can delete the base grid in the inputs geodatabase and copy a new one over from the duplicate inputs geodatabase, this process will need to be repeated for each of the eight noise grids. All the outputs will still be saved within the NM Tool Outputs geodatabase.

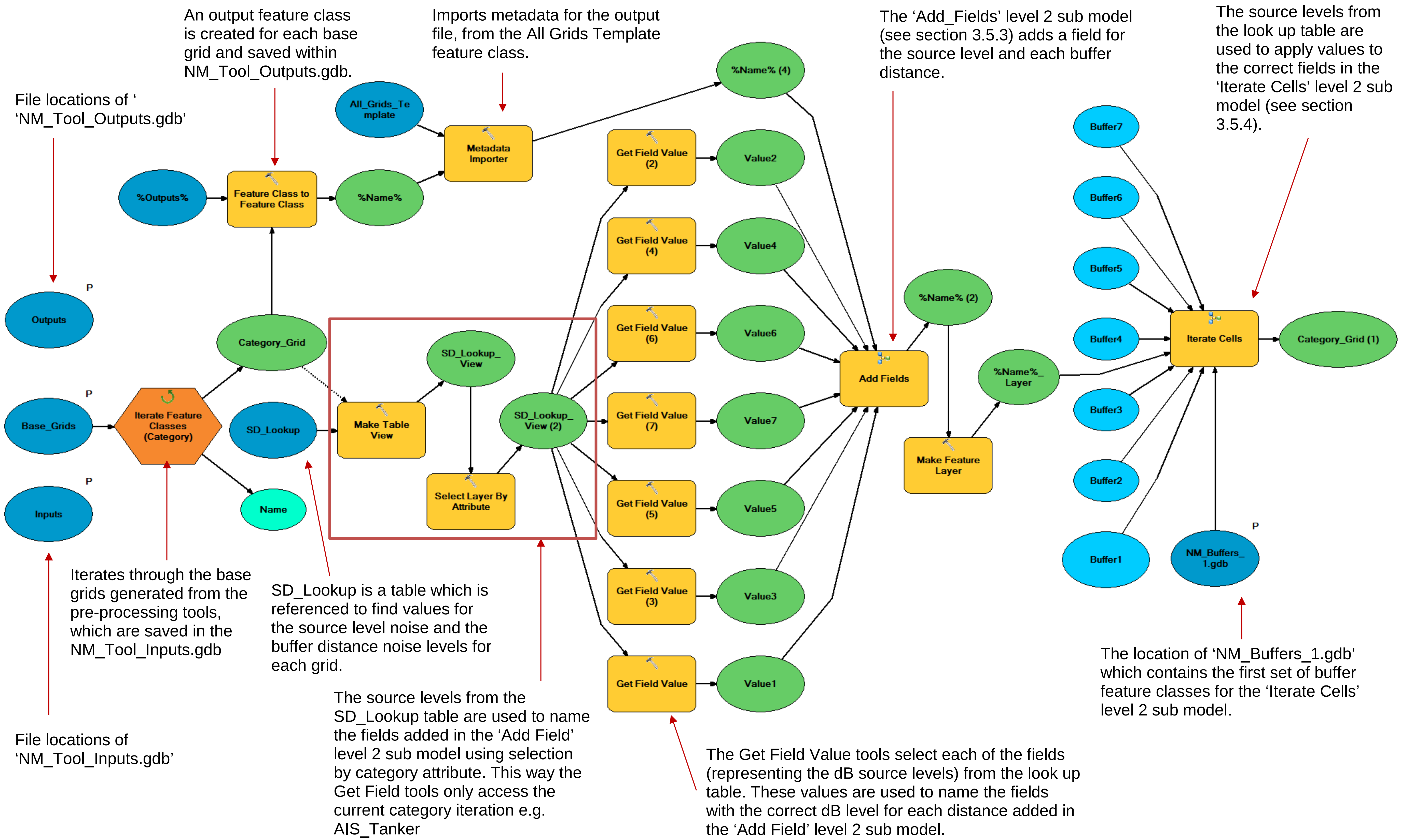
The South Coast Marine Plan areas have 6279 cells based on the output grid used for the propagation tools, buffers have been created for each cell and saved within the NM Buffers geodatabases. The noise propagation tool iterates through each of the buffer feature classes and applies calculations to the output grid. To reduce computational issues, the buffers have been spread across multiple geodatabases

The Noise Propagation Tool has been split into two parts to allow for applying successive buffer geodatabase to the gridded area. The Noise_Propagation_Part1 creates the appropriate field in the output grids before propagating the sound values by iterating through the grid cells and associated buffers. The Noise_Propagation_Part2 does not contain the Add Field sub-tool so will not attempt to duplicate existing fields, it can therefore be run on each successive buffer geodatabase.

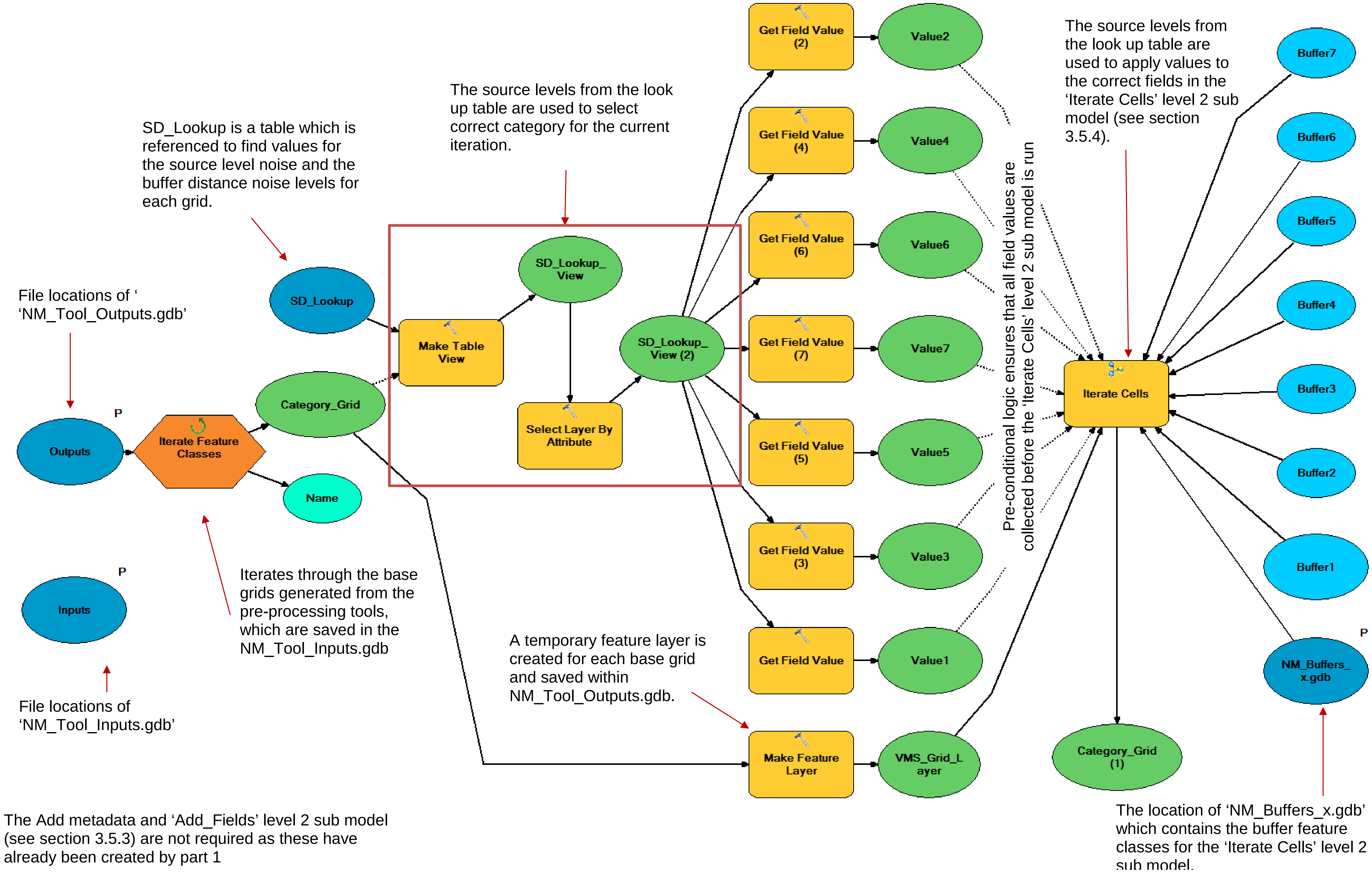
Note: The Noise Propagation Tools can take 20 hours to process a buffer geodatabase with 1288 features. Reference machine: Intel® Core™ i5-3320M CPU @ (2.6GHz x2), 4 GB RAM, 64-bit Windows 7 Operating System.

3.5.1 Noise propagation tool – Part 1

For further information on the relationship between the Noise Propagation model and the sub models please see Figure 4.



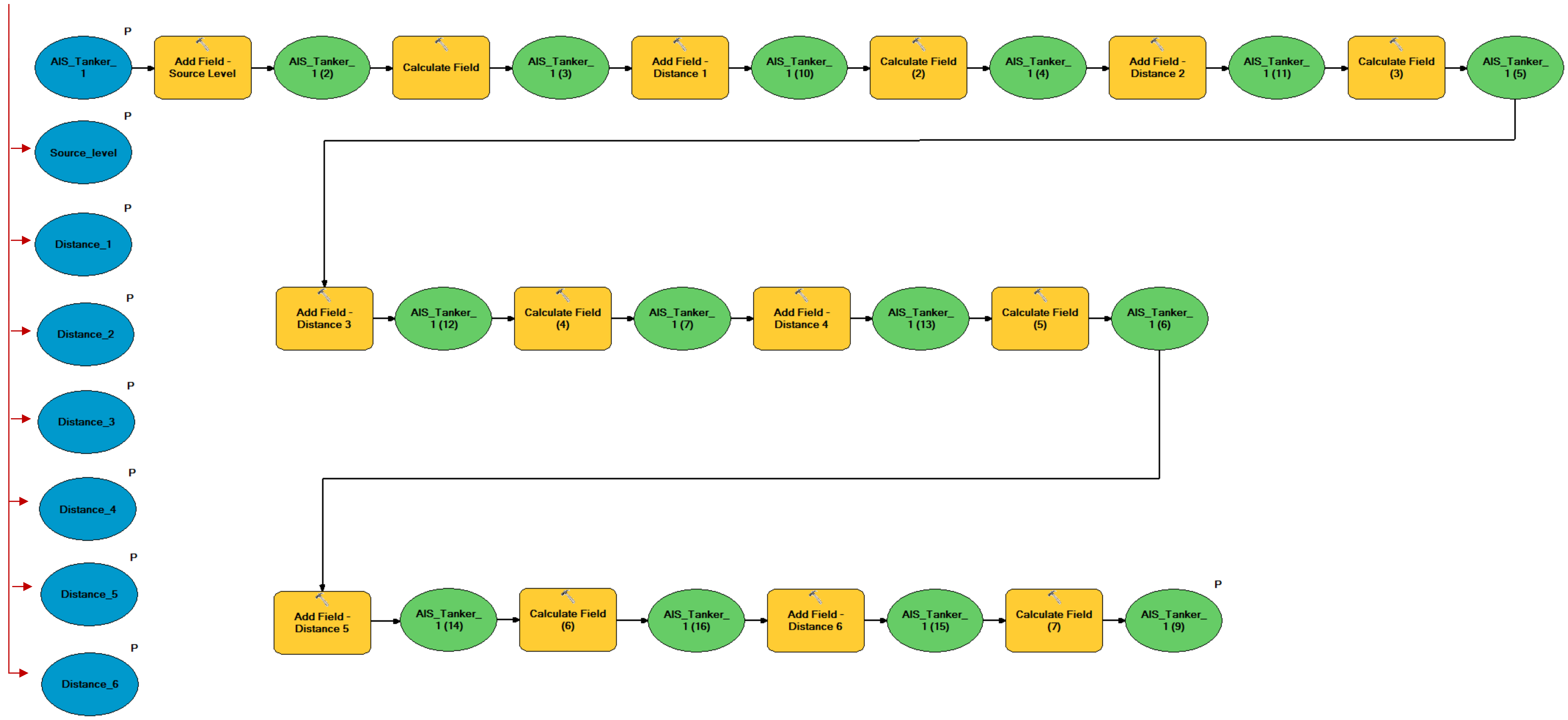
3.5.2 Noise propagation tool – Part 2



3.5.3 Noise propagation tool – Add Fields level 2 sub model

For further information on the relationship between the Noise Propagation model and the sub models please see Figure 4.

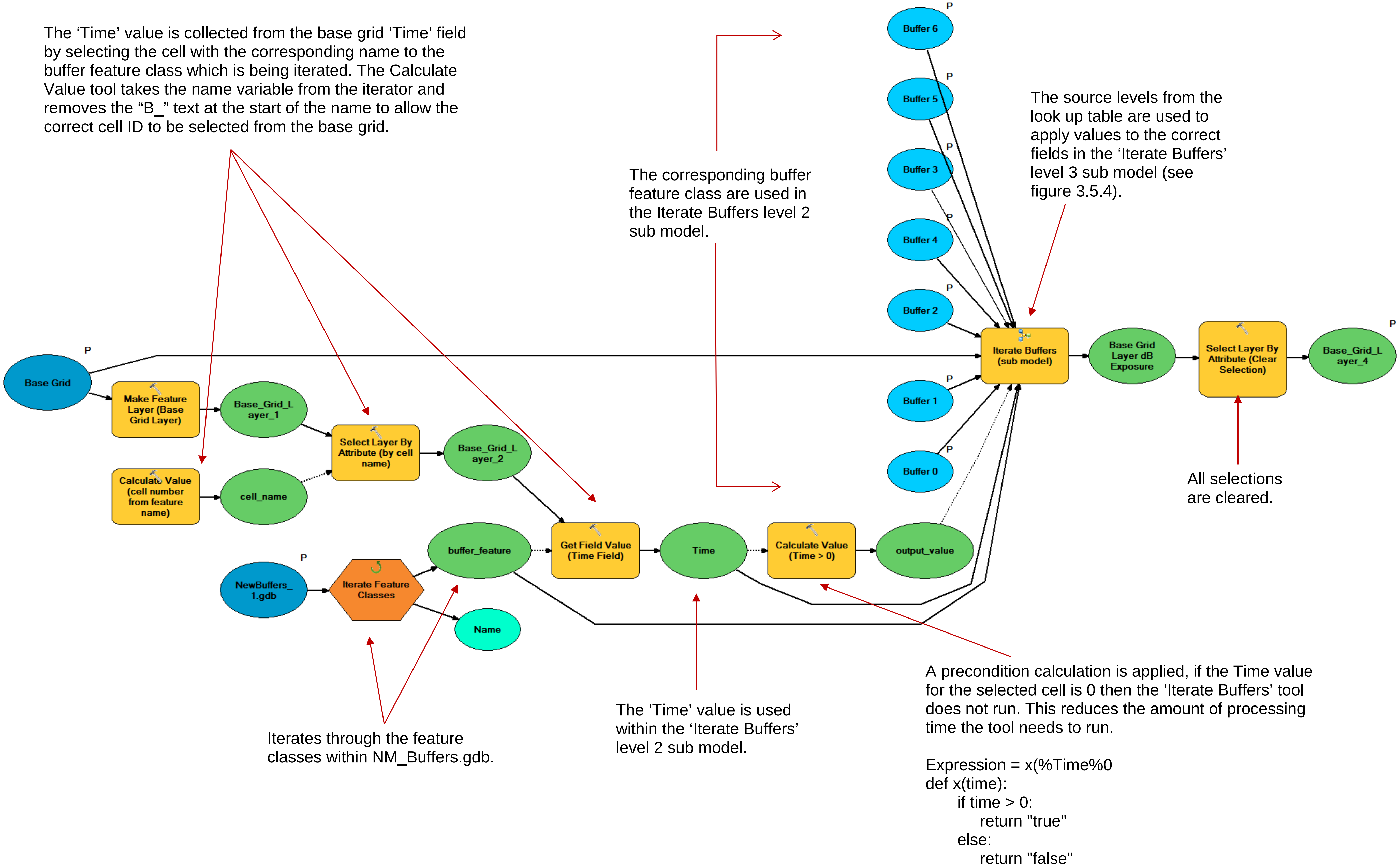
The source and buffer distance noise levels from the 'SD_Lookup' table are saved as model variables.



Each 'Add Field' tool adds a new field giving it the name which corresponds with the source or buffer distance (from the model variables) it represents, this is calculated using the in-line variable 'dB_%distance variable name%'. The calculate field tools then populate the fields with a value of 0.

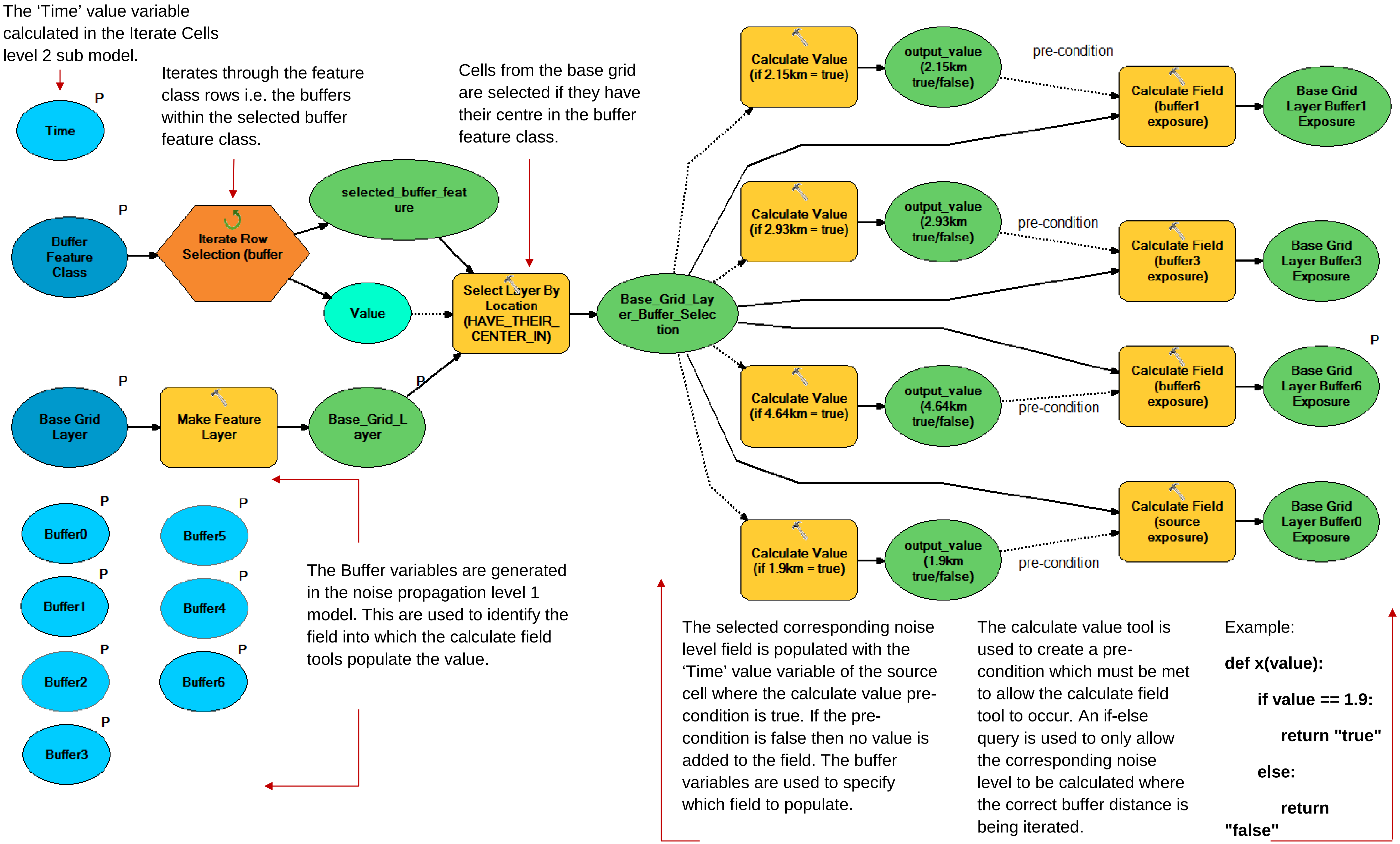
3.5.4 Noise propagation tool – Iterate Cells level 2 sub model

For further information on the relationship between the Noise Propagation model and the sub models please see Figure 4.



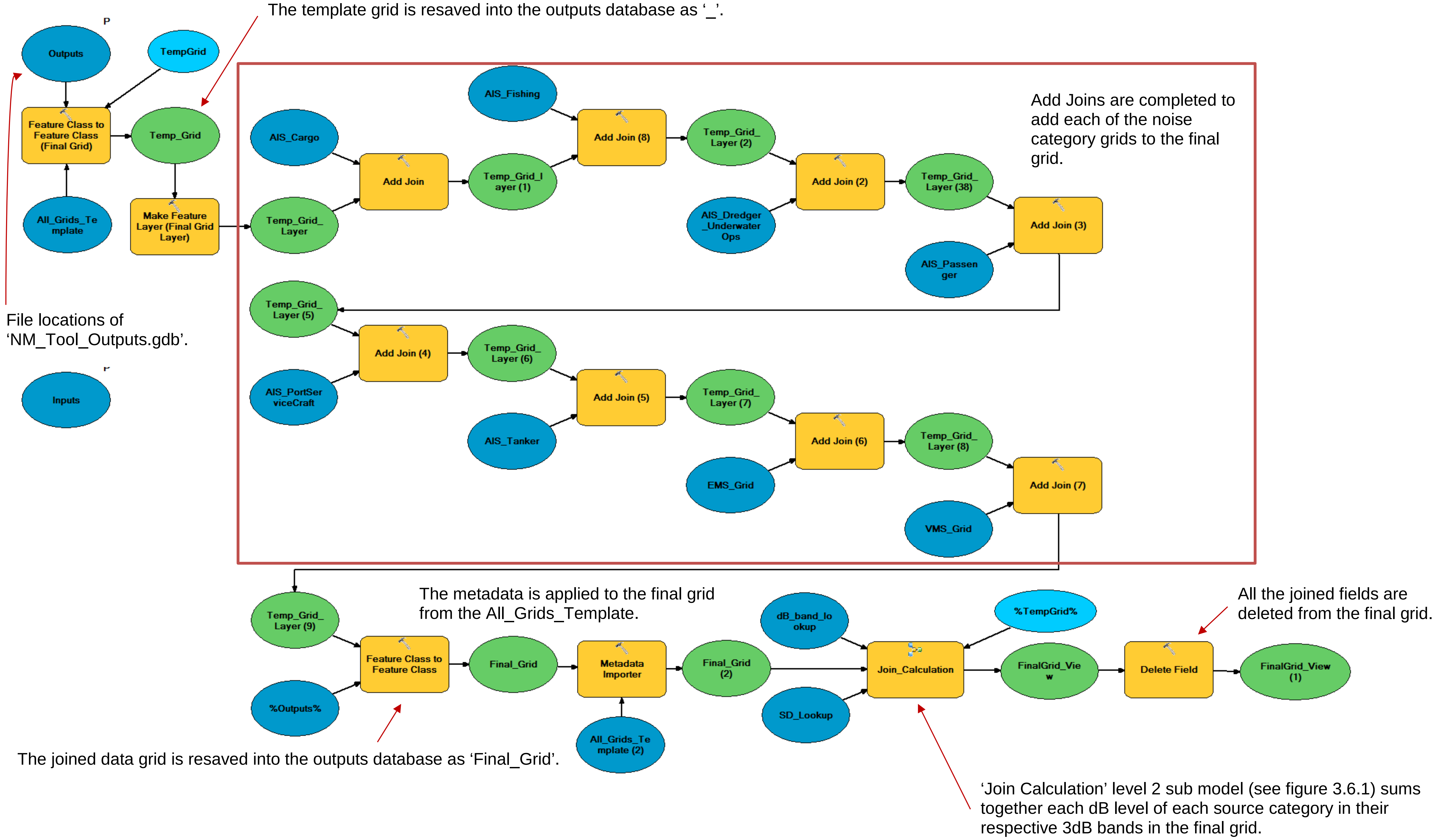
3.5.5 Noise propagation tool – Iterate Buffers level 3 sub model

For further information on the relationship between the Noise Propagation model and the sub models please see Figure 4.

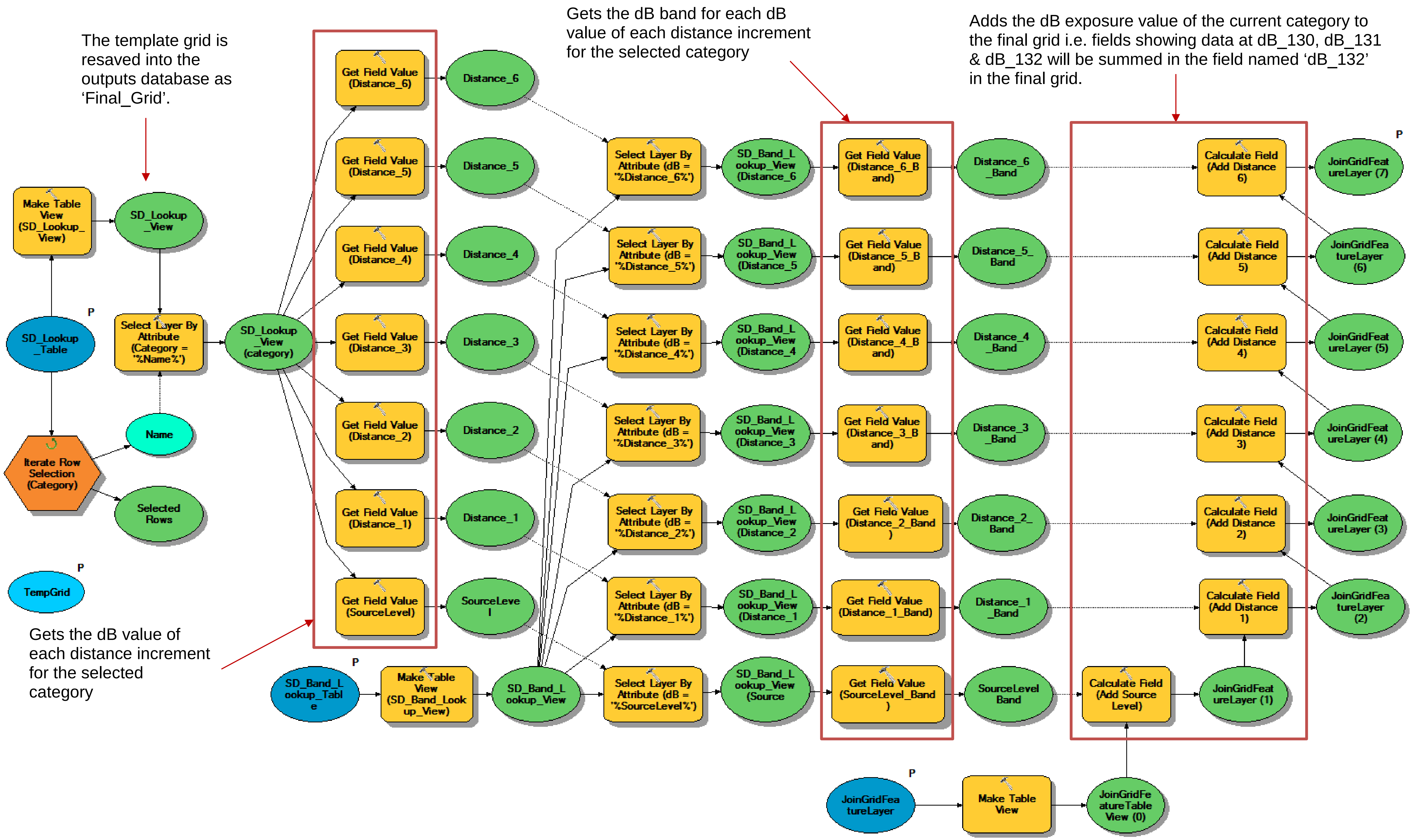


3.6 Final Join tool

For further information on the relationship between the Final Join model and the sub models please see Figure 4.



3.6.1 Final Join tool – 'Join Calculation' level 2 sub model



3.7 Tool updates

It is possible to update the tool to change noise source levels, include new data layers or even look at a new study area. There are a few steps within the Tool which would need to be changed to allow for these updates to be incorporated.

To update the source levels for the existing noise categories, the “SD Look Up” table which is provided within the “NM_Tool_Inputs.gdb” will need to be updated. This table contains the source noise level and the noise level at each of the buffer distances; these can easily be changed by editing the table.

To include new data layers to the model a new pre-processing tool will need to be created to convert the new layer into the same grid as the output grid. The values in the outputs are based on the length of time (hours) an activity occurs for a year within each of 2km by 2km cell. To convert a new layer to match the other layers multiple issues will need to be considered such as;

- What does the new layer show?
- Can this be converted into time in hours?
- What length of time does the data set cover? And
- Is it the same year as the other data sources?

A new row in the SD LookUp table will have to be added for this new layer and noise levels added for each of the buffer distances. The name within the Category field of the SD LookUp table needs to match exactly with the name of the new layer once it has been pre-processed.

The tool can be run on a new study area as long as the underlying data layers (AIS, EMS, VMS and any new data layers if added) cover this new study area. The tool selects data within the South Plan areas during the pre-processing tools and the “MMO South Marine Plan Areas” feature class which is provided within the NM Raw DataSets geodatabase is used to complete this selection. This boundary file can be replaced with another boundary file and the pre-processing tools will then select the data within the new study area. A new buffers geodatabase will need to be created by running the ‘multiple ring buffer’ ArcGIS tool on the centroids of the cells within the new study area. All the subsequent steps will then produce outputs for this new study area.

If any of the source levels have changed or a new data layer has been added then the ‘Final Join’ will need to be updated. This tool joins the tables of all the noise grids and then completes field calculations to generate a final joined grid. If a new data layer is added then a new join will need to be added to the tool to join this layer, the field calculations will then need to be updated to include the additional fields from the new layer. If source levels have been changed then only the field calculations will need to be updated within the tool. These updates will need to be done by editing the tool using ESRI ArcGIS ModelBuilder.

4. ArcGIS Geodatabase Schema

The schemas for the four geodatabases which accompany the tool and the feature classes which are used within the tool or are created by the tool are detailed within this section. As described in section 3, four geodatabases have been provided;

- NM_Raw_DataSets.gdb
- NM_Tool_Inputs.gdb
- NM_Tool_Outputs.gdb
- NM_Buffers_x.gdb.

4.1 NM Raw DataSets geodatabase schema

Table 6 details the feature classes within the NM_Raw_DataSets geodatabase, Tables 7 to 10 describe the schema for each of these feature classes.

Table 6: Schema of geodatabase 'NM_Raw_Datasets.gdb'.

Feature Class	Type	Description
DG_2012_Ave	Vector polygon	The 2012 AIS density grid for UK waters.
MMO_South_Marine_Plan_Areas	Vector polygon	Boundary of the south marine plan areas.
MMO_UK_Fishing_Activity_2011	Vector polygon	Fishing activity for 2011 in UK waters.
TCE_2012_Dredging_polygons	Vector polygon	Annual time of aggregate dredging activity for 2012.

Table 7: Schema of feature class 'DG_2012_AVE'.

Field Name	Field Type	Description
OBJECTID*	Object ID	Automatically generated, incremental ID.
Shape*	Geometry	Automatically generated, feature shape.
CELL_ID	Long	Unique ID given to each cell.
Ave2012_ST_0	Double	Density of vessels for 'Unknown' ship type.
Ave2012_ST_1	Double	Density of vessels for 'Non-port service craft' ship type.
Ave2012_ST_2	Double	Density of vessels for 'Port service craft' ship type.
Ave2012_ST_3	Double	Density of vessels for 'Vessels engaged in dredging or underwater operations' ship type.
Ave2012_ST_4	Double	Density of vessels for 'High speed craft' ship type.
Ave2012_ST_5	Double	Density of vessels for 'Military or law enforcement vessels' ship type.
Ave2012_ST_6	Double	Density of vessels for 'Passenger vessels' ship type.
Ave2012_ST_7	Double	Density of vessels for 'Cargo vessels' ship type.
Ave2012_ST_8	Double	Density of vessels for 'Tankers' ship type.
Ave2012_ST_9	Double	Density of vessels for 'Fishing vessels' ship type.
Ave2012_ST_10	Double	Density of vessels for 'Sailing and pleasure craft' ship type.
Ave2012_ST_All	Double	Density of vessels for all ship types.
Shape_Length	Double	Automatically generated, length of feature (m).
Shape_Area	Double	Automatically generated, area of feature (m).

Table 8: Schema of feature class 'MMO_South_Marine_Plan_Areas'.

Field Name	Field Type	Description
OBJECTID_1*	Object ID	Automatically generated, incremental ID.
Shape*	Geometry	Automatically generated, feature shape.
OBJECTID*	Object ID	Automatically generated, incremental ID.
REGIONREF	String	Reference code for plan area.
LABEL	String	Reference label for plan area.
INFO	String	Name of plan area.
AREA_SQKM	Double	The area in square kilometres.
Shape_Length	Double	Automatically generated, length of feature (m).
Shape_Area	Double	Automatically generated, area of feature (m).

Table 9: Schema of feature class 'MMO_UK_Fishing_Activity_2011'.

Field Name	Field Type	Description
OBJECTID_1*	Object ID	Automatically generated, incremental ID.
Shape*	Geometry	Automatically generated, feature shape.
ICES_ID	String	ICES rectangle ID.
SUB_REC	String	ICES sub rectangle ID.
ID	String	ICES rectangle and sub rectangle IDs combined.
TOTTIME	Double	The total time in minutes of fishing activity.
MOBTIME	Double	The time in minutes of fishing activity by mobile gears.
PASSTIME	Double	The time in minutes of fishing activity by passive gears.
Shape_Length	Double	Automatically generated, length of feature (m).
Shape_Area	Double	Automatically generated, area of feature (m).

Table 10: Schema of feature class 'TCE_2012_Dredging_polygons'.

Field Name	Field Type	Description
OBJECTID_1*	Object ID	Automatically generated, incremental ID.
Shape*	Geometry	Automatically generated, feature shape.
ID	Double	Unique ID.
GRIDCODE	Double	Value of 1 to 3 which represents the dredging activity. 1 <= 15 minutes, 2 = 15 minutes to 1 hour 15 minutes and 3 = >1 hour 15 minutes.
Shape_Length	Double	Automatically generated, length of feature (m).
Shape_Area	Double	Automatically generated, area of feature (m).

4.2 NM Tool Inputs geodatabase schema

Table 11 details the feature classes within the NM_Tool_Inputs geodatabase, Tables 12 to 20 describe the schema for each of these feature classes.

Table 11: Schema of geodatabase 'NM_Tool_Inputs.gdb'.

Feature Data Set	Feature Class	Type	Description
Base Grids	AIS_Cargo	Vector polygon	Generated by the Noise Model Toolbox Pre-processing tool 'AIS_Cargo'. Input data layer for the Noise Model Toolbox 'Noise Propagation Model'.
Base Grids	AIS_Dredger_UnderwaterOps	Vector polygon	Generated by the Noise Model Toolbox Pre-processing tool 'AIS_Dredger_UnderwaterOps'. Input data layer for the Noise Model Toolbox 'Noise Propagation Model'.
Base Grids	AIS_Fishing	Vector polygon	Generated by the Noise Model Toolbox Pre-processing tool 'AIS_Fishing'. Input data layer for the Noise Model Toolbox 'Noise Propagation Model'.
Base Grids	AIS_Passenger	Vector polygon	Generated by the Noise Model Toolbox Pre-processing tool 'AIS_Passenger'. Input data layer for the Noise Model Toolbox 'Noise Propagation Model'.
Base Grids	AIS_PortServiceCraft	Vector polygon	A Generated by the Noise Model Toolbox Pre-processing tool 'AIS_port_Service_Craft'. Input data layer for the Noise Model Toolbox 'Noise Propagation Model'.
Base Grids	AIS_Tanker	Vector polygon	Generated by the Noise Model Toolbox Pre-processing tool 'AIS_Tanker'. Input data layer for the Noise Model Toolbox 'Noise Propagation Model'.
Base Grids	EMS_Grid	Vector polygon	Generated by the Noise Model Toolbox Pre-processing tool 'EMS_to_Grid'. Input data layer for the Noise Model Toolbox 'Noise Propagation Model'.
Base Grids	VMS_Grid	Vector polygon	Generated by the Noise Model Toolbox Pre-processing tool 'VMS_to_Grid'. Input data layer for the Noise Model Toolbox 'Noise Propagation Model'.
none	ALL_Grids_Template	Vector polygon	An empty template grid for the south marine plan areas with 3dB increment fields for noise levels, this grid is used by the Noise Model Toolbox 'Final_Join' tool.
none	SD_Lookup	Table	This table is used as a lookup table by the Noise Model Toolbox 'Noise Propagation' tool to apply the correct noise levels for each category.
none	dB_band_lookup	Table	This table is used as a lookup table by the Noise Model Toolbox 'Noise Propagation' tool to assign sound level exposure to the correct 3 dB summary band.

Table 12: Schema of feature class 'AIS_Cargo'.

Field Name	Field Type	Description
OBJECTID_1*	Object ID	Automatically generated, incremental ID.
Shape*	Geometry	Automatically generated, feature shape.
CELL_ID	Long	Unique ID given to each cell.
Density	Double	The density value from the AIS ship type group 7 (Cargo Vessels).
Time	Double	The time in hours that cargo ships are present in a cell.
Shape_Length	Double	Automatically generated, length of feature (m).
Shape_Area	Double	Automatically generated, area of feature (m).

Table 13: Schema of feature class 'AIS_Dredger_UnderwaterOps'.

Field Name	Field Type	Description
OBJECTID_1*	Object ID	Automatically generated, incremental ID.
Shape*	Geometry	Automatically generated, feature shape.
CELL_ID	Long	Unique ID given to each cell.
Density	Double	The density value from the AIS ship type group 3 (Vessels engaged in dredging or underwater operations).
Time	Double	The time in hours that cargo ships are present in a cell.
Shape_Length	Double	Automatically generated, length of feature (m).
Shape_Area	Double	Automatically generated, area of feature (m).

Table 14: Schema of feature class 'AIS_Fishing'.

Field Name	Field Type	Description
OBJECTID_1*	Object ID	Automatically generated, incremental ID.
Shape*	Geometry	Automatically generated, feature shape.
CELL_ID	Long	Unique ID given to each cell.
Density	Double	The density value from the AIS ship type group 9 (fishing vessels).
Time	Double	The time in hours that cargo ships are present in a cell.
Shape_Length	Double	Automatically generated, length of feature (m).
Shape_Area	Double	Automatically generated, area of feature (m).

Table 15: Schema of feature class 'AIS_Passenger'.

Field Name	Field Type	Description
OBJECTID_1*	Object ID	Automatically generated, incremental ID.
Shape*	Geometry	Automatically generated, feature shape.
CELL_ID	Long	Unique ID given to each cell.
Density	Double	The density value from the AIS ship type group 6 (Passenger vessels).
Time	Double	The time in hours that cargo ships are present in a cell.
Shape_Length	Double	Automatically generated, length of feature (m).
Shape_Area	Double	Automatically generated, area of feature (m).

Table 16: Schema of feature class 'AIS_PortServiceCraft'.

Field Name	Field Type	Description
OBJECTID_1*	Object ID	Automatically generated, incremental ID.
Shape*	Geometry	Automatically generated, feature shape.
CELL_ID	Long	Unique ID given to each cell.
Density	Double	The density value from the AIS ship type group 2 (Port service craft).
Time	Double	The time in hours that cargo ships are present in a cell.
Shape_Length	Double	Automatically generated, length of feature (m).
Shape_Area	Double	Automatically generated, area of feature (m).

Table 17: Schema of feature class 'AIS_Tanker'.

Field Name	Field Type	Description
OBJECTID_1*	Object ID	Automatically generated, incremental ID.
Shape*	Geometry	Automatically generated, feature shape.
CELL_ID	Long	Unique ID given to each cell.
Density	Double	The density value from the AIS ship type group 8 (Tankers).
Time	Double	The time in hours that cargo ships are present in a cell.
Shape_Length	Double	Automatically generated, length of feature (m).
Shape_Area	Double	Automatically generated, area of feature (m).

Table 18: Schema of feature class 'EMS_Grid'.

Field Name	Field Type	Description
OBJECTID_1*	Object ID	Automatically generated, incremental ID.
Shape*	Geometry	Automatically generated, feature shape.
CELL_ID	Long	Unique ID given to each cell.
SUM_Time	Double	The time of aggregate dredging activity in hours for each cell, generated by the dissolve process in the pre-processing tool.
Time	Double	The time in hours that aggregate dredging activity occurs in a cell, the same value as the 'SUM_Time' field.
Shape_Length	Double	Automatically generated, length of feature (m).
Shape_Area	Double	Automatically generated, area of feature (m).

Table 19: Schema of feature class 'VMS_Grid'.

Field Name	Field Type	Description
OBJECTID_1*	Object ID	Automatically generated, incremental ID.
Shape*	Geometry	Automatically generated, feature shape.
CELL_ID	Long	Unique ID given to each cell.
Time	Double	The time in hours that fishing activity by mobile fishing gears occurs in a cell.
Shape_Length	Double	Automatically generated, length of feature (m).
Shape_Area	Double	Automatically generated, area of feature (m).

Table 20: Schema of feature class 'All_Grids_Template'.

Field Name	Field Type	Description
OBJECTID_1*	Object ID	Automatically generated, incremental ID.
Shape*	Geometry	Automatically generated, feature shape.
CELL_ID	Long	Unique ID given to each cell.
dB_90	Double	Empty field to be populated by the 'Final Join' tool.
dB_93	Double	Empty field to be populated by the 'Final Join' tool.
dB_96	Double	Empty field to be populated by the 'Final Join' tool.
dB_99	Double	Empty field to be populated by the 'Final Join' tool.
dB_102	Double	Empty field to be populated by the 'Final Join' tool.
dB_105	Double	Empty field to be populated by the 'Final Join' tool.
dB_108	Double	Empty field to be populated by the 'Final Join' tool.
dB_111	Double	Empty field to be populated by the 'Final Join' tool.
dB_114	Double	Empty field to be populated by the 'Final Join' tool.

Field Name	Field Type	Description
dB_117	Double	Empty field to be populated by the 'Final Join' tool.
dB_120	Double	Empty field to be populated by the 'Final Join' tool.
dB_123	Double	Empty field to be populated by the 'Final Join' tool.
dB_126	Double	Empty field to be populated by the 'Final Join' tool.
dB_129	Double	Empty field to be populated by the 'Final Join' tool.
dB_132	Double	Empty field to be populated by the 'Final Join' tool.
dB_135	Double	Empty field to be populated by the 'Final Join' tool.
dB_138	Double	Empty field to be populated by the 'Final Join' tool.
dB_141	Double	Empty field to be populated by the 'Final Join' tool.
dB_144	Double	Empty field to be populated by the 'Final Join' tool.
dB_147	Double	Empty field to be populated by the 'Final Join' tool.
dB_150	Double	Empty field to be populated by the 'Final Join' tool.
dB_153	Double	Empty field to be populated by the 'Final Join' tool.
dB_156	Double	Empty field to be populated by the 'Final Join' tool.
dB_159	Double	Empty field to be populated by the 'Final Join' tool.
dB_162	Double	Empty field to be populated by the 'Final Join' tool.
dB_165	Double	Empty field to be populated by the 'Final Join' tool.
dB_168	Double	Empty field to be populated by the 'Final Join' tool.
dB_171	Double	Empty field to be populated by the 'Final Join' tool.
dB_174	Double	Empty field to be populated by the 'Final Join' tool.
dB_177	Double	Empty field to be populated by the 'Final Join' tool.
dB_180	Double	Empty field to be populated by the 'Final Join' tool.
dB_183	Double	Empty field to be populated by the 'Final Join' tool.
dB_186	Double	Empty field to be populated by the 'Final Join' tool.
dB_189	Double	Empty field to be populated by the 'Final Join' tool.
dB_192	Double	Empty field to be populated by the 'Final Join' tool.
Shape_Length	Double	Automatically generated, length of feature (m).
Shape_Area	Double	Automatically generated, area of feature (m).

Table 21: Schema of feature class 'SD_Lookup'.

Field Name	Field Type	Description
OBJECTID_1*	Object ID	Automatically generated, incremental ID.
Category	String	The name of the noise category.
SourceLevel	Double	The dB source level (1.9 km) for the noise category.
Distance_1	Double	The dB level of propagated noise for the first buffer distance (2.15 km) for the noise category.
Distance_2	Double	The dB level of propagated noise for the second buffer distance (2.51 km) for the noise category.
Distance_3	Double	The dB level of propagated noise for the third buffer distance (2.93 km) for the noise category.
Distance_4	Double	The dB level of propagated noise for the fourth buffer distance (3.41 km) for the noise category.
Distance_5	Double	The dB level of propagated noise for the fifth buffer distance (3.98 km) for the noise category.
Distance_6	Double	The dB level of propagated noise for the sixth buffer distance (4.64 km) for the noise category.

Table 22: Schema of feature class 'dB_band_lookup'

Field Name	Field Type	Description
OBJECTID_1*	Object ID	Automatically generated, incremental ID.
dB	Integer	dB value.
Band	Integer	Associated 3 dB band.

4.3 NM Tool Outputs geodatabase schema

Table 23 details the feature classes within the NM_Tool_Inputs geodatabase, Table 23 to Table 32 describe the schema for each of these feature classes.

Table 23: Schema of geodatabase 'NM_Tool_Outputs.gdb'.

Feature Class	Type	Description
AIS_Cargo	Vector polygon	Generated by the Noise Model Toolbox 'Noise Propagation' tool. Input data layer for the Noise Model Toolbox 'Final Join'.
AIS_Dredger_UnderwaterOps	Vector polygon	Generated by the Noise Model Toolbox 'Noise Propagation' tool. Input data layer for the Noise Model Toolbox 'Final Join'.
AIS_Fishing	Vector polygon	Generated by the Noise Model Toolbox 'Noise Propagation' tool. Input data layer for the Noise Model Toolbox 'Final Join'.
AIS_Passenger	Vector polygon	Generated by the Noise Model Toolbox 'Noise Propagation' tool. Input data layer for the Noise Model Toolbox 'Final Join'.
AIS_PortServiceCraft	Vector polygon	Generated by the Noise Model Toolbox 'Noise Propagation' tool. Input data layer for the Noise Model Toolbox 'Final Join'.
AIS_Tanker	Vector polygon	Generated by the Noise Model Toolbox 'Noise Propagation' tool. Input data layer for the Noise Model Toolbox 'Final Join'.
EMS_Grid	Vector polygon	Generated by the Noise Model Toolbox 'Noise Propagation' tool. Input data layer for the Noise Model Toolbox 'Final Join'.
VMS_Grid	Vector polygon	Generated by the Noise Model Toolbox 'Noise Propagation' tool. Input data layer for the Noise Model Toolbox 'Final Join'.
Final_Grid	Vector polygon	The final grid output which combines all the noise category output layers into one. Output of the Noise Model Toolbox 'Final_Join' tool.

Table 24: Schema of feature class 'AIS_Cargo'.

Field Name	Field Type	Description
OBJECTID_1*	Object ID	Automatically generated, incremental ID.
Shape*	Geometry	Automatically generated, feature shape.
CELL_ID	Long	Unique ID given to each cell.
Density	Double	The density value from the AIS ship type group 7 (Cargo Vessels).
Time	Double	The time in hours that cargo ships are present in a cell.
dB_185	Double	The time of noise in hours at the source dB level.
dB_135	Double	The time of noise in hours for the buffer 1 distance dB level.
dB_134	Double	The time of noise in hours for the buffer 2 distance dB level.
dB_133	Double	The time of noise in hours for the buffer 3 distance dB level.
dB_132	Double	The time of noise in hours for the buffer 4 distance dB level.
dB_131	Double	The time of noise in hours for the buffer 5 distance dB level.
dB_130	Double	The time of noise in hours for the buffer 6 distance dB level.
Shape_Length	Double	Automatically generated, length of feature (m).
Shape_Area	Double	Automatically generated, area of feature (m).

Table 25: Schema of feature class 'AIS_Dredger_UnderwaterOps'.

Field Name	Field Type	Description
OBJECTID_1*	Object ID	Automatically generated, incremental ID.
Shape*	Geometry	Automatically generated, feature shape.
CELL_ID	Long	Unique ID given to each cell.
Density	Double	The density value from the AIS ship type group 3 (Vessels engaged in dredging or underwater operations).
Time	Double	The time in hours that cargo ships are present in a cell.
dB_181	Double	The time of noise in hours at the source dB level.
dB_131	Double	The time of noise in hours for the buffer 1 distance dB level.
dB_130	Double	The time of noise in hours for the buffer 2 distance dB level.
dB_129	Double	The time of noise in hours for the buffer 3 distance dB level.
dB_128	Double	The time of noise in hours for the buffer 4 distance dB level.
dB_127	Double	The time of noise in hours for the buffer 5 distance dB level.
dB_126	Double	The time of noise in hours for the buffer 6 distance dB level.
Shape_Length	Double	Automatically generated, length of feature (m).
Shape_Area	Double	Automatically generated, area of feature (m).

Table 26: Schema of feature class 'AIS_Fishing'.

Field Name	Field Type	Description
OBJECTID_1*	Object ID	Automatically generated, incremental ID.
Shape*	Geometry	Automatically generated, feature shape.
CELL_ID	Long	Unique ID given to each cell.
Density	Double	The density value from the AIS ship type group 9 (Fishing Vessels).
Time	Double	The time in hours that cargo ships are present in a cell.
dB_150	Double	The time of noise in hours at the source dB level.
dB_100	Double	The time of noise in hours for the buffer 1 distance dB level.
dB_99	Double	The time of noise in hours for the buffer 2 distance dB level.
dB_98	Double	The time of noise in hours for the buffer 3 distance dB level.
dB_97	Double	The time of noise in hours for the buffer 4 distance dB level.
dB_96	Double	The time of noise in hours for the buffer 5 distance dB level.
dB_95	Double	The time of noise in hours for the buffer 6 distance dB level.
Shape_Length	Double	Automatically generated, length of feature (m).
Shape_Area	Double	Automatically generated, area of feature (m).

Table 27: Schema of feature class 'AIS_Passenger'.

Field Name	Field Type	Description
OBJECTID_1*	Object ID	Automatically generated, incremental ID.
Shape*	Geometry	Automatically generated, feature shape.
CELL_ID	Long	Unique ID given to each cell.
Density	Double	The density value from the AIS ship type group 6 (Passenger vessels).
Time	Double	The time in hours that cargo ships are present in a cell.
dB_155	Double	The time of noise in hours at the source dB level.
dB_105	Double	The time of noise in hours for the buffer 1

Field Name	Field Type	Description
		distance dB level.
dB_104	Double	The time of noise in hours for the buffer 2 distance dB level.
dB_103	Double	The time of noise in hours for the buffer 3 distance dB level.
dB_102	Double	The time of noise in hours for the buffer 4 distance dB level.
dB_101	Double	The time of noise in hours for the buffer 5 distance dB level.
dB_100	Double	The time of noise in hours for the buffer 6 distance dB level.
Shape_Length	Double	Automatically generated, length of feature (m).
Shape_Area	Double	Automatically generated, area of feature (m).

Table 28: Schema of feature class 'AIS_PortServiceCraft'.

Field Name	Field Type	Description
OBJECTID_1*	Object ID	Automatically generated, incremental ID.
Shape*	Geometry	Automatically generated, feature shape.
CELL_ID	Long	Unique ID given to each cell.
Density	Double	The density value from the AIS ship type group 2 (Port service craft).
Time	Double	The time in hours that cargo ships are present in a cell.
dB_166	Double	The time of noise in hours at the source dB level.
dB_116	Double	The time of noise in hours for the buffer 1 distance dB level.
dB_115	Double	The time of noise in hours for the buffer 2 distance dB level.
dB_114	Double	The time of noise in hours for the buffer 3 distance dB level.
dB_113	Double	The time of noise in hours for the buffer 4 distance dB level.
dB_112	Double	The time of noise in hours for the buffer 5 distance dB level.
dB_111	Double	The time of noise in hours for the buffer 6 distance dB level.
Shape_Length	Double	Automatically generated, length of feature (m).
Shape_Area	Double	Automatically generated, area of feature (m).

Table 29: Schema of feature class 'AIS_Tanker'.

Field Name	Field Type	Description
OBJECTID_1*	Object ID	Automatically generated, incremental ID.
Shape*	Geometry	Automatically generated, feature shape.
CELL_ID	Long	Unique ID given to each cell.

Field Name	Field Type	Description
Density	Double	The density value from the AIS ship type group 8 (Tankers).
Time	Double	The time in hours that cargo ships are present in a cell.
dB_184	Double	The time of noise in hours at the source dB level.
dB_134	Double	The time of noise in hours for the buffer 1 distance dB level.
dB_133	Double	The time of noise in hours for the buffer 2 distance dB level.
dB_132	Double	The time of noise in hours for the buffer 3 distance dB level.
dB_131	Double	The time of noise in hours for the buffer 4 distance dB level.
dB_130	Double	The time of noise in hours for the buffer 5 distance dB level.
dB_129	Double	The time of noise in hours for the buffer 6 distance dB level.
Shape_Length	Double	Automatically generated, length of feature (m).
Shape_Area	Double	Automatically generated, area of feature (m).

Table 30: Schema of feature class 'EMS_Grid'.

Field Name	Field Type	Description
OBJECTID_1*	Object ID	Automatically generated, incremental ID.
Shape*	Geometry	Automatically generated, feature shape.
CELL_ID	Long	Unique ID given to each cell.
Density	Double	The density value from EMS.
Time	Double	The time in hours that cargo ships are present in a cell.
dB_187	Double	The time of noise in hours at the source dB level.
dB_137	Double	The time of noise in hours for the buffer 1 distance dB level.
dB_136	Double	The time of noise in hours for the buffer 2 distance dB level.
dB_135	Double	The time of noise in hours for the buffer 3 distance dB level.
dB_134	Double	The time of noise in hours for the buffer 4 distance dB level.
dB_133	Double	The time of noise in hours for the buffer 5 distance dB level.
dB_132	Double	The time of noise in hours for the buffer 6 distance dB level.
Shape_Length	Double	Automatically generated, length of feature (m).
Shape_Area	Double	Automatically generated, area of feature (m).

Table 31: Schema of feature class 'VMS_Grid'.

Field Name	Field Type	Description
OBJECTID_1*	Object ID	Automatically generated, incremental ID.
Shape*	Geometry	Automatically generated, feature shape.
CELL_ID	Long	Unique ID given to each cell.
Density	Double	The density value from VMS.
Time	Double	The time in hours that cargo ships are present in a cell.
dB_147	Double	The time of noise in hours at the source dB level.
dB_97	Double	The time of noise in hours for the buffer 1 distance dB level.
dB_96	Double	The time of noise in hours for the buffer 2 distance dB level.
dB_95	Double	The time of noise in hours for the buffer 3 distance dB level.
dB_94	Double	The time of noise in hours for the buffer 4 distance dB level.
dB_93	Double	The time of noise in hours for the buffer 5 distance dB level.
dB_92	Double	The time of noise in hours for the buffer 6 distance dB level.
Shape_Length	Double	Automatically generated, length of feature (m).
Shape_Area	Double	Automatically generated, area of feature (m).

Table 32: Schema of feature class 'Final_Grid'.

Field Name	Field Type	Description
OBJECTID_1*	Object ID	Automatically generated, incremental ID.
Shape*	Geometry	Automatically generated, feature shape.
CELL_ID	Long	Unique ID given to each cell.
dB_90	Double	The time in hours of noise at the 90 dB interval level for all noise categories.
dB_93	Double	The time in hours of noise at the 93 dB interval level for all noise categories.
dB_96	Double	The time in hours of noise at the 96 dB interval level for all noise categories.
dB_99	Double	The time in hours of noise at the 99 dB interval level for all noise categories.
dB_102	Double	The time in hours of noise at the 102 dB interval level for all noise categories.
dB_105	Double	The time in hours of noise at the 105 dB interval level for all noise categories.
dB_108	Double	The time in hours of noise at the 108 dB interval level for all noise categories.
dB_111	Double	The time in hours of noise at the 111 dB interval level for all noise categories.
dB_114	Double	The time in hours of noise at the 114 dB interval level for all noise categories.
dB_117	Double	The time in hours of noise at the 117 dB interval level for all noise categories.
dB_120	Double	The time in hours of noise at the 120 dB interval level for all noise categories.
dB_123	Double	The time in hours of noise at the 123 dB interval level for all noise categories.
dB_126	Double	The time in hours of noise at the 126 dB interval level for all noise categories.
dB_129	Double	The time in hours of noise at the 129 dB interval level for all noise categories.
dB_132	Double	The time in hours of noise at the 132 dB interval level for all noise categories.
dB_135	Double	The time in hours of noise at the 135 dB interval level for all noise categories.
dB_138	Double	The time in hours of noise at the 138 dB interval level for all noise categories.
dB_141	Double	The time in hours of noise at the 141 dB interval level for all noise categories.
dB_144	Double	The time in hours of noise at the 144 dB interval level for all noise categories.
dB_147	Double	The time in hours of noise at the 147 dB interval level for all noise categories.
dB_150	Double	The time in hours of noise at the150 dB interval level for all noise categories.
dB_153	Double	The time in hours of noise at the 153 dB interval level for all noise categories.
dB_156	Double	The time in hours of noise at the 156 dB interval level for all noise categories.
dB_159	Double	The time in hours of noise at the 159 dB interval level for all noise categories.
dB_162	Double	The time in hours of noise at the 162 dB interval level for all noise categories.
dB_165	Double	The time in hours of noise at the 165 dB interval level for all noise categories.
dB_168	Double	The time in hours of noise at the 168 dB interval level for all noise categories.
dB_171	Double	The time in hours of noise at the 171 dB interval level for all noise categories.
dB_174	Double	The time in hours of noise at the 174 dB interval level for all noise categories.
dB_177	Double	The time in hours of noise at the 177 dB interval level for all noise categories.
dB_180	Double	The time in hours of noise at the 180 dB interval level for all noise categories.
dB_183	Double	The time in hours of noise at the 183 dB interval level for all noise categories.

Field Name	Field Type	Description
dB_186	Double	The time in hours of noise at the 186 dB interval level for all noise categories.
dB_189	Double	The time in hours of noise at the 189 dB interval level for all noise categories.
dB_192	Double	The time in hours of noise at the 192 dB interval level for all noise categories.
Shape_Length	Double	Automatically generated, length of feature (m).
Shape_Area	Double	Automatically generated, area of feature (m).

4.4 NM Buffers geodatabase schema

The NM_Buffers_x.gdb contains the buffer feature classes (Tables 32 and 33). Each of the feature classes represents a multiple ring buffer for a cell within the south marine plan template grid and the final output grids. The buffers are used by the Noise Model Toolbox 'Noise Propagation' tools.

Table 33: Schema of geodatabase 'NM_Buffers_x.gdb'.

Feature Class	Type	Description
B_63217	Vector polygon	Multiple ring buffer at 4 distances: 1.9 km, 2.15 km, 2.93 km and 4.64 km. from the centroid of cell 63217.
Contains 6279 buffers in total from B_63217 to B_.100407.	Vector polygon	Multiple ring buffers for all 6279 cells
B_100407	Vector polygon	Multiple ring buffer at 4 distances: 1.9 km, 2.15 km, 2.93 km and 4.64 km. from the centroid of cell 100407.

Table 34: Schema of feature class 'B_100407' as an example of the schema of all feature classes contained within 'NM_Buffers_x.gdb'.

Field Name	Field Type	Description
OBJECTID_1*	Object ID	Automatically generated, incremental ID.
Shape*	Geometry	Automatically generated, feature shape.
distance	Double	The distance in kilometres of the buffer from the centroid of the cell.
Shape_Length	Double	Automatically generated, length of feature (m).
Shape_Area	Double	Automatically generated, area of feature (m).

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