



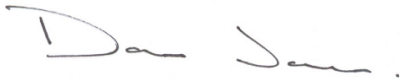
BROUGHTON PARK RUFC
GAA BALL STRIKE ASSESSMENT



LABOSPORT

BALL STRIKE ASSESSMENT– BROUGHTON PARK RUFC – GAA PITCH

CLIENT	PSD Agronomy
SITE ADDRESS	Broughton Park FC 2 Houghend Crescent Off Mauldeth Road West Manchester UNITED KINGDOM LANCASHIRE M21 7TL
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INTRODUCTION	To assess the potential risk of sliotars and Gaelic footballs surpassing the boundaries of a GAA pitch at Broughton Park RUFC, Labosport Ltd has reviewed the site distances and topography to analyse the risk of balls surpassing the site boundaries. The analysis uses a Hurling sliotar trajectory model and Gaelic football trajectory model that have been developed by Labosport. If required, the report will identify the height of any ball trajectory mitigation to minimise the potential risks. Note: This is a desk study, Labosport have not visited the site, taken measurements, or carried out a visual inspection. All measurement information has been provided by the client and any error in measurements are not the responsibility of Labosport. This assessment is undertaken on the basis of accurate data.
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Section 1 – Executive Summary of Conclusions

Executive Summary of Conclusions

This report has been prepared to assess the potential risk of sliotars and Gaelic footballs surpassing the boundaries of the pitches at Broughton Park RUFC and advise on the height and location of mitigation recommended to provide a suitable level of protection.

Orientation	Recommended mitigation height
North	16.5 m
West	16.5 m

Please Note: This may not stop all shots from landing beyond the site boundary, but it is believed from the assessment of the ball trajectory it will significantly reduce their frequency.

The below diagram shows the proposed locations of the recommended mitigation for heights detailed above:



Section 2 – Site Specifics

Playing Standard of GAA on the Site

Labosport have investigated the level of Hurling and Football that is played on this site. We have been advised that recreational level GAA is played on this site.

For recreational level hurling the maximal shot velocity of 40 m/s has been selected for this ball strike assessment.

There are a number of GAA pitches proposed at Broughton Park RUFC for both adult and junior play therefore, a maximal kick velocity of 28 m/s with a spin rate of 40 rad/s has been selected for this ball strike assessment.

It is on this basis that the recommendations in this report have been made.

Existing Mitigation

To our knowledge there is no existing or planned mitigation around the facility.

This report does not account for any existing, or planned planting (trees, hedges etc). It is our informed opinion that planting cannot be relied upon to provide protection against ball trajectories. The planting may not be sufficiently dense to stop the ball, nor homogeneous across the length. The planting may change during the seasons, or indeed be cut back or removed.

Site Measurements and Topography



Note shots in red are probable hurling hit scenarios whereas cyan represents probable Gaelic football kick scenarios.
Note that there are not significant topographical changes on this site.

Orientation of Risk

This boundary risk assessment will evaluate possible ball trajectories in all directions from the GAA pitches ; however, the focus on the analysis is based on the shortest distances from the closest pitches to the site boundaries.

The client has informed Labosport that the main areas of concern are the service road to the northwest and the adjacent car park.

Section 3– Site Measurements

Site Measurements

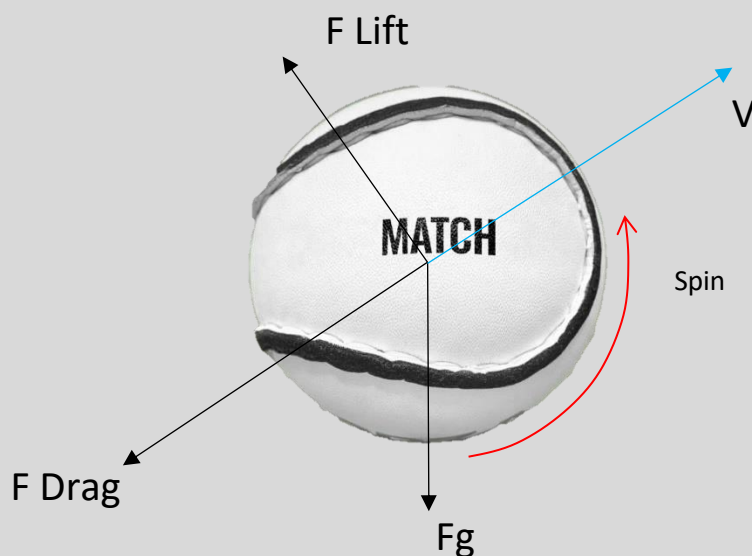
The above diagram illustrates the minimum distances from the GAA pitch to the site boundaries. Note as this is a risk assessment the worst-case scenarios are considered; consequently, the shortest measured (and calculated) distance is used for the study. The following distances have been used to calculate the projected height of the ball for different shot conditions as specified below:

Measured Distance	Shortest Boundary (m)
Northwest – Closest reasonable shot location to proposed mitigation location	Circa 19.07 m for Gaelic football Circa 40.76 m for Hurling

Section 4 – GAA Trajectory Model

Sliotar Trajectory Model Overview

The trajectory model uses aerodynamic principles and Newtonian physics to predict the ball flight path whilst accounting for the effect of air resistance. The model uses aerodynamic coefficients taken from published wind tunnel studies on baseballs at different velocities given the limited peer reviewed literature to determine sliotar drag coefficients. Baseballs have a similar external geometry to sliotars, and it is reasonable to assume that they will exhibit similar aerodynamic behaviour.



The aerodynamic forces of drag (F_D) and lift (F_L) are proportional to the ball's velocity relative to the air flow, frontal area, air density and the drag coefficient respectively lift coefficient. The forces are defined as:

$$F_D = \frac{1}{2} C_D \rho V^2 A$$

$$F_L = \frac{1}{2} C_L \rho V^2 A$$

where C_D and C_L are the non-dimensional drag and lift coefficients, ρ is the air density in kg/m^3 , V is the air stream velocity in m/s and A is the frontal area of the ball in m^2 . Due to the complexity of the flight dynamics, the trajectory can only be resolved by using

a numerical time step approach whereby the ball conditions are calculated at small timesteps throughout the trajectory. The conditions at time step 1 are used to calculate the conditions at time step 2; the conditions at time step 2 are used to calculate the conditions at time step 3 and henceforth. A timestep of 0.001 seconds was used to generate high-resolution trajectory data.

Trajectory models are known to exhibit high accuracy. However, it is not possible to simulate the full complexity of the real world and this model does not account for variations in bat/ball restitution or wind (speed and direction). Due to these limitations, the model is regarded as an indicative prediction tool.

Gaelic Football Trajectory Model

A sophisticated three-dimensional trajectory model was developed to analyse the trajectory of the Gaelic football ball. The model was built in the numerical programming software 'Matlab' and incorporated aerodynamic drag and lift forces, and the complexities arising from the ball's spin rate.

The model used published aerodynamic coefficients taken from wind tunnel studies on football balls at different kick velocities (Asai, T., Seo, K., Kobayashi, O. *et al.* Fundamental aerodynamics of the soccer ball. Sports Eng 10, 101–109). No peer reviewed studies on the aerodynamic coefficients of Gaelic footballs have been published; however, the external geometry of a Gaelic Football is similar to a soccer ball, and it is reasonable to assume that their aerodynamic behaviour will be similar. Note that the different size and mass of a Gaelic football were taken into account.

The aerodynamic forces of drag (F_D) and lift (F_L) are proportional to the ball's velocity relative to the air flow, frontal area, air density and the drag coefficient respectively lift coefficient. The forces are defined as:

$$F_D = \frac{1}{2} C_D \rho V^2 A$$
$$F_L = \frac{1}{2} C_L \rho V^2 A$$

with C_D and C_L are the non-dimensional drag and lift coefficients, ρ the air density in kg/m^3 , V the air stream velocity in m/s and A the frontal area of the ball in m^2 .

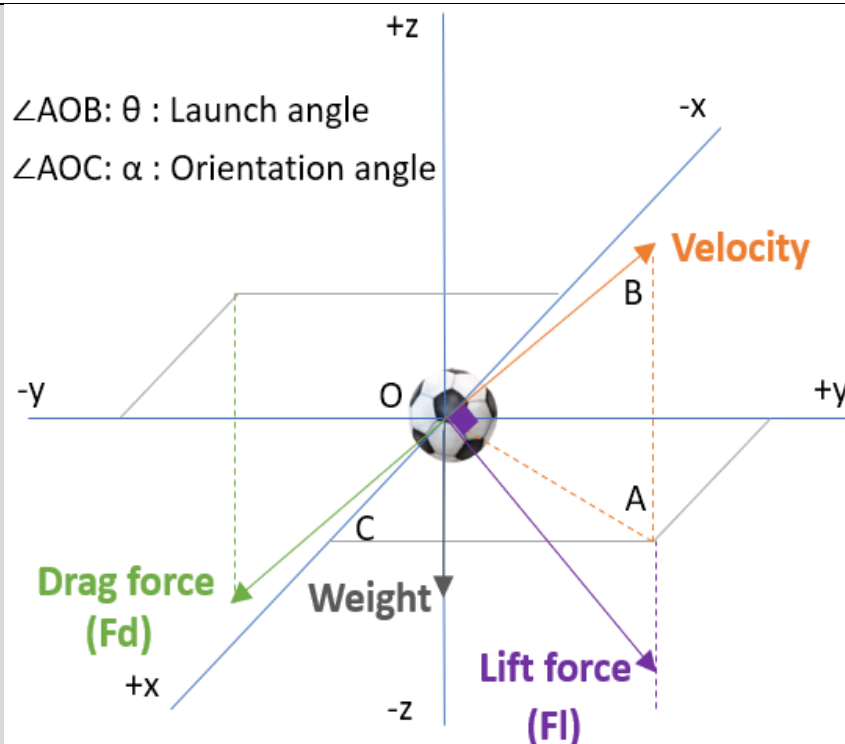


Figure 5.. A free body diagram for the football ball trajectory model showing the aerodynamic drag and lift forces.

Due to the complexity of the flight dynamics, the trajectory can only be resolved by using a numerical time step approach whereby the ball conditions are calculated at small timesteps throughout the trajectory. The conditions at time step 1 are used to calculate the conditions at time step 2; the conditions at timestep 2 are used to calculate the conditions at time step 3 and henceforth. A timestep of 0.001 seconds was used to generate high-resolution trajectory data.

Trajectory models are known to exhibit high accuracy; however, it is not possible to model the full complexity of the real world and the model developed for this project is best regarded as an indicative predictive tool.

Hurling Hit and Gaelic Football Kick Scenarios

In the game of Hurling and Gaelic football, the ball can be hit in any direction with a wide range of velocities (speeds and angles). Nonetheless, some trajectories are far more common than others. This risk assessment uses a proportionate approach by focusing on the common trajectories to determine the most likely scenarios where a ball may surpass the site boundary.

In both Hurling and Gaelic Football points are scored in 2 ways, either by scoring a goal whereby the sliotar or football is hit/kicked into the goal between the posts and under the crossbar or where the sliotar or football is hit/kicked over the crossbar but between the posts. This analysis will consider shots at goal at a lower launch angle as well as shots for a 'point' between the uprights and over the crossbar at a higher launch angle.

Hurling Hit Velocities

-In the game of Hurling, the ball can be hit in any direction with a wide range of velocities. There is little to no peer reviewed literature regarding batted ball velocities and spin rates, however given the similarities between equipment baseball velocities are well documented. The table below summarises hit velocities from 19 athletes at three different levels of play (professional, collegiate and high school) (taken from; Greenwald, Penna, and Joseph J. Crisco "Differences in batted ball speed with wood and aluminum baseball bats: A batting cage study." Journal of Applied Biomechanics, 2001, 17, 241-252.

Mean ($\pm$ SD) of Highest 10% of Hits Measured by Batted Ball Speed by Bat Model

Bat model	Top 10% (n)	Batted ball speed (mean $\pm$ SD)	p-value
W	15	98.6 $\pm$ 2.4 mph	
M1	8	100.8 $\pm$ 2.9 mph	0.220
M2	11	106.5 $\pm$ 0.7 mph	<0.001
M3	7	103.6 $\pm$ 2.9 mph	<0.001
M4	10	103.2 $\pm$ 1.3 mph	<0.001
M5	8	101.7 $\pm$ 2.1 mph	0.023

Note: Top 10% n refers to number of hits per bat in this category. P-values refer to post hoc comparisons of batted ball speed by bat model to wood (W) bats.

Figure 7. Maximum resultant ball velocity achieved with different baseball bat types overview

We also must consider the level of play and age when considering velocities. The same study also broke down the batted ball velocity changes for all bats depending on the level of play shown in the graph below.

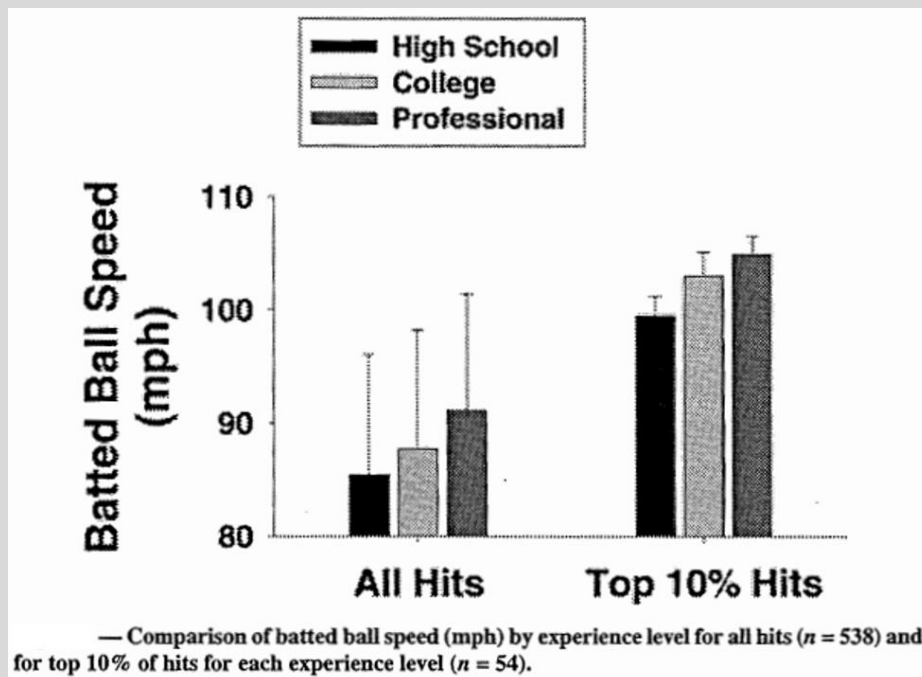


Figure X. Mean for hitting performance variables according to level of play.

Football Kick Velocities

It is reasonable to assume the ball speeds of Gaelic football will be similar to those of association football. In the game of football, the ball can be kicked with a wide range of velocities (speeds and angles). Nonetheless, previous researchers have made accurate measurements of ball speeds and spin rates using high speed video and similar technologies. The table below summarises maximal kick velocities from three different studies (taken from; Sterzing, Thorsten, and Ewald M. Hennig. "The influence of soccer shoes on kicking velocity in full-instep kicks." Exercise and Sport Sciences Reviews 36.2 (2008): 91-97).

TABLE 1. Maximum resultant ball velocity achieved with selected kicking techniques.

Study/Authors	Kicking Technique	Maximum Ball Velocity (ms ⁻¹)	SD (ms ⁻¹)	Subject Characterization
Levanon and Dapena (1998) (15)	Full-instep	28.6	2.2	Intercollegiate players, n = 6
	Side-foot	22.5	1.8	
Nunome et al. (2002) (18)	Full-instep	28.0	2.1	High school players, n = 5
	Side-foot	23.4	1.7	
Neilson and Jones (2005) (17)	Full-instep	27.1	2.2	Professional club players, n = 25
	Inner-instep	23.5	2.3	
	Outer-instep	20.9	3.1	

Figure 7. Maximum resultant ball velocity achieved with selected kicking techniques overview

We also have to consider the level of play and age when considering velocities. The table below defines the findings collated from the study into ‘Kicking Performance in Young U9 to U20 Soccer Players: Assessment of Velocity and Accuracy Simultaneously’. (Luiz H. P. Vieira et al. (2018) Kicking Performance in Young U9 to U20 Soccer Players: Assessment of Velocity and Accuracy Simultaneously, Research Quarterly for Exercise and Sport, 89:2, 210-220).

Table 1. Mean ± standard deviation (95% confidence limits) for kicking performance variables according to age (n = 366).

	U9	U11	U13	U15	U17	U20
V _{ball} (km/hr ⁻¹)	48.54 ± 8.31 ^{a, b, c, d} [42.96, 54.12]	57.87 ± 10.93 ^{e, f, g, h} [55.32, 60.42]	66.70 ± 13 ^{i, j, k} [63.81, 69.60]	76.92 ± 15.58 ^l [73.90, 79.93]	81.35 ± 16.04 ^m [77.74, 84.97]	98.74 ± 16.35 [90.55, 106.62]
V _{foot} (km/hr ⁻¹)	49.08 ± 5.16 ^{a, b, c, d} [45.62, 52.55]	53.79 ± 7.25 ^{e, f, g, h} [52.10, 55.48]	60.54 ± 8.77 ^{i, j, k} [58.58, 62.49]	65.17 ± 10.43 ^l [63.15, 67.19]	68.44 ± 11.83 ^m [65.77, 71.10]	78.24 ± 9.49 [73.66, 82.81]
V _{ball} /V _{foot} ratio (a.u.)	0.99 ± 0.13 ^{a, b, c, d} [0.90, 1.07]	1.07 ± 0.11 ^{f, g, h} [1.05, 1.10]	1.1 ± 0.11 ^{i, j, k} [1.07, 1.12]	1.18 ± 0.1 ^l [1.16, 1.20]	1.19 ± 0.1 [1.16, 1.21]	1.26 ± 0.11 [1.21, 1.31]
LSL (m)	1.09 ± 0.14 ^{a, b, c, d} [1.00, 1.18]	1.25 ± 0.14 ^{e, f, g, h} [1.21, 1.28]	1.36 ± 0.19 ^k [1.32, 1.40]	1.43 ± 0.23 ^l [1.38, 1.47]	1.44 ± 0.2 ^m [1.39, 1.48]	1.6 ± 0.14 [1.54, 1.67]
D _{support-ball} (m)	0.33 ± 0.07 [0.28, 0.37]	0.3 ± 0.07 ^{e, f, g} [0.29, 0.32]	0.34 ± 0.06 [0.33, 0.35]	0.34 ± 0.09 [0.33, 0.36]	0.34 ± 0.06 [0.33, 0.36]	0.35 ± 0.04 [0.32, 0.37]
MRE (m)	1.4 ± 0.49 [1.07, 1.73]	1.65 ± 0.6 ^{f, g, h} [1.52, 1.79]	1.59 ± 0.59 ^{i, j, k} [1.46, 1.72]	1.34 ± 0.48 [1.24, 1.43]	1.29 ± 0.5 [1.18, 1.40]	1.14 ± 0.35 [0.98, 1.31]
BVE (m)	1.26 ± 0.58 [0.87, 1.65]	1.47 ± 0.73 ^{f, g, h} [1.31, 1.64]	1.30 ± 0.57 [1.17, 1.43]	1.18 ± 0.51 [1.08, 1.27]	1.17 ± 0.5 [1.06, 1.28]	1.05 ± 0.32 [0.90, 1.21]
ACUR (m)	1.93 ± 0.64 [1.50, 2.36]	2.25 ± 0.84 ^{f, g, h} [2.06, 2.45]	2.09 ± 0.72 [1.93, 2.25]	1.81 ± 0.62 [1.69, 1.93]	1.77 ± 0.5 [1.63, 1.92]	1.57 ± 0.4 [1.38, 1.76]

Note. a = U9 × U13; b = U9 × U15; c = U9 × U17; d = U9 × U20; e = U11 × U13; f = U11 × U15; g = U11 × U17; h = U11 × U20; i = U13 × U15; j = U13 × U17; k = U13 × U20; l = U15 × U20; m = U17 × U20. Confidence limits = (lower, upper bound). V_{ball} = ball velocity; V_{foot} = foot velocity; V_{ball}/V_{foot} = ball velocity-to-foot velocity ratio; LSL = last stride length; D_{support-ball} = distance between support foot and ball; MRE = mean radial error; BVE = bivariate variable error; ACUR = accuracy. Significance level of post-hoc comparisons: V_{ball} = ^{a, e} p < .01, ^{b, c, d, f, g, h, i, j, k, l, m} p < .001. V_{foot} = ⁱ p < .05, ^{a, m} p < .01, ^{c, d, e, f, g, h, j, k, l} p < .001. V_{ball}/V_{foot} ratio = ^{a, l} p < .05, ^{b, c, d, f, g, h, i, j, k} p < .001. LSL = ^{e, l, m} p < .01, ^{a, b, b, d, f, g, h, k} p < .001. D_{support-ball} = ^{e, f, g} p < .01. MRE = ^{i, k} p < .05, ^{f, h, j} p < .01, ^g p < .001. BVE = ^{g, h} p < .05, ^f p < .01. ACUR = ^k p < .05, ^h p < .01, ^{f, g} p < .001.

Figure 8. Mean standard deviation for kicking performance variables according to age

Previous Work

Labosport Ltd have undertaken this type of boundary risk assessment for numerous different sports over the past 5 years when there have been perceived problems with various sports balls exceeding the boundary, or the potential influence of a new adjacent development to an existing club. Through this work, Labosport Ltd have developed significant expertise that supports our judgements in these matters.

Section 5 – Estimated Ball Height

Hurling Estimated Ball Height (Using the Projection Modelling Tool)

Northwest Orientation

Estimated Ball Height @ 40.76 m		20	25	30	35	40	45
Velocity (m/s)	20	0	0	0	0	0	0
	25	0	0	0	0	0	0
	30	2.7	5.8	8.8	11.8	14.7	17.3
	35	6.1	9.5	13.0	16.5	20.1	23.7
	40	8.4	12.0	15.7	19.6	23.6	27.9
Estimated Ball Height @ 44.44 m		20	25	30	35	40	45
Velocity (m/s)	20	0	0	0	0	0	0
	25	0	0	0	0	0	0
	30	1.5	4.7	7.8	10.8	13.6	15.9
	35	5.6	9.1	12.7	16.3	19.9	23.5
	40	8.2	12	15.9	19.9	24.1	28.4

See Appendix A for example trajectories.

Gaelic Football Estimated Ball Height (Using the Projection Modelling Tool)

Northwest Orientation

Shot 1 – 19.07 metres to proposed fence

Ball Height @ 19.07m		Launch Angle (degrees)					
Ball Velocity (m/s)		20	25	30	35	40	
	22	0.2	1.1	1.7	1.7	0.5	
	24	2.0	3.2	4.2	4.9	4.9	
	26	3.3	4.7	6.1	7.3	8.2	
	28	4.3	5.9	7.5	9.1	10.6	
	30	5.1	6.8	8.6	10.5	12.4	

Shot 2 – 19.18 metres to Proposed fence

Ball Height @ 19.18 m		Launch Angle (degrees)					
Ball Velocity (m/s)		20	25	30	35	40	
	20	0.2	1.1	1.7	1.7	0.5	
	24	2.0	3.2	4.2	4.9	4.9	
	26	3.3	4.7	6.1	7.3	8.2	
	28	4.3	5.9	7.5	9.1	10.6	
	30	5.1	6.8	8.6	10.5	12.4	

See Appendix A for example trajectories.

Section 6 – Risk Assessment Discussion

Risk Assessment Discussion

This report has been prepared to assess the potential risk of sliotars and Gaelic footballs surpassing the boundaries of the playing fields at Broughton Park RUFC and to advise on the height and location of mitigation recommended to provide a suitable level of protection.

Mitigation Recommendations – Northwest Orientation

Distance	Distance to boundary	Mitigation height (majority of risk removed)	Mitigation height (vast majority removed)	Overall mitigation height recommendation
Closest to site boundary @ 40 m/s	40.76 m	16.5 m high	28 m high	16.5 m high

Please Note: This may not stop all shots from landing beyond the site boundary, but it is believed from the assessment of ball trajectory it will significantly reduce their frequency.

Further Notes

This report does not recommend the specific design of a mitigation system, however options could include;

- Ball stop netting
- Rigid panel fencing
- Permanent or temporary fencing structures

It is recommended the client discuss design options with the relevant stakeholders.

In addition, the client may wish to consider alternative mitigation options such as the location and orientation of the pitches, or controlling the level of Gaelic games played on the site. It is recommended that the client discusses any such plans with any other relevant organisations along with the club to ensure that plans are suitable in mitigating the risk but also practicable for the club's day to day use.

Section 7 – Conclusions

Conclusions

This report has been prepared to assess the potential risk of sliotars and Gaelic footballs surpassing the boundaries of the playing fields at Broughton Park RUFC and advise on the height and location of mitigation recommended to provide a suitable level of protection.

Orientation	Recommended mitigation height
Northwest	16.5 m

Please Note: This may not stop all shots from landing beyond the site boundary, but it is believed from the assessment of the ball trajectory it will significantly reduce their frequency.

The below diagram shows the proposed locations of the recommended mitigation for heights detailed above:

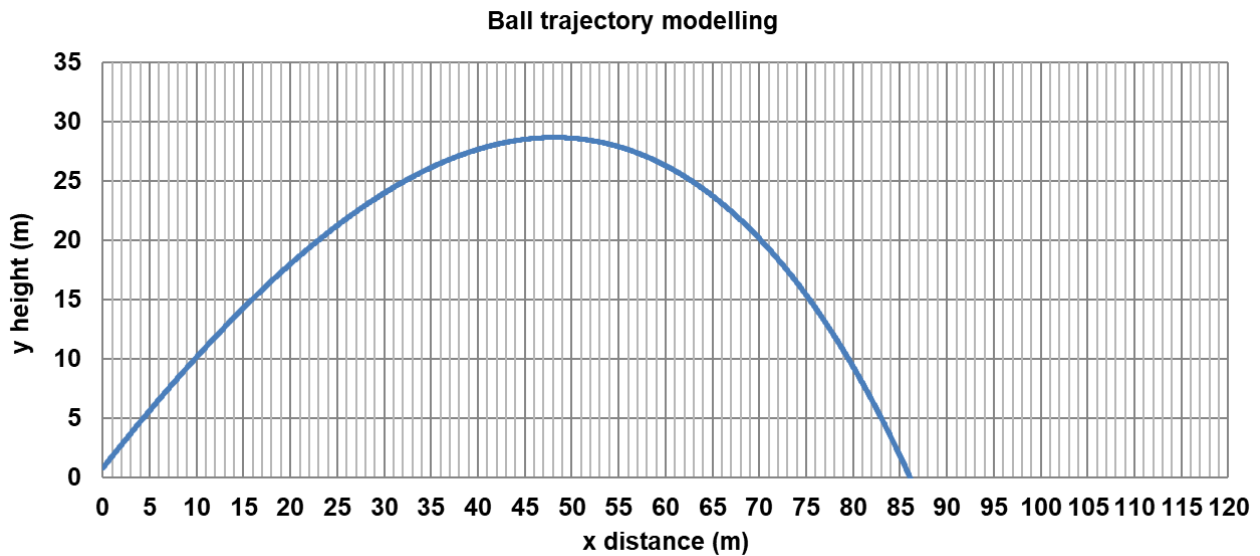


References

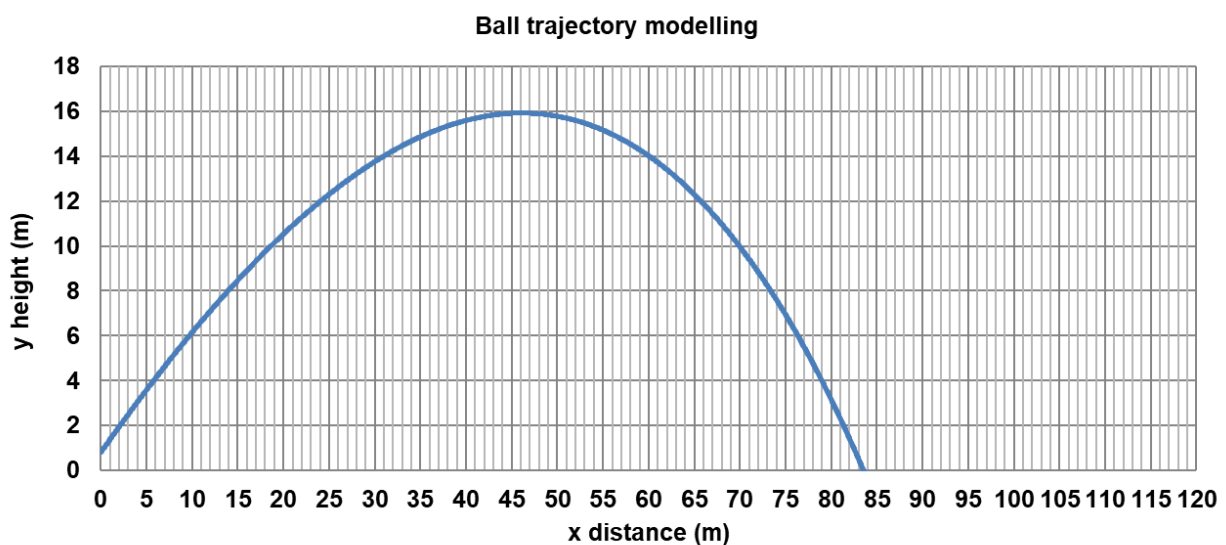
Greenwald, R.M., Penna, L.H. and Crisco, J.J. (2001) 'Differences in batted ball speed with wood and aluminum baseball bats: A batting cage study', Journal of Applied Biomechanics, 17(3), pp. 241–252. doi:10.1123/jab.17.3.241.

Appendix A – Typical Example Trajectories

45 ° @ 40 m/s



30 ° @ 40 m/s



20 ° @ 40 m/s

