DOHERTY MODELLING INTERIM REPORT TO NATIONAL CABINET 17TH SEPTEMBER 2021

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APPENDIX

EXECUTIVE SUMMARY

Sensitivity analyses were undertaken in response to queries raised at National Cabinet about the scenarios represented in the Doherty Modelling Technical Report and Addendum (10th August 2021);

- We have provided assurance that delays to full efficacy of two dose completion are incorporated in our dynamic assumptions, and clarified that coverage achieved at threshold cut points is further augmented by single dose completions to that date;
- Robustness of recommendations regarding 70% and 80% coverage scenarios to the number of infections seeding epidemics was assessed. We considered three levels of introduction in the order of low (tens, approximately 10-100), medium (hundreds, approximately 300-1,000) or high (thousands, approximately 1,000-4,500) initial cases;
    - At the 70% coverage threshold with baseline PHSMs and partial TTIQ, an increase from tens to hundreds of seeded infections results in a leftward shift of timing of the epidemic meaning that it completes within the reporting window of 180 days but does not differ in overall impact;
    - At the 70% coverage threshold with baseline PHSMs and partial TTIQ, seeding of thousands of infections shifts both the timing and peak of the epidemic significantly. Overall size is notably increased. This is because the window in time between 70 and 80% coverage is sufficient to allow early epidemic growth from high numbers, resulting in 'overshoot' (Figure ES1);
    - Much less impact on the overall size of epidemics is observed when these seeding scenarios (tens, hundreds, thousands) are introduced from the 80% coverage timepoint, with baseline PHSMs and partial TTIQ (Figure ES1);
    - For all of the above scenarios, infections and corresponding harms are markedly reduced by application of either 1) optimal TTIQ (Figure ES2); or 2) 'low' PHSMs and partial TTIQ (Figure ES3), (Table ES1).
- Given the observed sensitivity to 'high' seeding infections at 70%, ongoing application of 'medium' PSHMs at the time of transition to Phase B is deemed prudent in such cases, at least until the 80% coverage threshold is achieved (Figure ES3)(Table ES2);
- At high caseloads, maintenance of optimal TTIQ is unlikely to be possible. In such instances, flexibility to strengthen PHSMs generally or locally will be needed (as envisaged in the National Plan) to regain epidemic control. The required intensity and duration of measures should be informed by ongoing situational assessment of transmission and its related health impacts.

The scenarios in this report representing a single national COVID-19 epidemic are clearly (and deliberately) artificial and serve to inform high level policy strategy. Their key message is to highlight the importance of a combination of timely public health responses (TTIQ) and ongoing social and behavioural measures (PHSMs) to constrain transmission, even in highly immunised populations;

- **In reality, the national COVID-19 epidemic has been and will continue to be a 'fire' fought on multiple fronts.** Bridging of this high-level strategy to implementation requires attention to localised risk determinants, differential impact of PHSMs, small area reporting of vaccine coverage and optimisation of TTIQ and public health responses to address focal outbreaks;
    - The next phase of modelling work will focus on addressing these issues in consultation with jurisdictions and relevant committees to define evidence based and sustainable approaches;
- Previous findings of the relatively small contribution of the 12-15 years age cohort to infection transmission have not been reinterrogated. Current model outputs do not incorporate direct protective effects of immunising this age group, or anticipated related indirect protection of children <12 years;
    - Given the recent shift in the national immunisation strategy regarding this cohort our next work phase will include attention to immunisation coverage in school settings. We are consulting with Operation COVID-Shield to identify vaccine implementation approaches that will influence likely future coverage in schools, within their population context.

Figure ES1: Epidemic growth to 180 days for Baseline PHSMs and Partial TTIQ

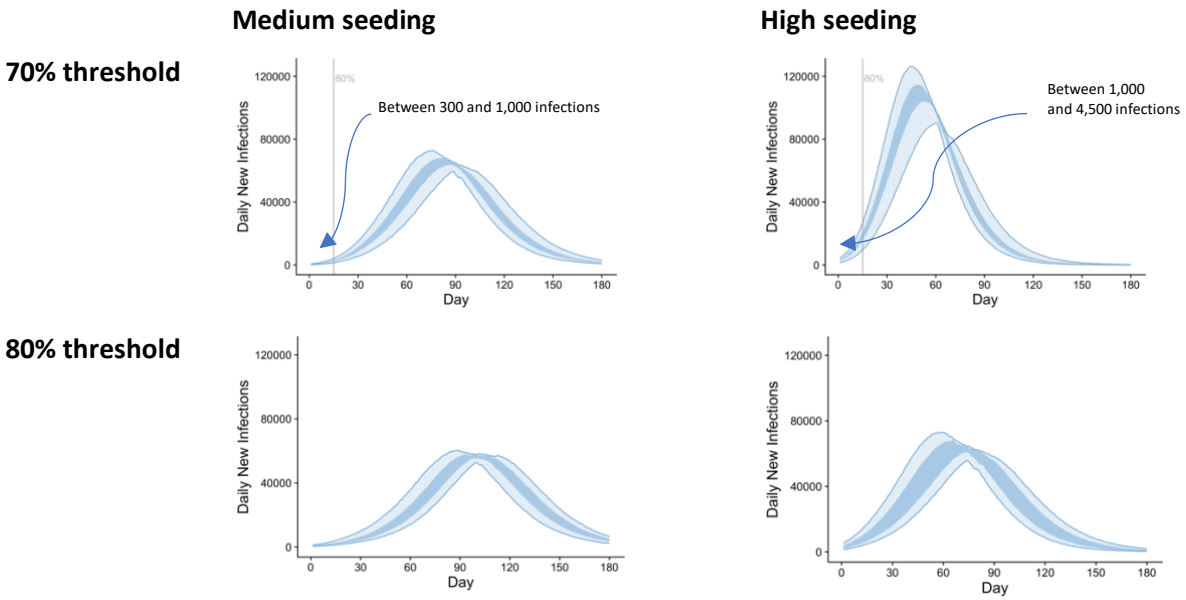


Figure ES2: Epidemic growth to 180 days for Baseline PHSMs and Optimal TTIQ

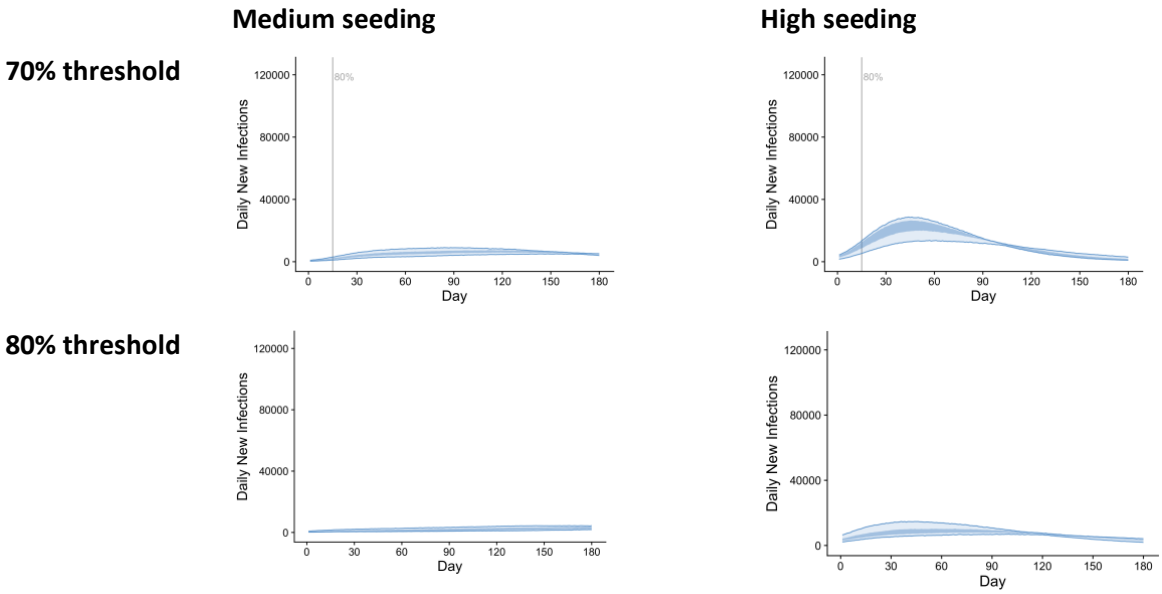
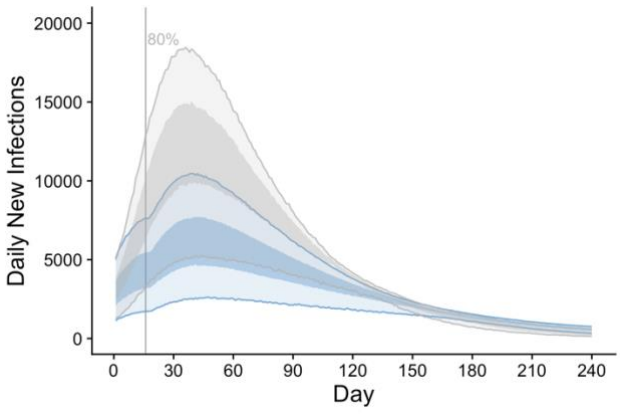


Figure ES3: Epidemic growth to 240 days for High seeding epidemics at the 70% threshold with Partial TTIQ. Grey curves assume continuously overlaid low PHSMs. Blue curves show enhanced suppression by medium PHSMs during the transition between 70 and 80%, reverting to low PHSMs from 80%*



**Note y axes smaller than for Figures ES1 and ES2, to enable comparison of infections at 80% threshold*

Table ES1: Cumulative symptomatic infections, ward admissions, ICU admissions and deaths over the first 180 days for the coverage threshold of 70% and low seeding infections assuming different combinations of PHSMs and TTIQ effectiveness, broken down by vaccination status and age

		<16 yrs #		16-39 yrs		40-59 yrs		60+ yrs	
	PSHMs + TTIQ	**Vacc'd**	**Unvac**	**Vacc'd**	**Unvac**	**Vacc'd**	**Unvac**	**Vacc'd**	**Unvac**
Symptomatic infections	Baseline + Partial	0	479,538	54,937	153,876	53,848	84,235	31,962	13,831
	Baseline + Optimal	0	12,710	1,239	3,865	1,086	2,017	605	269
	Low + Partial	0	4,407	492	1,631	401	765	220	97
Ward admissions	Baseline + Partial	0	5,029	1,342	5,394	3,273	8,148	4,816	5,109
	Baseline + Optimal	0	111	28	134	63	182	91	97
	Low + Partial	0	41	11	57	24	70	33	35
ICU admissions	Baseline + Partial	0	409	228	920	929	2,305	1,162	1,279
	Baseline + Optimal	0	8	4	20	15	45	19	21
	Low + Partial	0	3	2	9	7	20	8	9
Deaths	Baseline + Partial	0	162	52	303	358	1,294	1,441	2,085
	Baseline + Optimal	0	3	1	7	6	26	26	37
	Low + Partial	0	1	0	3	3	11	10	14

 # In this and all subsequent tables '<16 yrs' refers to the complete population cohort aged 0 through 15 years inclusive. All individuals in this age category are assumed to be unvaccinated in these scenarios as the vaccine rollout model predated a positive recommendation for immunisation of children aged 12-15 years.

Table ES2: Cumulative symptomatic infections, ward admissions, ICU admissions and deaths over the first 180 days for the coverage threshold of 70% and high seeding infections assuming different combinations of PHSMs and TTIQ effectiveness, broken down by vaccination status and age

		<16 yrs#		16-39 yrs		40-59 yrs		60+ yrs	
	PSHMs + TTIQ	**Vacc'd**	**Unvac**	**Vacc'd**	**Unvac**	**Vacc'd**	**Unvac**	**Vacc'd**	**Unvac**
Symptomatic infections	Baseline + Partial	0	567,797	107,326	261,401	80,704	119,531	43,901	19,103
	Baseline + Optimal	0	220,455	35,630	97,968	25,090	43,368	12,870	5,788
	Low + Partial	0	121,335	19,597	57,584	13,490	24,371	6,943	3,079
	Med/Low + Partial[§]	*0*	*79,172*	*11,652*	*35,993*	*8,341*	*15,373*	*4,337*	*1,931*
Ward admissions	Baseline + Partial	0	6,407	2,292	9,084	4,938	11,967	6,711	7,149
	Baseline + Optimal	0	2,181	742	3,435	1,505	4,175	1,964	2,157
	Low + Partial	0	1,174	408	2,022	810	2,341	1,069	1,145
	Med/Low + Partial	*0*	*752*	*248*	*1,276*	*500*	*1,469*	*667*	*718*
ICU admissions	Baseline + Partial	0	578	431	1,683	1,588	3,823	1,842	2,020
	Baseline + Optimal	0	181	130	612	448	1,235	489	556
	Low + Partial	0	95	71	362	241	689	266	292
	Med/Low + Partial	*0*	*58*	*43*	*225*	*142*	*417*	*157*	*174*
Deaths	Baseline + Partial	0	221	104	533	607	2,090	2,179	3,139
	Baseline + Optimal	0	74	33	202	181	708	632	937
	Low + Partial	0	39	18	121	100	397	352	497
	Med/Low + Partial	*0*	*26*	*11*	*76*	*61*	*248*	*217*	*309*

 # In this and all subsequent tables '<16 yrs' refers to the complete population cohort aged 0 through 15 years inclusive. All individuals in this age category are assumed to be unvaccinated in these scenarios as the vaccine rollout model predated a positive recommendation for immunisation of children aged 12-15 years.

§ *These outcomes are for the scenario where medium PHSMs are overlaid between the 70 and 80% coverage thresholds (an interval of approximately 2 weeks given assumptions of the vaccine rollout model underpinning the scenarios (Figure ES3)), with reversion to low PHSMs thereafter, as shown in Figure ES3*

MAIN REPORT

Background

On 30 July 2021, National Cabinet considered advice from the Doherty Institute and Commonwealth Treasury to inform the National Plan to Transition Australia's National COVID Response. Infectious disease models were used to consider the likely relative impacts of COVID-19 epidemics introduced after achieving two-dose vaccine coverage at thresholds of 50, 60, 70 and 80% of the age-eligible (16+) population. The economic consequences of imposed social measures for disease control were also assessed.

The combined modelling/Treasury conclusion was that strict lockdowns were likely to be required to manage outbreaks until completed coverage of 70% or more had been achieved and that a 'low case' strategy was likely to be lower economic cost than managing higher transmission within the community. At vaccination rates of 70% or more, lockdowns were less expected but ongoing disease control measures would be needed to prevent case escalation that over-runs health system capacity, as follows:

- At 70% immunisation coverage, optimal 'test, trace, isolate, quarantine' (TTIQ) responses supported by continuous application of 'low' public health and social measures (PHSMs);
- At 80% immunisation coverage, partial TTIQ responses combined with low PHSMs.

This report presents a sensitivity analysis on some of the underpinning assumptions of that modelling. In particular, it examines sensitivity to the number of seeding infections present in the population at the time that the 70 and 80% thresholds are reached, with new 'high' and 'medium' seeding scenarios more representative of the likely status of jurisdictions with established community transmission. Given that only 'partial' TTIQ can be reasonably anticipated at higher caseloads, this analysis extends on reporting of earlier scenarios to demonstrate the important synergies of overlaid PHSMs to support partial TTIQ capacity.

Sensitivity analysis on scenarios in the Addendum (10th August 2021)

Scenarios below add further details of the 'transmission reducing' vaccine allocation strategy that was deemed implementable within the context of Australia's COVID-19 vaccination rollout, as outlined in the Addendum to our full Technical Report dated 10th August 2021. That scenario allocates vaccines sequentially as for Australia's national program, through to inclusion of individuals 40+ in July 2021. Within the projected simulation timeframe, the 30-39 years cohort becomes eligible from 30 August, and 16-29 years on 11 October. Subsequent policy determinations have broadened eligibility to the 16-39 years cohort from the 30 August date, but that scenario is not modelled here.

Completed effective coverage and single dose recipients at each threshold

Our threshold transitions in the dynamic modelling are initiated by two dose completions achieved by the end of the reporting week to/above the coverage target threshold. The rate of achieving these targets is based on outputs derived from the Quantium model of vaccine allocation. As the time to full vaccine efficacy following the second dose is 2 weeks, individuals immunised over the preceding fortnight will not be fully protected by vaccine at that cut point. It should also be noted that single dose coverage at any given threshold is over and above the proportion who have completed their two-dose schedule, contributing additional population protection. Numbers and proportions of individuals in each of these groups are reported in Table 1.1.

Table 1.1: Second dose completions by coverage threshold from the Quantium simulation model, including the subset of second doses received in the past two weeks. Additional first dose completions are also shown at this timepoint. All percentages refer to age-eligible (16+ years) population coverage

Simulated second dose completions at threshold (%)	Second doses received in past 2 weeks by threshold (%)	Additional first dose completions at 2 dose threshold (%)
10,999,882 (54%)	1,948,738 (18%)	3,277,732 (16%)
13,305,236 (65%)	2,305,354 (17%)	2,487,105 (12%)
14,592,405 (71%)	1,287,169 (9%)	2,501,924 (12%)
16,888,681 (82%)	1,454,236 (9%)	1,176,973 (6%)

Size of seeding outbreak

We have simulated a range of epidemic dynamic scenarios to demonstrate the impact of seeding infection numbers on the subsequent epidemic time course and scale. Figures 1.1 to 1.4 show outputs for each of the 70 and 80% coverage scenarios which are the transition thresholds of interest. Side-by-side figures show epidemic growth for outbreaks seeded by different numbers of initial infections.

Previous work considered a (low) seed of 30 unvaccinated infections to ensure that epidemics would grow and not become extinct. To reproduce the conditions of reopening in the context of already established community transmission, we now seed simulations with a variable number of infections in both unvaccinated and vaccinated individuals. The simulations are designed so that there will be a low (approximately 10-100), medium (approximately 300-1,000) or high (approximately 1,000-4,500) number of infections at the time the threshold date (day 0) is reached. This approach ensures a more realistic distribution of initial cases by age and vaccine status at the time of the transition.

Epidemic dynamics

We consider the implications of epidemic seeds across these different orders of magnitude (tens, hundreds, thousands) for subsequent epidemic growth and clinical consequences. Exploring some variability in these inputs is useful, given the uncertainty of the number of infections that may be reported in the population at the time of making decisions about the transition to Phase B. As previously, we consider the implications of seeding with baseline PHSMs and either 'partial TTIQ' or 'optimal TTIQ'. Acknowledging that optimal TTIQ is unlikely to be maintained at high case numbers, we further consider two additional scenarios: 'low PHSMs and partial TTIQ' and 'medium PHSMs and partial TTIQ'.

In all figures, dark banding represents the central 50% credible interval (i.e., from the 25th to 75th centile) for simulations. The light banding represents the central 90% credible interval (i.e., from the 5th to 95th centile) for simulations.

Figure 1.1: Epidemic growth to 180 days given transition to Phase B leading to established community transmission for threshold coverage targets of 70% assuming low (tens), medium (hundreds) or high (thousands) numbers of seeding infections, for <u>baseline PHSMs and partial TTIQ</u>

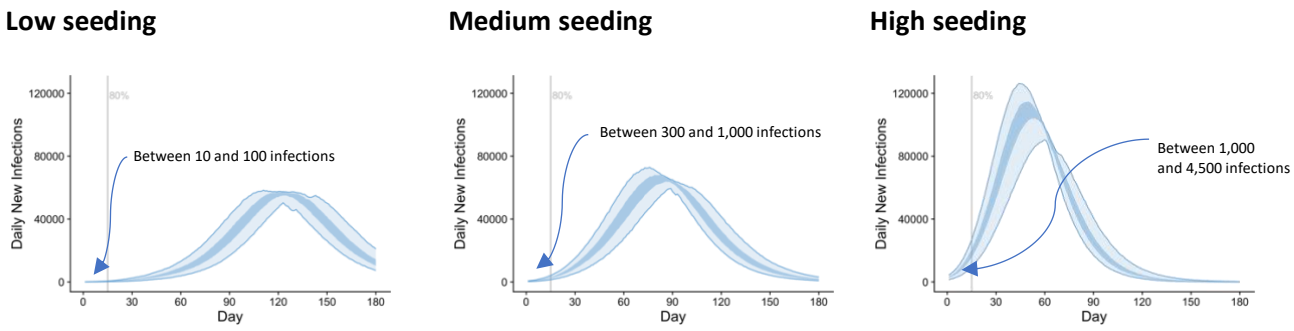


Figure 1.2: As for Figure 1.1, but for <u>baseline PHSMs and optimal TTIQ</u>

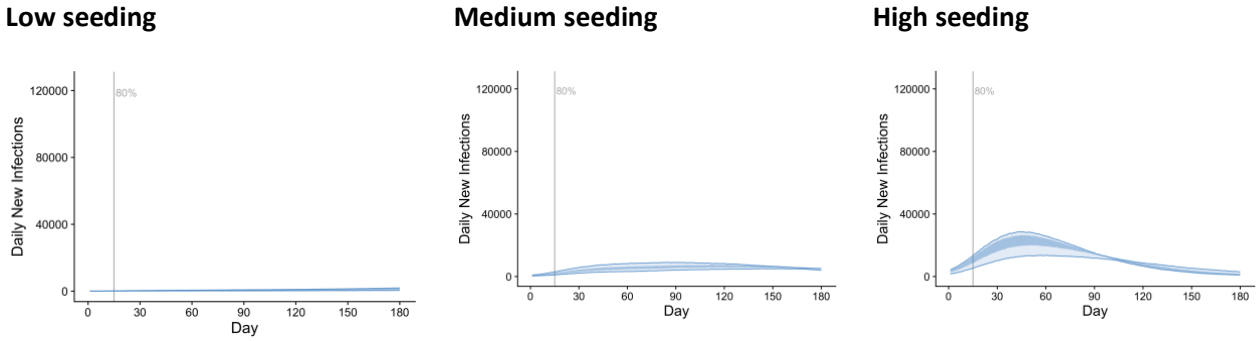


Figure 1.3: Epidemic growth to 180 days given transition to Phase B leading to established community transmission for the threshold coverage targets of 80% assuming low (tens), medium (hundreds) or high (thousands) numbers of seeding infections, assuming <u>baseline PHSMs and partial TTIQ</u>

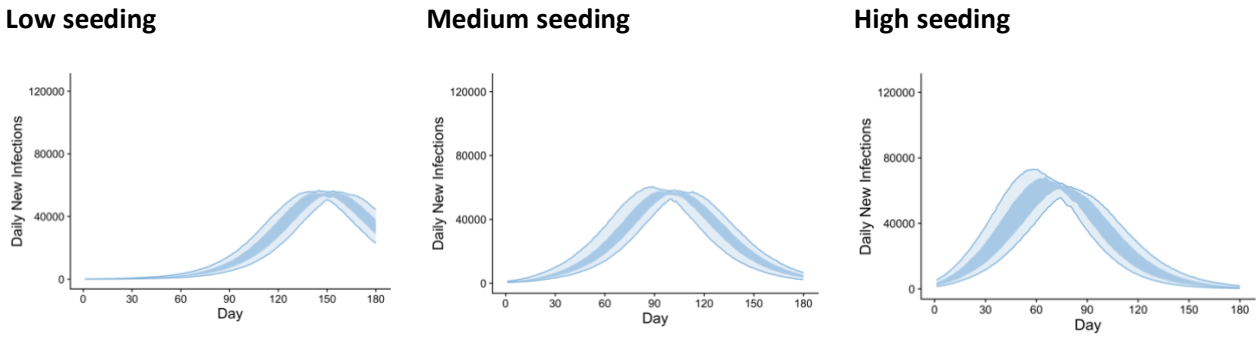


Figure 1.4: As for Figure 1.3, but for <u>baseline PHSMs and optimal TTIQ</u>

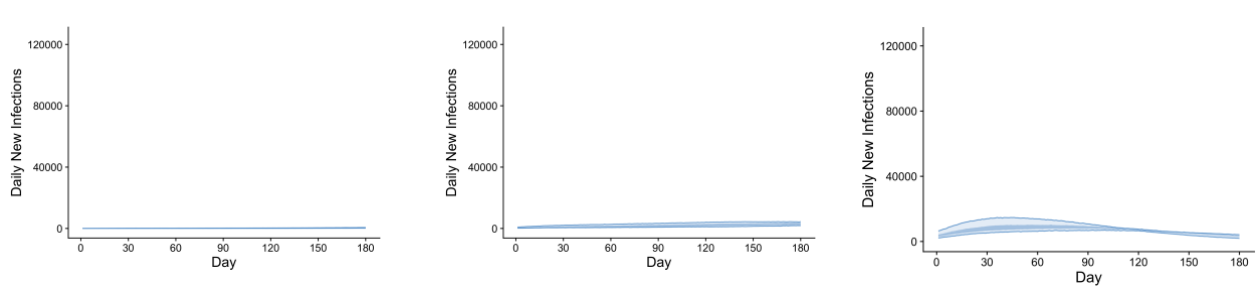


Figure 1.5: Epidemic growth to 240 days given transition to Phase B leading to established community transmission for the threshold coverage targets of 70% (left) and 80% (right) assuming high (thousands) numbers of seeding infections and assuming low PHSMs and partial TTIQ*

70% Coverage **80% Coverage**

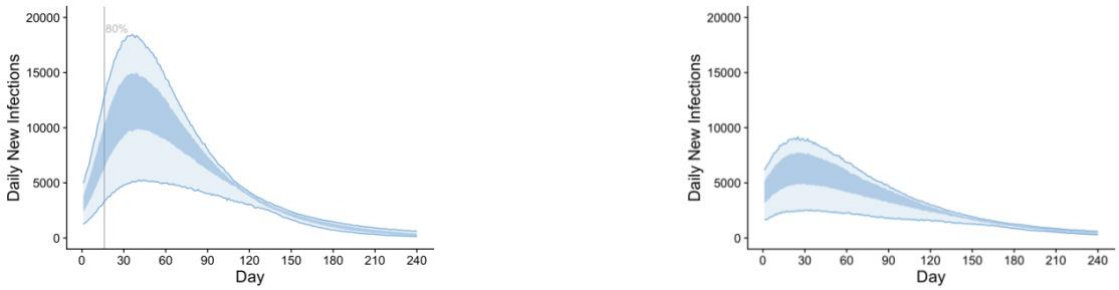


Figure 1.6: As for Figure 1.5, but for medium PHSMs and partial TTIQ*

70% Coverage **80% Coverage**

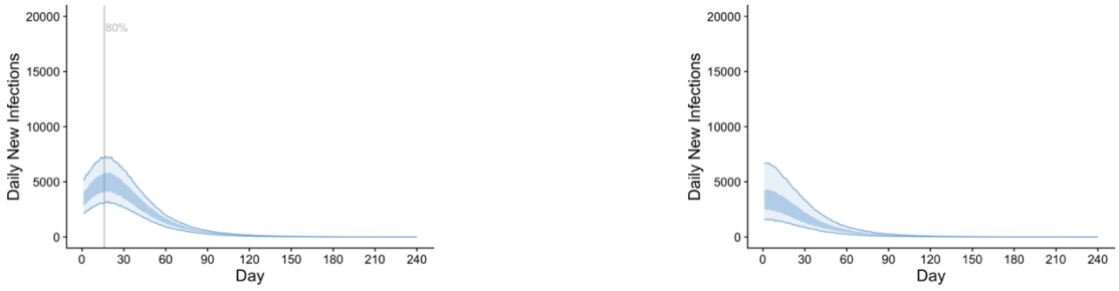
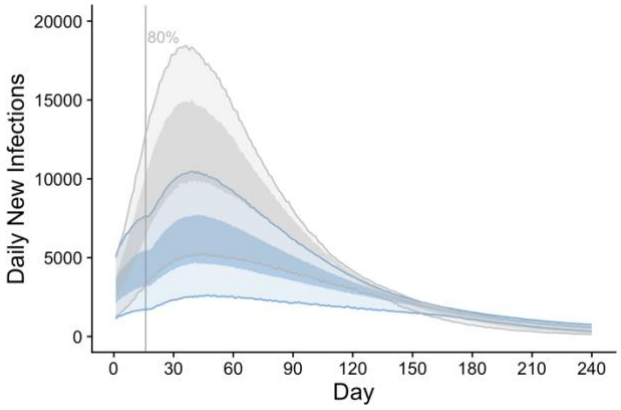


Figure 1.7: Epidemic growth to 240 days for High seeding epidemics at the 70% threshold with Partial TTIQ. Grey curves assume continuously overlaid low PHSMs. Blue curves show enhanced suppression by medium PHSMs growth during the transition between 70 and 80%, reverting to low PHSMs from 80%*



**Note y axes smaller than for Figures 1.1 to 1.4, to enable comparison of infections at 80% threshold*

Figure 2.1: Deaths to 180 days given transition to Phase B leading to established community transmission for the threshold coverage target of 70% assuming low (tens), medium (hundreds) or high (thousands) numbers of seeding infections, assuming baseline PHSMs and partial TTIQ

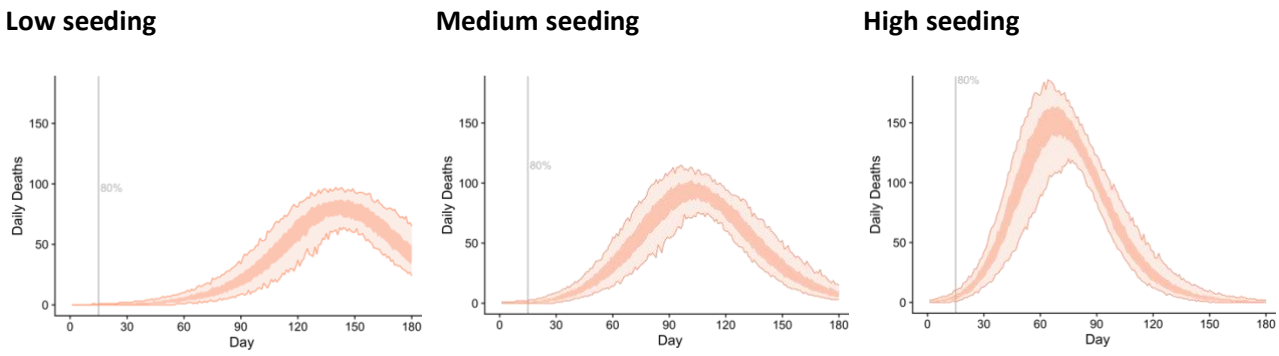


Figure 2.2: As for Figure 2.1, but for baseline PHSMs and optimal TTIQ

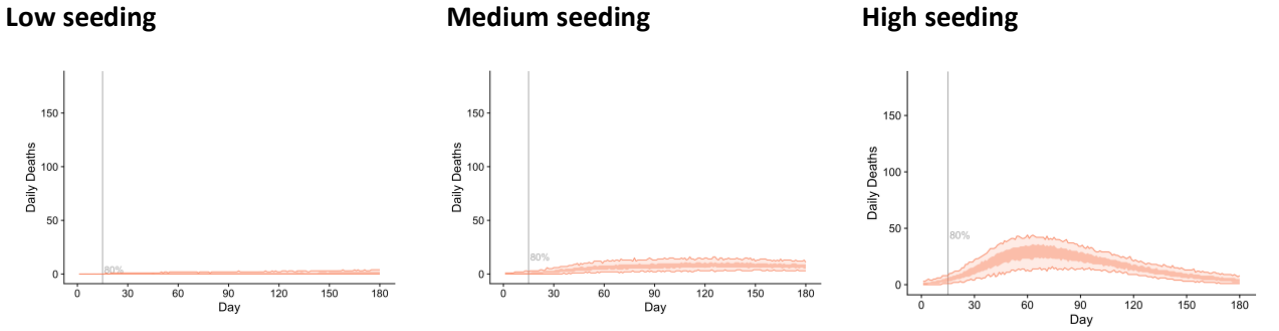


Figure 2.3: Deaths to 180 days given transition to Phase B leading to established community transmission for the threshold coverage target of 80% assuming low (tens), medium (hundreds) or high (thousands) numbers of seeding infections, assuming baseline PHSMs and partial TTIQ

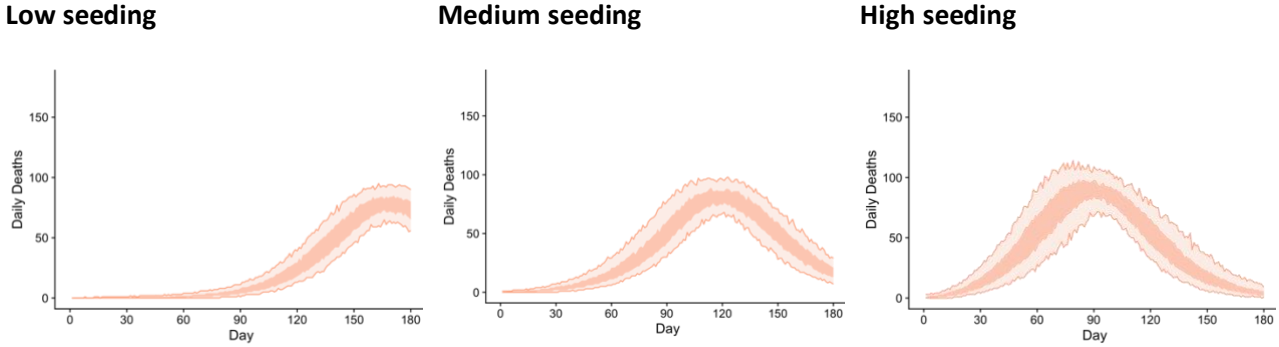
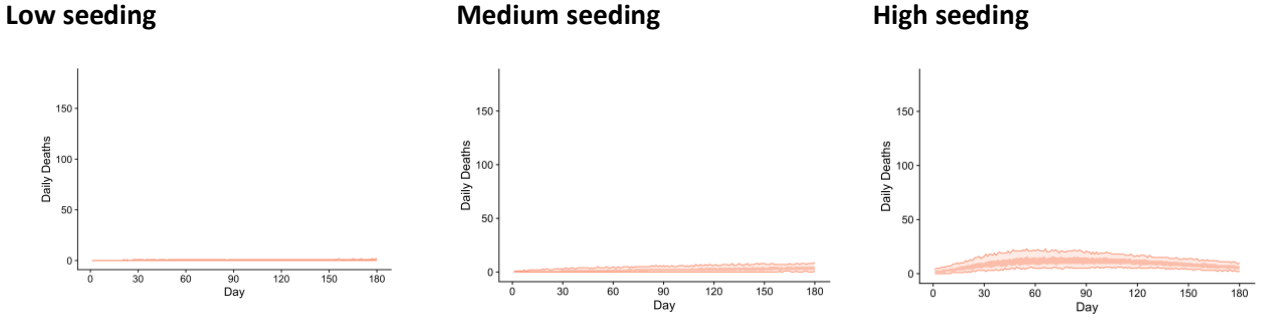


Figure 2.4: As for Figure 2.3, but for baseline PHSMs and optimal TTIQ



Figures 1.1 to 1.4 report all infections with or without symptoms occurring in 'baseline PHSM' scenarios, to allow comparison of the dynamics of epidemics. Figures 2.1 to 2.4 report corresponding deaths, enabling assessment of the most severe consequences of each. Within all simulations vaccine continues to be delivered to the population according to the model provided by Quantium. As in our earlier reports, we stress the deliberately artificial nature of our assumption that Australia's population would experience a uniform national epidemic. The purpose of the figures is to demonstrate comparisons between epidemic timings and impacts to inform high level strategy.

Figure 1.1 shows that when infections are seeded at the 70% threshold in the setting of baseline PSHMs and partial TTIQ, there is important sensitivity to the size of the seeding number of infections (Figure 1.1). An increase from tens to hundreds results in a leftward shift in the timing of the epidemic meaning that it completes within the reporting window of 180 days. What appears to be a modest increase in the epidemic size is lost when the fully completed 'low' seeded epidemic is compared (Table S1.1).

When thousands of infections are seeded, both the epidemic timing and peak shift significantly. The total epidemic size also increases notably. The window in time between 70 and 80% coverage is sufficient to allow epidemic growth to the extent that there is 'overshoot' in the peak number of infections even after the higher vaccine threshold of 80% is achieved. This scenario has similar dynamics to the 'low seeding at 50% threshold' scenario in our previous report. Figure 1.2 demonstrates that in the context of baseline PHSMs and 'optimal TTIQ' these same trends in timing and relative sizes are observed, but infection numbers are markedly reduced in magnitude.

Figures 1.3 and 1.4 confirm that much less impact on the overall size of epidemics is observed when these seeding scenarios are introduced from the 80% coverage timepoint. Seeding with an increasing number of infections in the context of baseline PHSMs and 'partial TTIQ' effectively shifts these epidemics sequentially 'to the left', meaning that the medium and high epidemic curves complete within the reporting timeframe of 180 days (Figure 1.3). The completed 'low' seeding scenario is shown in Table S1.2 for comparison. As before, overall impacts are reduced in the case where baseline PHSMs and 'optimal TTIQ' can be achieved (Figure 1.4).

Figures 1.5 and 1.6 demonstrate the ability of PHSMs to additionally constrain the epidemic and support the public health response in settings where only 'partial TTIQ' can be achieved. High-seeded scenarios at 70 and 80% thresholds demonstrate suppressed (Figure 1.5) and declining (Figure 1.6) epidemic growth with application of low and medium PHSMs respectively. These observations provide quantitative support for overlay of additional social measures over the period of transition from 70 to 80% for jurisdictions or subregions with high daily incident cases.

Figure 1.7 shows that application of PHSMs between the thresholds of 70-80% suppresses epidemic growth over this window to the extent that it is only marginally higher than that used in the "high seeding" scenarios at the time of reaching the 80% threshold. Corresponding clinical outcomes for this 'medium/low' PHSM scenario are shown in Table S1.5.

The degree of public health and social measures required during this bridging period will need reference to ongoing epidemic situational assessment, and the level of measures needed for disease control prior to the vaccine threshold. Similarly, clinical outcomes in that time window will be situation specific related to the actual starting number of cases, the population characteristics (e.g., vaccine coverage, age, co-morbidities, and vulnerabilities), the rate of vaccination and the level of epidemic suppression achieved.

Clinical outcomes

The breakdown of infections by severity of clinical outcome by age and vaccine status is reported for the 70% coverage transition (Tables 2.1-2.2) and 80% coverage transition (Tables 2.3-2.4) with seeding thresholds ranging from low to high, assuming partial and optimal TTIQ. The additional benefits of overlaid 'low PHSMs' are shown for the low seeding 70% threshold case in Supplementary Figure S1.1 and Table S1.3. Note that all values in tables are central estimates arising from approximately 200 simulations. For any given set of 200 simulations with the same starting assumptions results will be subtly different, because of the inherent variability of the stochastic model framework which represents the chance effects that impact on real world infection spread. Relative differences between input assumptions and outputs will not change materially as a result.

Table 2.1: Cumulative symptomatic infections, ward admissions, ICU admissions and deaths over the first 180 days for the coverage threshold of 70% and low, medium or high seeding infections assuming baseline PHSMs and partial TTIQ, broken down by vaccination status and age

		<16 yrs		16-39 yrs		40-59 yrs		60+ yrs	
	Seeds	**Vacc'd**	**Unvac**	**Vacc'd**	**Unvac**	**Vacc'd**	**Unvac**	**Vacc'd**	**Unvac**
Symptomatic infections	Low	0	479,538	54,937	153,876	53,848	84,235	31,962	13,831
	Med	0	517,100	68,179	182,483	62,339	95,564	36,251	15,722
	High	0	567,797	107,326	261,401	80,704	119,531	43,901	19,103
Ward admissions	Low	0	5,029	1,342	5,394	3,273	8,148	4,816	5,109
	Med	0	5,610	1,616	6,412	3,839	9,421	5,528	5,875
	High	0	6,407	2,292	9,084	4,938	11,967	6,711	7,149
ICU admissions	Low	0	409	228	920	929	2,305	1,162	1,279
	Med	0	492	298	1,178	1,193	2,909	1,464	1,609
	High	0	578	431	1,683	1,588	3,823	1,842	2,020
Deaths	Low	0	162	52	303	358	1,294	1,441	2,085
	Med	0	192	68	382	456	1,616	1,770	2,559
	High	0	221	104	533	607	2,090	2,179	3,139

 # In this and all subsequent tables '<16 yrs' refers to the complete population cohort aged 0 through 15 years inclusive. All individuals in this age category are assumed to be unvaccinated in these scenarios as the vaccine rollout model predated a positive recommendation for immunisation of children aged 12-15 years.

As the number of infections seeding the epidemic increases, some increase in clinical outcomes is observed for the 'medium' compared with the 'low' starting point. These impacts are greater for the 'high' scenario, reflecting the greater increase in epidemic magnitude seen in Figures 1.1 and 2.1. Note, however, that the 'low' seeded epidemic has not completely resolved within the 180-day window over which events are captured. The full epidemic outcomes for that scenario are shown in Table S1.1 for completeness and are closer to the values observed for the 'medium' case than those in the table above.

Table 2.2: As for table 2.1, assuming <u>baseline PHSMs and optimal TTIQ</u>

		<16 yrs		16-39 yrs		40-59 yrs		60+ yrs	
	Seeds	**Vacc'd**	**Unvac**	**Vacc'd**	**Unvac**	**Vacc'd**	**Unvac**	**Vacc'd**	**Unvac**
Symptomatic infections	Low	0	12,710	1,239	3,865	1,086	2,017	605	269
	Med	0	110,543	12,773	38,058	10,456	18,815	5,704	2,537
	High	0	220,455	35,630	97,968	25,090	43,368	12,870	5,788
Ward admissions	Low	0	111	28	134	63	182	91	97
	Med	0	1,014	285	1,333	620	1,753	861	928
	High	0	2,181	742	3,435	1,505	4,175	1,964	2,157
ICU admissions	Low	0	8	4	20	15	45	19	21
	Med	0	71	44	204	155	432	180	201
	High	0	181	130	612	448	1,235	489	556
Deaths	Low	0	3	1	7	6	26	26	37
	Med	0	32	12	75	69	274	261	378
	High	0	74	33	202	181	708	632	937

These findings confirm our earlier strategic advice, that maintenance of optimal TTIQ capacity enables substantial reduction of the clinical consequences of the transition to Phase B. In the case that optimal TTIQ capacity is not able to be maintained, additional 'low-level' public health and social measures in combination with partial TTIQ can achieve similar epidemiological and clinical outcomes (Table S1.3).

Table 2.3: Cumulative symptomatic infections, ward admissions, ICU admissions and deaths over the first 180 days for the coverage threshold of 80% and low, medium or high seeding infections assuming baseline PHSMs and partial TTIQ, broken down by vaccination status and age

		<16 yrs		16-39 yrs		40-59 yrs		60+ yrs	
	Seeds	**Vacc'd**	**Unvac**	**Vacc'd**	**Unvac**	**Vacc'd**	**Unvac**	**Vacc'd**	**Unvac**
Symptomatic infections	Low	0	420,145	44,737	129,360	44,331	71,511	26,199	11,446
	Med	0	499,071	58,703	162,229	57,176	88,575	33,916	14,687
	High	0	515,182	66,578	178,501	61,744	94,563	35,990	15,596
Ward admissions	Low	0	4,184	1,075	4,462	2,630	6,704	3,871	4,130
	Med	0	5,325	1,449	5,725	3,514	8,682	5,154	5,473
	High	0	5,586	1,598	6,305	3,800	9,339	5,509	5,837
ICU admissions	Low	0	257	134	579	540	1,409	683	756
	Med	0	425	240	966	982	2,432	1,219	1,347
	High	0	486	293	1155	1165	2853	1438	1573
Deaths	Low	0	120	36	222	253	938	1,038	1,501
	Med	0	179	59	337	410	1,459	1,619	2,339
	High	0	192	67	381	453	1,609	1,767	2,250

For the 80% scenario, the high achieved level of vaccine coverage in the population at the time of seeding means that the number of infections seeding the outbreak is less influential, although some differences are observed. Note that for the 'low' seeded scenario, the full epidemic outcomes are not confined to the 180-day reporting window. These are shown in Table S1.2, for completeness and more closely approximate the 'medium' seeded scenario.

Table 2.4: As for table 2.3, assuming <u>baseline PHSMs and optimal TTIQ</u>

		<16 yrs		16-39 yrs		40-59 yrs		60+ yrs	
	Seeds	**Vacc'd**	**Unvac**	**Vacc'd**	**Unvac**	**Vacc'd**	**Unvac**	**Vacc'd**	**Unvac**
Symptomatic infections	Low	0	3,359	298	962	275	515	151	67
	Med	0	42,746	4,156	12,879	3,667	6,747	2,071	923
	High	0	152,647	18,146	52,848	14,891	26,436	8,150	3,643
Ward admissions	Low	0	28	7	33	15	46	22	24
	Med	0	379	96	455	216	617	308	336
	High	0	1,446	413	1,885	902	2,520	1,243	1,355
ICU admissions	Low	0	2	1	5	4	10	4	5
	Med	0	22	12	59	44	124	52	59
	High	0	103	66	305	231	646	260	298
Deaths	Low	0	1	0	2	2	7	6	9
	Med	0	11	4	25	23	91	88	132
	High	0	49	18	113	106	422	392	578

As before, baseline PHSMs in combination with optimal TTIQ responses has the potential to markedly reduce clinical outcomes. In the case that optimal TTIQ capacity is not able to be maintained, additional 'low-level' public health and social measures in combination with partial TTIQ can improve epidemiological and clinical outcomes (Table S1.4).

Initial transmission potential (TP)
Our earlier report derived coverage threshold targets based on a starting TP of 3.6 for the Delta variant. This figure was based on averaged observations of population behaviours and contact rates from NSW in March 2021 and assuming partial TTIQ capacity. This period was characterised by minimal social restrictions and no major outbreaks.

Table 1.3 reports estimates of TP from all Australian jurisdictions at selected dates under which similar conditions were experienced, from late 2020 onwards (Table 1.3). Observed differences largely reflect the level of concern about COVID-19 in different states and territories, which correlates with their experience of local community transmission and lockdowns. At different times over recent months when stringent PHSMs have been applied to jurisdictions, marked reductions in TP have been observed that result in more consistent and low TP values. These observations indicate that population behaviour can change rapidly and so we anticipate that the achievable TP will be more uniform in the face of a perceived threat and public health orders. Some residual variation in the achievable TP is nonetheless expected based on socio-economic factors.

Table 1.3: Scaled values of Delta variant transmission potential (TP) for 50%, 60%, 70% and 80% population coverage for the transmission reducing allocation strategy, assuming different starting transmission potentials based on relevant jurisdictional examples of heterogeneity under limited restrictions due to variation in population mixing and behaviour

	Eligible population coverage (16+)			
Starting TP	**50%**	**60%**	**70%**	**80%**
NSW March 2021 (3.6)	2.1	1.8	1.4	1.3
ACT March 2021 (4.5)	2.6	2.2	1.7	1.6
NT March 2021 (5.1)	2.9	2.4	2.0	1.8
QLD 7 Feb – 9 March 2021 (4.0)	2.3	1.9	1.6	1.4
SA March 2021 (4.4)	2.6	2.1	1.7	1.5
TAS March 2021 (4.2)	2.5	2.1	1.6	1.5
VIC 13-20 December 2020 (2.7)	1.6	1.3	1.1	1.0
WA March 2021 (4.5)	2.6	2.2	1.8	1.6

Importation of the Delta variant into every Australian jurisdiction is now inevitable. It can no longer be assumed that even stringent lockdown measures will achieve local extinction given the demonstrated importance of small area foci where such measures have reduced impacts (e.g., high proportion of essential workers, large household size, etc). These local effects are combined with an anticipated general decline in population co-operation with restrictions, even in jurisdictions with relatively low baseline TP. If population mobility, fatigue and/or increasing complacency are correlated with low levels of vaccine uptake, affected jurisdictions will be at heightened risk of rapidly escalating outbreaks given importation of infection.

Implications for TTIQ and other measures
The relatively unconstrained outbreaks reflected in Figures 1.1 to 1.4 assume some ongoing level of 'partial TTIQ' throughout. We have previously stated that maintenance of this capacity at caseloads into the 1000s is implausible. Our work in collaboration with Treasury recognises that these scenarios would not be allowed to continue unconstrained and that reinforcing social measures would be required to achieve the goal of maintaining TP around 1 to avoid escalating epidemic growth. Our future work plan seeks to further explore the importance of synergies of interventions, including the way in which vaccination can support sustainable public health response capacity by refining and refocussing such intensive public health responses. Our future assumptions about TTIQ effectiveness will be based on current and ongoing consultations with all jurisdictions about devising future evidence based public health actions that are demonstrably effective and sustainable.

Currency of proposed next phase work plan

Critical importance of data-informed optimisation and targeting of TTIQ response (Work Package 1)
TTIQ capacity is an important constraint on forward transmission of infection to minimise harms. Multi-jurisdictional consultations co-ordinated by Health are ongoing with CDNA and AHPPC to determine the most efficient and effective public health responses in Phase A and through transition to Phase B and C. These discussions are informed by the current experience of evolving epidemics in NSW and VIC where rationalisation of response actions has been needed to deal with high caseloads in the setting of low vaccine coverage. In the transition to Phase B, the constraining effects of vaccine on transmission will greatly assist the public health response. Importantly, in that phase there will be a shift in the objectives of TTIQ from 'zero tolerance' containment to transmission reduction allowing a lesser focus on casual and place-based contact tracing outside high-risk settings.

Real world evaluation of impact of social measures at small area level (Work Package 2)
The scenarios in this report representing a single national COVID-19 epidemic are clearly (and deliberately) artificial and serve to inform high level policy strategy. In reality, the national COVID-19 epidemic has been and will continue to be a 'fire' fought on multiple fronts. Public health units are aware that small areas and subpopulations with different age and household structures and levels of advantage have different risks of infection transmission and adverse health outcomes. Throughout the pandemic, we have also observed that such individuals may also be disproportionately engaged in essential service occupations that cannot be safely performed at home meaning that broadly applied social measures and lockdowns provide less effective protection. The national situational assessment team has been working in collaboration with A/Prof James Wood (UNSW) to support the current NSW response, including through reporting of TP at small area level. Within work package 2, we will examine case studies based on data from NSW and VIC to demonstrate how population determinants influence risk both in outbreak and immunised settings. It is anticipated that in the future, TP reporting will be available at small area level to inform ongoing risk assessment, including the need for focused intensified TTIQ responses in areas where social measures have reduced impacts, aligning with WP1. WP2 includes consultations with key populations groups including through the Aboriginal and Torres Strait Islander Advisory Group and the CALD Advisory Group.

Small area requirements for augmented vaccine coverage and delivery
Areas at increased risk of transmission and with reduced impacts of social measures should be prioritised for vaccine delivery and higher target thresholds may be recommended. We are liaising closely with the Quantium team in Health to determine how findings from our work may map to their characterisation of small areas to support strategic vaccine allocation moving forward.

Timeliness and prioritisation of 12-15 years program extension
Recent announcements regarding intentions to immunise the 12-15 years age group pending a positive ATAGI recommendation have elevated the priority of work to inform vaccine strategy in the school years. We are consulting with Operation COVID-shield to identify vaccine implementation approaches that will influence assumptions about likely future coverage within schools, in their population context. Such understandings will inform models of infection transmission in school settings in a largely immunised population, informing recommendations for ongoing COVID-safe measures, proportionate public health responses to school-based outbreaks and any requirements for school closure in the setting of broad social restrictions. Addition of this age group to the National Program will enhance the within-household 'indirect' effects anticipated from immunising parents, further reducing the risk of infecting siblings less than 12 years within the home environment.

Additional implications of jurisdictional TP for border risk tolerance (Work Package 3)
Consultations co-ordinated by PMC have commenced with a broad range of government departments, to define aspirational arrivals targets over the six months following transition to Phase B. Findings will inform input risk assumptions and distribution of arrivals pathways to allow evaluation of outbreak risks associated with any breaches of the quarantine system. Outbreaks risks and consequences will be assessed in the context of TP achieved through vaccination and social measures in exemplar jurisdictions. This phase of work will bring together relevant insights from the preceding work packages.

APPENDIX

Extension of 'full' epidemic course for low seeding epidemics at 70/80% coverage, assuming baseline PHSMs and partial TTIQ

Table S1.1: Cumulative symptomatic infections, ward admissions, ICU admissions and deaths over the full epidemic course for the coverage threshold of 70% and low seeding infections assuming baseline PHSMs and partial TTIQ, broken down by vaccination status and age

	<16 yrs		16-39 yrs		40-59 yrs		60+ yrs	
	Vacc'd	Unvac	Vacc'd	Unvac	Vacc'd	Unvac	Vacc'd	Unvac
Symptomatic infections	0	506,617	59,475	164,401	58,455	90,115	34,780	14,992
Ward admissions	0	5,443	1,468	5,811	3,615	8,864	5,308	5,613
ICU admissions	0	491	281	1,097	1,165	2,820	1,459	1,598
Deaths	0	187	62	351	437	1,529	1,713	2,463

Table S1.2: As for Table S1.1, but for the coverage threshold of 80%

	<16 yrs		16-39 yrs		40-59 yrs		60+ yrs	
	Vacc'd	Unvac	Vacc'd	Unvac	Vacc'd	Unvac	Vacc'd	Unvac
Symptomatic infections	0	504,192	57,915	161,211	57,622	89,103	34,287	14,834
Ward admissions	0	5,417	1,442	5,708	3,563	8,763	5,249	5,561
ICU admissions	0	490	275	1,081	1,149	2,782	1,443	1,578
Deaths	0	188	60	345	426	1,513	1,699	2,445

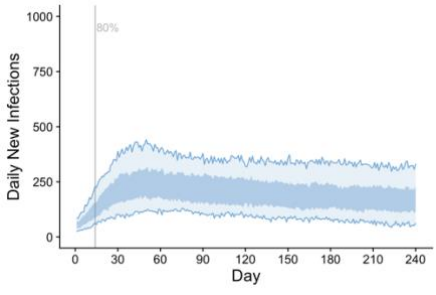
**Note that some figures for these 'low' scenarios are now higher than those reported in related tables for the 'medium' seeding scenarios, which have almost but not quite completed in the 180 days.*

Overlay of PHSMs on partial TTIQ scenarios reduces clinical outcomes

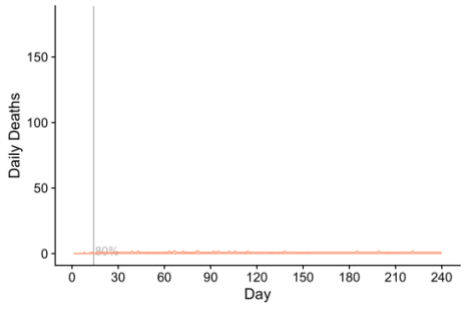
The additional constraint of continuous 'low' PHSMs augments the ability of 'partial TTIQ' capacity to suppress epidemic growth to a level similar to that observed for the 'baseline PHSM and optimal TTIQ' scenario in our earlier report.

Figure S1.1: Epidemic growth to 180 days given transition to Phase B leading to established community transmission for the coverage threshold of 70% and low seeding infections, assuming continuous low PHSMs and partial TTIQ*

All infections



Deaths



**Note the y axis in the 'all infections' plots is substantively lower than that in the comparison Figure 1.1 (leftmost plot – low seeding) where the y axis extends to 120,000*

Table S1.3: Cumulative symptomatic infections, ward admissions, ICU admissions and deaths over the first 180 days for the coverage threshold of 70% and low seeding infections assuming continuous low PHSMs and partial TTIQ, broken down by vaccination status and age

	<16 yrs		16-39 yrs		40-59 yrs		60+ yrs	
	Vacc'd	Unvac	Vacc'd	Unvac	Vacc'd	Unvac	Vacc'd	Unvac
Symptomatic infections	0	4,407	492	1,631	401	765	220	97
Ward admissions	0	41	11	57	24	70	33	35
ICU admissions	0	3	2	9	7	20	8	9
Deaths	0	1	0	3	3	11	10	14

**Note that this epidemic is so slow growing that it does not 'complete' within a reportable window*

Table S1.4: As for Table S1.3 but for high seeding infections

	<16 yrs		16-39 yrs		40-59 yrs		60+ yrs	
	Vacc'd	Unvac	Vacc'd	Unvac	Vacc'd	Unvac	Vacc'd	Unvac
Symptomatic infections	0	121,335	19,597	57,584	13,490	24,371	6,943	3,079
Ward admissions	0	1,174	408	2,022	810	2,341	1,069	1,145
ICU admissions	0	95	71	362	241	689	266	292
Deaths	0	39	18	121	100	397	352	497

Table S1.5: As for Table S1.4 but assuming continuously overlaid medium PHSMs during the transition between 70 and 80% coverage thresholds, reverting to low PHSMs from 80%*

	<16 yrs		16-39 yrs		40-59 yrs		60+ yrs	
	Vacc'd	Unvac	Vacc'd	Unvac	Vacc'd	Unvac	Vacc'd	Unvac
Symptomatic infections	0	79,172	11,652	35,993	8,341	15,373	4,337	1,931
Ward admissions	0	752	248	1,276	500	1,469	667	718
ICU admissions	0	58	43	225	142	417	157	174
Deaths	0	26	11	76	61	248	217	309

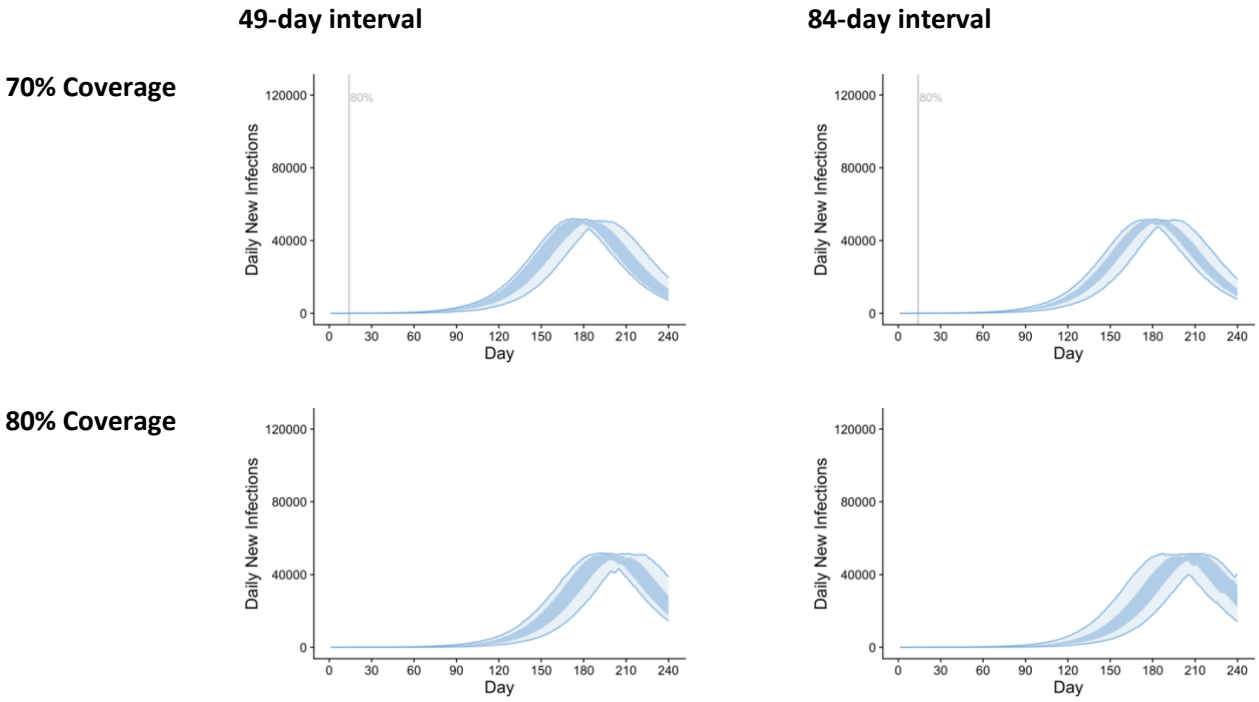
Identification of code error related to AZ dosing interval in simulations contained in dynamic model outputs up to and including the Technical Report and Addendum (10th August 2021)

When reviewing the code for the purpose of running these simulations, an input error was identified relating to the assumed dose spacing of Astra Zeneca vaccines. Second doses were assigned to individuals at 49 days (7 weeks) instead of 84 days (12 weeks). Full efficacy following second dose completion was assumed. As a result, individuals who had received Astra Zeneca were deemed fully protected sooner.

Careful code checking has always ensured that seeding occurred only when the target vaccine coverage threshold of 50% or more was reached in the simulated population. The bulk of Astra Zeneca delivered in the Australian program was in the early phases of vaccine rollout. The consequence of this error was to increase the relative proportion of individuals deemed fully immunised in the earlier phases of the simulations with minimal influence on the later phases of simulated epidemics.

We have rerun our (original) model simulations with the corrected dose spacing of 84 days. The numerical impact of the change is minor, with no change to interpretation.

Figure S2.1: Epidemic growth to 240 days given transition to Phase B leading to established community transmission for the threshold coverage targets of 70% and 80% (rows) with 30 seeded infections in unimmunised individuals, assuming baseline PHSMs and partial TTIQ. The original and updated dose spacings for the AZ vaccine are shown in columns.



We have also run our updated model with low, medium and high initial infections with an 84-day AZ dosing interval. Comparing the updated results below (Figures S2.2–2.5) with the equivalent results for a 49-day dose interval in Figures 1.1–1.4 show no material impact under this change.

Figure S2.2: Epidemic growth to 240 days given transition to Phase B leading to established community transmission for the threshold coverage targets of 70% assuming low (tens), medium (hundreds) or high (thousands) numbers of seeding infections (columns), assuming baseline PHSMs and partial TTIQ (i.e., equivalent to Figure 1.1) with an 84-day AZ dosing interval

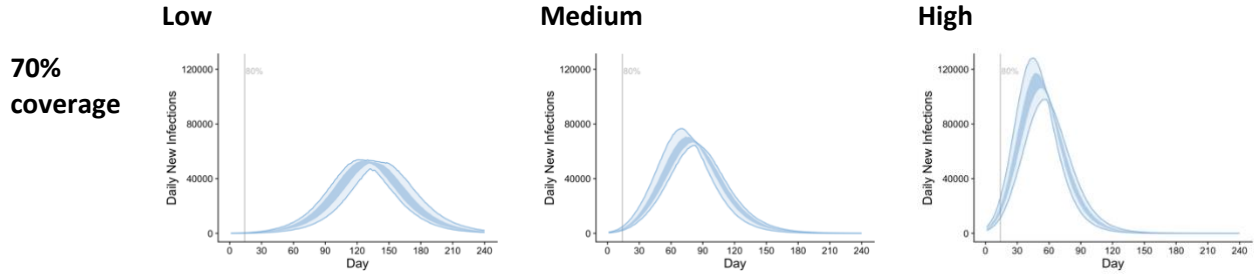


Figure S2.3: As for Figure S2.2 with coverage target of 80% (i.e., equivalent to Figure 1.3)

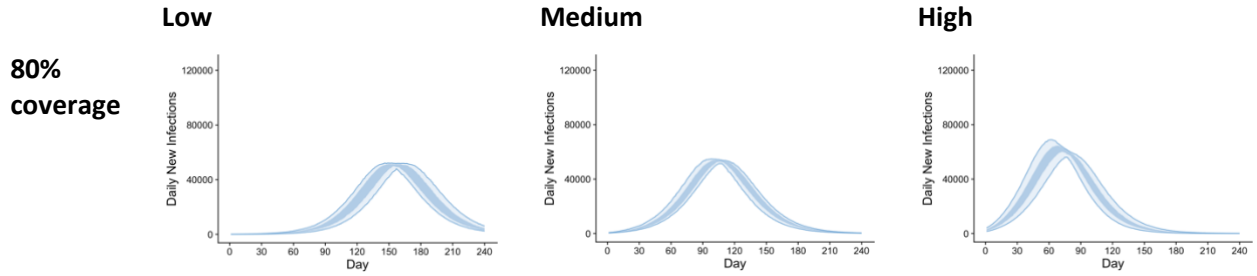


Figure S2.4: Epidemic growth to 240 days given transition to Phase B leading to established community transmission for the threshold coverage targets of 70% assuming low (tens), medium (hundreds) or high (thousands) numbers of seeding infections (columns), assuming baseline PHSMs and optimal TTIQ (i.e., equivalent to Figure 1.2) with an 84-day AZ dosing interval

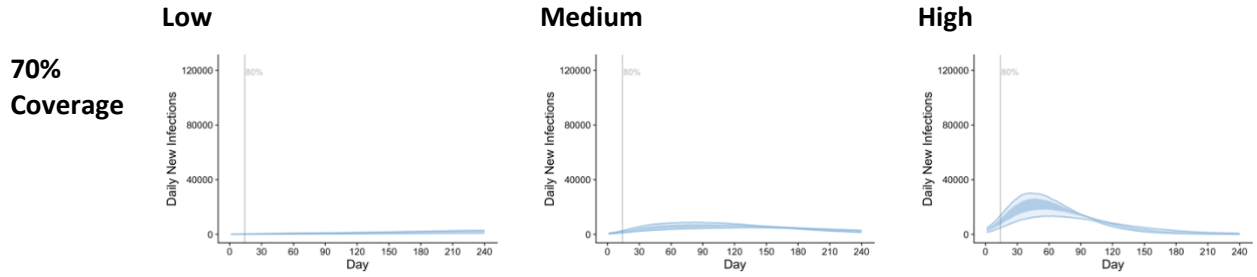


Figure S2.5: As for Figure S2.4 with coverage target of 80% (i.e., equivalent to Figure 1.4)

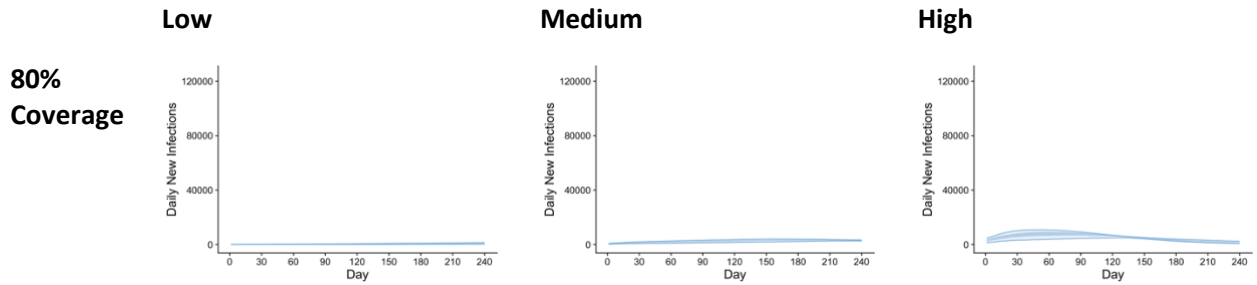


Table S2.1: Cumulative symptomatic infections, ward admissions, ICU admissions and deaths over the full epidemic course for the coverage threshold of 70% with low, medium and high seeding infections assuming baseline PHSMs and partial TTIQ, broken down by vaccination status and age, with the 84-day AZ dosing interval

		<16 yrs		16-39 yrs		40-59 yrs		60+ yrs	
	Seeds	Vacc'd	Unvac	Vacc'd	Unvac	Vacc'd	Unvac	Vacc'd	Unvac
Symptomatic infections	Low	0	456,821	38,754	141,508	47,140	78,132	29,246	12,766
	Med	0	516,792	62,419	185,332	61,251	95,915	36,416	15,726
	High	0	570,330	107,764	266,085	81,230	120,789	45,262	19,379
Ward admissions	Low	0	4,702	1,067	4,959	2,889	7,494	4,386	4,699
	Med	0	5,604	1,535	6,517	3,783	9,445	5,576	5,879
	High	0	6,441	2,301	9,245	4,964	12,102	6,951	7,252
ICU admissions	Low	0	376	179	839	802	2,091	1,042	1,155
	Med	0	494	289	1,208	1,194	2,948	1,497	1,630
	High	0	583	434	1,715	1,604	3,872	1,912	2,054
Deaths	Low	0	149	38	275	304	1,161	1,279	1,871
	Med	0	192	63	387	450	1,626	1,802	2,568
	High	0	222	103	545	606	2,111	2,284	3,187

Table S2.2: As for Table S2.1 but for 80% coverage

		<16 yrs		16-39 yrs		40-59 yrs		60+ yrs	
	Seeds	Vacc'd	Unvac	Vacc'd	Unvac	Vacc'd	Unvac	Vacc'd	Unvac
Symptomatic infections	Low	0	387,224	29,547	114,809	37,156	63,793	23,136	10,144
	Med	0	485,323	42,947	153,041	51,823	84,294	32,091	13,951
	High	0	507,815	54,879	172,535	57,963	91,858	35,063	15,203
Ward admissions	Low	0	3,763	807	3,940	2,214	5,906	3,393	3,636
	Med	0	5,124	1,187	5,403	3,225	8,219	4,885	5,196
	High	0	5,474	1,413	6,103	3,611	9,070	5,370	5,694
ICU admissions	Low	0	239	106	523	473	1,276	618	688
	Med	0	409	198	905	885	2,271	1,149	1,262
	High	0	475	261	1,120	1,109	2,771	1,408	1,543
Deaths	Low	0	106	25	190	202	797	875	1,284
	Med	0	172	45	316	367	1,367	1,522	2,206
	High	0	187	58	368	428	1,562	1,735	2,486

Table S2.3: As for Table S2.1 (70% coverage) but with <u>baseline PHSMs and optimal TTIQ</u>

		<16 yrs		16-39 yrs		40-59 yrs		60+ yrs	
	Seeds	**Vacc'd**	**Unvac**	**Vacc'd**	**Unvac**	**Vacc'd**	**Unvac**	**Vacc'd**	**Unvac**
Symptomatic infections	Low	0	16,914	1,354	5,134	1,372	2,651	800	355
	Med	0	111,015	11,083	38,123	10,124	18,717	5,737	2,550
	High	0	218,148	33,145	96,749	24,398	42,398	13,022	5,734
Ward admissions	Low	0	147	34	180	81	238	119	128
	Med	0	1,021	262	1,342	605	1,750	868	939
	High	0	2,151	709	3,396	1,471	4,123	2,002	2,143
ICU admissions	Low	0	10	5	27	20	58	25	28
	Med	0	72	41	208	155	440	185	207
	High	0	182	126	611	443	1,228	505	933
Deaths	Low	0	4	1	9	8	35	34	49
	Med	0	33	11	76	68	276	265	384
	High	0	74	32	203	180	698	654	933

Table S2.4: As for Table S2.2 (80% coverage) but with <u>baseline PHSMs and optimal TTIQ</u>

		<16 yrs		16-39 yrs		40-59 yrs		60+ yrs	
	Seeds	**Vacc'd**	**Unvac**	**Vacc'd**	**Unvac**	**Vacc'd**	**Unvac**	**Vacc'd**	**Unvac**
Symptomatic infections	Low	0	5,606	407	1,588	440	851	261	116
	Med	0	50,527	3,953	15,014	4,143	7,878	2,431	1,085
	High	0	135,067	13,310	45,177	12,356	22,740	7,077	3,144
Ward admissions	Low	0	48	10	56	26	76	39	43
	Med	0	449	100	529	248	721	362	397
	High	0	1,266	324	1,611	752	2,152	1,079	1,166
ICU admissions	Low	0	3	2	8	6	18	8	9
	Med	0	26	14	69	53	150	64	72
	High	0	87	51	254	187	538	225	248
Deaths	Low	0	1	0	3	3	11	11	17
	Med	0	14	4	29	26	110	106	157
	High	0	42	13	96	88	354	340	496

Bundles of public health and social measures (PHSMs)

Table S3: Description of measures implemented under PHSM 'bundles'

	High PHSM	Medium PHSM	Low PHSM	Baseline PHSM
Reference period	VIC 23 August 2020	NSW 1 July 2021	NSW 23 August 2020	NSW March 2021
Stay at home orders	• Stay-at-home except essential purposes	• Stay-at-home except for work, study and essential purposes	• No stay-at-home orders	• No stay-at-home orders
Density restrictions	• 4 sqm rule	• 2 sqm rule	• 2 sqm rule	• 2 sqm rule
Retail trade	• Non-essential retailers and venues closed to public. • Take away and home delivery only.	• Increased retail activity, subject to density restrictions • Seated dining for small groups at cafes/restaurants	• Social distancing rules apply • Larger groups allowed	• Social distancing rules apply •
Work	• Only workplaces categorised as permitted work allowed to operate on-site and subject to restrictions	• Work from home if possible, capacity limits and restrictions on office space apply	• Return to work, but social distancing and capacity restrictions on office space apply	• 1.5 sqm rule
Schools and childcare	• Closed – remote learning only	• Closed or graduated return	• Open	• Open
Capacity restrictions	• No gatherings - Non-essential venues etc closed.	• Indoor venues closed. • Capacity limits restricted to small groups outdoors	• Recreational activities allowed and venues open but social distancing and capacity limits apply	• Large sporting venues to operate at 70 per cent capacity
Travel restrictions	• Essential movements only within 5 or 10 km radius • No intra- or inter-state travel	• Non-essential travel limited – no intra or inter-state travel •	• No travel restrictions • Interstate travel allowed	• No travel restrictions • Interstate travel allowed
Other	• Curfew • No household visitors and 2-person limit on exercise	• 5 visitors to household and limited outdoor gatherings e.g., 10 people	• Requirements for record keeping, COVID-safe plans etc	•